Eddie Shu-yin Chan
Tadashi Matsuda
*Editors*

# Endourology Progress

## Technique, Technology and Training

Springer

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# Foreword 1

Urology has the most innovative advances among the surgical specialties. Recent technology started with shockwave lithotripsy in 1979 followed by percutaneous lithotripsy in the 1980s. Lithotripters were installed worldwide and have revolutionized the treatment of stones from incisions to "no scars." The last decade has seen an accelerated technological journey including laparoscopic instruments, robotic equipment, and endoscopes with video cameras that can be made so small as to get retrograde access to the kidney, which was only imaginable in the movies of the 1970s.

With these advances it is a constant learning and upgrading process for urologists to keep pace with new techniques. Among the many endoscopes and types of lasers we have to find out which is the most effective, appropriate, and safe for our patients. We adopt some and discard those that are not effective. It is almost impossible for a single urologist to go into all the new equipment. We need to attend meetings, talk to the experienced, and then adopt which is the best for our patients bounded by the availability of resources in our health care systems.

This book is unique because it is Asian and represents the diverse cultures and the progress made in countries with health care systems of different priorities. Illustrations are clear and readers get to pick up the procedures step-by-step such as in robotic surgery. Tips and tricks are helpful. Further dedicated structured training is important to ensure we are able to handle the new technology. Further experience should be obtained by assisting the masters at work.

Eddie Chan and Tadashi Matsuda, the editors of ***Endourology Progress: Technique, Technology and Training***, should be congratulated for this innovative book. This book is a comprehensive introduction for residents and trained urologists to pick up some new knowledge and techniques.

It is my wish that this book will enable all urologists to offer our patients the most effective treatment in the era of modern endourological technology.

January 2019

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# Foreword 2

It is a privilege to write a Foreword for this outstanding book entitled *Endourology Progress: Technique, Technology and Training* which is focused on all aspects of minimally invasive urology. The book is unique in its East Asian origins and with over 100 contributors, all of whom are from East Asian countries.

The opening chapter by Drs. Matsuda and Naito, which archives the history and development of endourology in East Asia, is a wonderful chronicle of the overall impact this urologic community has had towards progress in the field. The mission of the East Asian Society of Endourology is articulated "to study all questions related to endourology, to stimulate international cooperation in the field of urology and to encourage the development, evaluation and application of all aspects of minimally invasive therapy of urological disease across the East Asia region." There may be no better tangible example of the success in achieving this aspiration than the superb text *Endourology Progress: Technique, Technology and Training*.

The book is both comprehensive in its scope and current in all aspects of endourology, laparoscopy, robotics, and image-guided therapies in urology. Books can often lag in a field that is progressing as rapidly as endourology, but this comprehensive text manages to be completely up to date. This includes detailed descriptions of leading edge interventions in areas as diverse as pediatrics, transplantation, BPH, and MRI-guided diagnostics. The tables, illustrations, and figures in the book are excellent and the chapters are all very well referenced. As an academic urologist with a subspecialty interest in endourology I fully expect to be referring to this book, both for patient care questions and for purposes related to teaching students, residents, and fellows. Practicing urologists, trainees, and investigators with an interest in urologic technology and innovation will all find this to be a very practical and useful text.

I have had the privilege of visiting almost all of the countries classified as being in East Asia and in the case of some countries have visited on numerous occasions. This has often included the experience of operating side by side with the local urologic surgeons, many of whom have become good friends. It is my impression that many of the innovations and technical advances in endourology and minimally invasive approaches are emanating from the major centers in East Asian countries. In addition, I have witnessed the great value placed on training in this world region and the chapters in *Endourology Progress* focused on various aspects of training are among the best I have come across.

The editors, Drs. Eddie Chan and Tadashi Matsuda, along with all of the contributing chapter authors are to be congratulated for the production of this tremendous text. *Endourology Progress: Technique, Technology and Training* is an excellent contribution to existing resources in the rapidly changing field of endourology.

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# Introduction

This book represents the work and development of endourology in Asia and the contribution of East Asian Society of Endourology. The horizons of endourologic surgery are expanding. Application of robot-assisted technique is one of the many examples of how new technologies change the surgical practice. Urologists from Asian countries encountered a lot of challenges due to high patient load, different diseases preference, limited access to new technologies, diversity in languages, and surgical practice. Innovative techniques have been developed in order to adapt the unique working environment. This book is intended to familiarize the modern urologists with the common endourology, laparoscopic and robotic urologic procedures, and the development of technology, techniques, and training in Asian countries.

On behalf of the East Asian Society of Endourology, recognized Asian experts in the field of endourology have contributed to share their experiences and opinions. It consisted of latest update and advancement of surgical techniques and technology in minimally invasive surgery. The development of endoscopic, laparoscopic, and robotic urological operations is reviewed. A whole session dedicated to training in endourology is included. Detailed descriptions of perioperative preparation, step-by-step surgical procedures, and tips/tricks will be emphasized in the corresponding chapters, supplemented by photographs and illustrations. The textbook will be divided into three specific sessions. The first session covers the important areas of endourology training and the development of endourology in different Asian countries. In the second session, techniques on various urologic surgeries are discussed. The third session is dedicated to the advances of new technologies in endourology. This book is most suitable for urology residents and young fellows who are keen to start their endourological training. It also provides up-to-date information on current topics of endourology for practicing urologists and experienced endourologists in Asian and other countries.

This book is contributed by more than 100 leading experts and their young fellows from China, Japan, Korea, the Philippines, Taiwan, and Hong Kong.

# Contents

# Part I

# Endourology Training

# 1 Introduction of East Asian Society of Endourology and Development of Endourology in East Asia

Tadashi Matsuda and Seiji Naito

**Abstract**

The East Asian Society of Endourology (EASE) was established in 2003 to promote advances in minimally invasive urological surgery in East Asia, to educate young endourologists of the member territories and to cultivate and cement friendship among endourologists from member territories including Japan, Korea, Taiwan, China, and Hong Kong. The Philippines subsequently became a member in 2007 and the annual meeting of EASE has been held in one of these territories on a rotational basis. This book was planned and published as one of the activities of EASE. Thanks to innovations in endoscopic technology and surgical technique, together with the activities of the relevant associations and societies in the EASE territories, a variety of endourological, laparoscopic and robotic procedures have been widely disseminated to minimize invasiveness and enhance effectiveness of urological treatments.

**Keywords**

East Asia · Endourology · Laparoscopy

## 1.1 Introduction to the East Asian Society of Endourology (EASE)

### 1.1.1 History of EASE

The Yamanouchi International Symposium was held in conjunction with the Japanese Society of Endourology and ESWL annual congress from 2001. Here, endourologists from East Asian territories gathered to discuss recent advances in endourology in East Asia. On November 19th, 2003 in Fukuoka, Japan, the leaders of endourology from Japan, Korea, China, Taiwan, and Hong Kong met and decided to establish EASE as the progression of this symposium. The following doctors gathered as the representatives of endourologists from each country/region:

- Japan: Dr. Eiji Higashihara, Kyorin University, Dr. Shiro Baba, Kitasato University, Drs. Shinichi Oshima and Yoshinari Ono, Nagoya University
- Korea: Dr. Tchun Yong Lee, Hanyang University, and Dr. Tae-Kon Hwang, the Catholic University of Korea
- China: Dr. Li-Qun Zhou, Peking University
- Taiwan: Dr. Jun Chen, National Taiwan University
- Hong Kong: Dr. Shu-Keung Li

The first EASE annual congress was held on November 19th, 2004 in Okayama under the presidency of Dr. Eiji Higashihara, Kyorin University, Japan, in conjunction with the 18th Congress of the Japanese Society of Endourology and ESWL.

At the Board of Directors (BOD) meeting of EASE held on December 13th, 2007 in Hong Kong, it was decided that the Philippines would join EASE and that the Annual Congress of 2009 would be held in Manila.

### 1.1.2 Activities of EASE

According to the by-laws, the mission of EASE is to study all questions relating to endourology, to stimulate international co-operation in the field of urology and to encourage the development, evaluation and application of all aspects of minimally invasive therapies of urological disease across the East-Asian region.

The annual congress of EASE has been held every year since 2004, to enable through international co-operation in education and research, all EASE territories to achieve the highest quality of urological patient care (Table 1.1).

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**Table 1.1** Annual Congress of East Asian Society of Endourology

| | Year | City | Country/region | President |
|---|---|---|---|---|
| 1st | 2004 | Okayama | Japan | Eiji Higashihara |
| 2nd | 2005 | Jeju Island | Korea | Tae Kon Hwang |
| 3rd | 2006 | Taipei | Taiwan | Jun Chen |
| 4th | 2007 | Hong Kong | Hong Kong | Shu-Keung Li |
| 5th | 2008 | Shanghai | China | Liqun Zhou |
| 6th | 2009 | Manila | Philippine | Joel P. Aldana |
| 7th | 2010 | Seoul | Korea | Hyeon Hoe Kim |
| 8th | 2011 | Kyoto | Japan | Seiji Naito |
| 9th | 2012 | Taipei | Taiwan | Allen Chiu |
| 10th | 2013 | Hefei | China | Yinghao Sun |
| 11th | 2014 | Hong Kong | Hong Kong | Berry Fung |
| 12th | 2015 | Manila | Philippine | Joel P. Aldana |
| 13th | 2016 | Osaka | Japan | Toshiro Terachi |
| 14th | 2017 | Hong Kong | Hong Kong | Eddie Chan |

**Table 1.2** Global-scale Congress of Endourology held in EASE countries/region

| Year | Name of congress | Country | President |
|---|---|---|---|
| 1989 | Seventh World Congress of Endourology and SWL | Kyoto, Japan | Osamu Yoshida |
| 1991 | Third World Congress on Videourology | Hakone, Japan | Hiroshi Tazaki |
| 1995 | Seventh World Congress on Videourology | Taipei, Taiwan | Luke S. Chang |
| 2003 | 15th World Congress on Videourology | Busan, Korea | Hwang Choi, Jin Han Yoon, Gyung Tak Sung |
| 2008 | 26th World Congress of Endourology and SWL | Shanghai, China | Yinghao Sun |
| 2011 | 29th World Congress of Endourology and SWL | Kyoto, Japan | Tadashi Matsuda |
| 2012 | 23rd World Congress on Videourology | Hong Kong | Sidney KH Yip |
| 2014 | 32th World Congress of Endourology and SWL | Taipei, Taiwan | Allen Chiu |

EASE published the proceedings of the annual congress as its official journal named Recent Advances of Endourology from 2005 to 2012. As the progression from Recent Advances of Endourology, EASE has published this textbook of endourology, Endourology Progress—Technique, Technology and Training.

Since the establishment of EASE, the World Congress of Endourology and the World Congress of Videourology has been held in EASE territories as shown in Table 1.2 thanks to the support of the other EASE members. EASE has had close communication with the Urological Association of Asia and the Asian Society of Endourology, and some EASE congresses have been held in conjunction with these bodies.

### 1.1.3 Future of EASE

Since its establishment in 2004, EASE has played important roles in promoting advances in minimally invasive urology in East Asia, educating young endourologists of the member territories and cultivating and cementing friendship among endourologists in the region. The activities of EASE have become well-known throughout the global endourology community. At the 2016 BOD meeting in Osaka, the BOD members agreed that EASE would continue holding annual congresses in the 2020s and pursue new and diverse activities such as the publishing of this textbook.

## 1.2 Development of Endourology in East Asia

### 1.2.1 Endourological Societies of East Asian Countries

Endourologists in East Asian countries meet at their respective national endourological society or endourological branch or subgroup of their respective national urological association. The year of establishment and the number of members of each national endourological society are shown in Table 1.3. These societies and subgroups have played a major role in the development and dissemination of minimally invasive endourological procedures in each country together with their respective national urological associations.

### 1.2.2 Advancement of Endourology in East Asia

Due to the development of endourological instruments such as the Stern-McCarthy resectoscope in 1931, electrohydraulic lithotripter in 1950, endoscopes equipped with rod lens and fiber-optic light cable system around 1960, and ultrasonic lithotripter in 1973, a variety of endourological procedures including TURP, TUL and PCNL have

**Table 1.3** Endourological societies of EASE territories

| Country | Name of the society/group | Establishment year | No. of members |
|---|---|---|---|
| China | The Endourological Branch of Chinese Urological association | 1993 | |
| Hong Kong | Hong Kong Endourological Society | 2006 | 252 |
| Japan | Japanese Society of Endourology | 1987 | 3969 |
| Korea | Korean Endourological Society | 1992 | 750 |
| Philippine | Philippine Endourological Society | 2009 | 41 |
| Taiwan | Taiwan Urological Association | 1978[a] | 938[a] |

[a]Data on the Urological Association, not the Endourological Group

**Table 1.4** Year of start of endourological procedures in EASE territories

| Country | TURP | PCNL | TUL | SWL | Lap. nephrectomy | Lap. prostatectomy |
|---|---|---|---|---|---|---|
| China | 1980 | 1985 | 1986 | 1984 | 1992 | 2000 |
| Hong Kong | | 1984 | | 1985 | 1996 | 2002 |
| Japan | 1960s | 1982 | 1984 | 1984 | 1991 | 1999 |
| Korea | 1977 | 1984 | 1984 | 1987 | 1996 | 2002 |
| Philippine | 1969 | 1985 | 2004 | 1996 | 2001 | 2004 |
| Taiwan | | 1984 | 1984 | 1985 | 1992 | |

been developed and used around the world (Miki and Aizawa 2009; Higashihara 2012). The year of introduction of these procedures in East Asian territories is shown in Table 1.4.

As for the endoscopic surgery for benign prostate hypertrophy, enucleation of prostate hypertrophy was first performed by Hiraoka and Akimoto (1989) in Japan using a mechanical instrument, which was the precursor of the Holnium laser or bipolar electronic enucleation of the prostate.

A flexible ureteroscope was first developed by Takayasu and Aso in 1971 in collaboration with Olympus in Japan (Takayasu et al. 1971) and the world's first TUL was performed by Pretz-Castro in 1980 using a Storz rigid ureteroscope (Pérez-Castro Ellendt and Martínez-Piñeiro 1982). Rigid ureteroscopes were launched by Storz, Wolf and Olympus in 1980, 1982 and 1984 respectively. Flexible ureteroscopes were launched by Storz in 1976 and by Olympus in 1986. Shock wave lithotripsy (SWL), first developed by Chaussy et al. in 1980 (Higashihara 2012; Chaussy et al. 1982), spread rapidly in East Asian countries. The current number of SWL machines is 911, 726, 12 and 50 in Japan, Korea, Hong Kong and the Philippines, respectively. Furthermore, in Korea and Hong Kong, the number of SWL procedures performed annually was more than 175,000 and 1300, respectively.

Thanks to improvements in endoscopes or SWL machines and in surgical technique, the treatment strategy for urolithiasis has dramatically shifted from open surgery to endoscopic and shock wave treatments in East Asian countries. The transition of treatment modalities for urolithiasis in Japan during the past 40 years is shown in Fig. 1.1 according to the nation-wide surveys performed every 5–10 years since 1965 (Terai and Yoshida 2001; Yasui et al. 2008). The number of PCNL and TUL in Korea are increasing as shown in Fig. 1.2a, b, respectively.

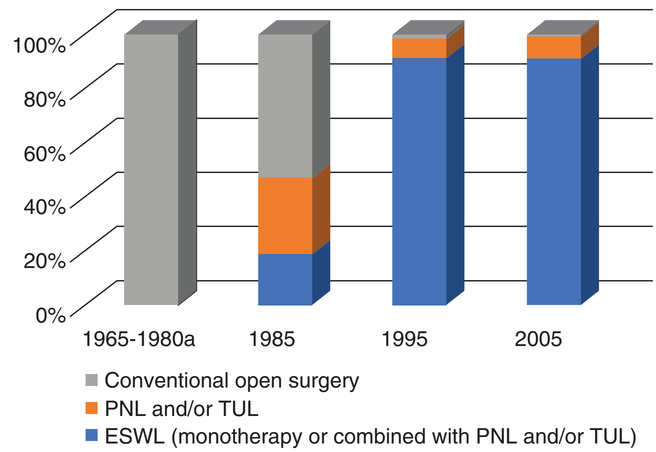


**Fig. 1.1** The transition of treatment modalities for urolithiasis in Japan during the past 40 years according to the nation-wide surveys performed every 5–10 years since 1965 (Terai and Yoshida 2001; Yasui et al. 2008)

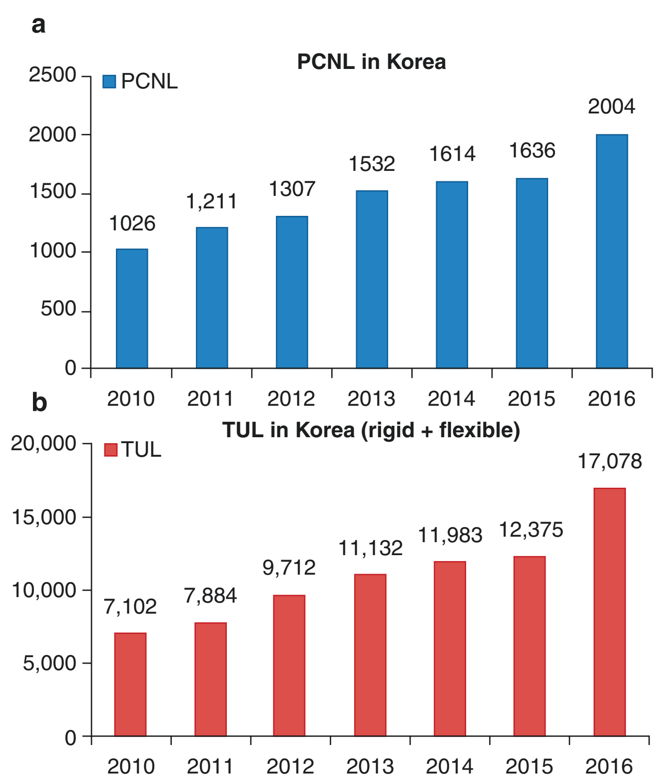


**Fig. 1.2** The number of PCNL and TUL in Korea since 2010. (**a**) PCNL, (**b**) TUL

### 1.2.3 Development of Laparoscopic Surgery in East Asia

The first urologic laparoscopic surgery in East Asian countries as a disease treatment was a laparoscopic varicocelectomy in 1990 (Matsuda et al. 1992). The world's first laparoscopic adrenalectomy was performed in February of

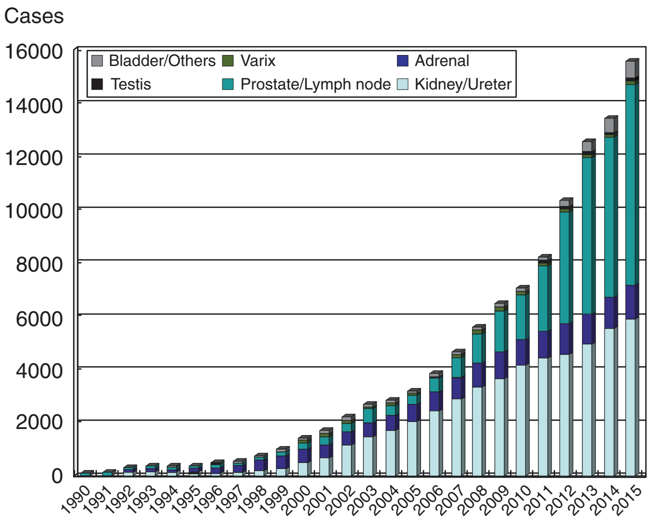


**Fig. 1.3** The number of urologic laparoscopic surgeries in Japan since 1990

1992 by Japanese doctors (Go et al. 1993). The year of introduction of laparoscopic nephrectomy and prostatectomy is shown in Table 1.4. Since then, a variety of urologic laparoscopic surgeries have been introduced in these countries and the number of surgeries in Japan is still increasing as shown in Fig. 1.3, according to the nation-wide survey of urologic laparoscopic surgeries (The Japanese Society of Endoscopic Surgery 2016).

### 1.2.4 Introduction of Robotic Assisted Surgery in East Asia

The surgical robot, da Vinci was first introduced to East Asia in 2003 in Japan and has since been used in East Asian countries as shown in Table 1.5. Now in 2016, the number of da Vinci S, Si or Xi across the EASE region together with the number of urological robotic operations in 2016 are shown in Table 1.5.

**Table 1.5** Introduction of surgical robot da Vinci in EASE territories

| Country/region | Year of the first case | No. of machines[a] | No. of urologic operations in 2016 |
|---|---|---|---|
| China | 2007 | 50 | 8000 |
| Hong Kong | 2006 | 10 | 600 |
| Korea | 2006 | 60 | 5000 |
| Japan | 2003 | 250 | 16,000 |
| Philippine | 2005 | 3 | 100 |
| Taiwan | 2005 | 30 | 2000 |

[a]At the end of 2016

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## References

Chaussy C, Schmiedt E, Jocham D, et al. First clinical experience with extracorporeally induced destruction of kidney stones by shock waves. J Urol. 1982;127:417–20.

Go H, Takeda M, Takahashi H, et al. Laparoscopic adrenalectomy for primary aldosteronism: a new operative method. J Laparoendosc Surg. 1993;3:455–9.

Higashihara E. Japanese contribution to endourology. Jpn J Endourol. 2012;25:183–201.

Hiraoka Y, Akimoto M. Transurethral enucleation of benign prostatic hyperplasia. J Urol. 1989;142:1247–50.

Matsuda T, Horii Y, Higashi S, et al. Laparoscopic varicocelectomy: a simple technique for clip ligation of the spermatic vessels. J Urol. 1992;147:636–8.

Miki M, Aizawa. The history of endourology. Jpn J Endourol ESWL. 2009;22:127–9.

Pérez-Castro Ellendt E, Martínez-Piñeiro JA. Ureteral and renal endoscopy. A new-approach. Eur Urol. 1982;8:117–20.

Takayasu H, Aso Y, Takagi T, et al. Clinical application of fiber-optic pyeloureteroscope. Urol Int. 1971;26:97–104.

Terai A, Yoshida O. Epidemiology of urolithiasis in Japan. In: Akimoto M, Higashihara E, Orikasa S, et al., editors. Recent advances in endourology, vol. 3. Tokyo: Springer; 2001. p. 23–36.

The Japanese Society of Endoscopic Surgery. Results of 13th nationwide survey of endoscopic surgery in Japan. J Jpn Soc Endosc Surg. 2016;21:772–96.

Yasui T, Iguchi M, Suzuki S, et al. Prevalence and epidemiological characteristics of urolithiasis in Japan: national trends between 1965 and 2005. Urology. 2008;71:209–12.

# 2 Training of Endourology in Asia

Kai Zhang, Tao Han, and Gang Zhu

**Abstract**

For over hundred years, the training for surgeon was the accumulation of personal experience following the model of "see one, do one, teach one". Even when this worked, such training lacked standardization because of different cases and teachers' experience. This is clearly suboptimal from a safety viewpoint. More importantly, modern clinical ethics sits poorly with surgeons practicing new techniques on patients without any attempt at learning the skills on simulators. Patients are also increasingly reluctant to be the "guinea pigs" for inexperienced surgeons. Asia has a vast territory and a large population, the development of endourology varies greatly among different countries and regions. Systematic training and standardization of technique is in pressing need in Asia, especially in developing countries. In the last couple of decades, numbers of new animal and mechanical models and simulators have been developed and validated. Based on the currently available data, endourological training could help surgeons to gain experience and improve skills outside the operating room in a short time. Efforts should be made to identify the best aspects of every model and procedure-specific simulation courses should be developed and validated. Conclusive data on the training effect and feedback on real clinical environment is also needed in Asia.

**Keywords**

Endourology · Training · Training model

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## 2.1 Training Models of Endourology

Animal and mechanical models are most commonly used for endourology training worldwide, with the advantages of cost-effective, easy accessibility and high reliability. A large number of models have been developed to train medical students, residents and young urologists with limited experience in transurethral resection (TUR) surgery, ureteroscopy, percutaneous nephrolithotripsy (PCNL), laparoscopy and robotic surgery (Ganpule et al. 2015; Chandrasekera et al. 2006; Zhang et al. 2008; Soria et al. 2015; Celia and Zeccolini 2011). Some models could simulate the whole procedures with high fidelity and some could only simulate basic tasks or be used for specific steps but with low cost and good reusability.

A model was designed with an *in vitro* porcine heart tissue model for laser prostatectomy endoscopic technique training in China (Zhang et al. 2009). In the evaluation study, ten junior surgeons without experience of benign prostatic hyperplasia (BPH) laser prostatectomy were assessed for ability and speed over a period of time with two technique evaluation points: resection and vaporization. A 26F irrigating laser resectoscope was used to perform laser resection and vaporization on left ventricle chordae tendineae (Figs. 2.1 and 2.2). Before the first and the second training stage, the trainees were trained in theory and techniques. Feasibility, technique and both resection and vaporization speed were analyzed. There was significant improvement in terms of resection time, vaporization time and the total manipulation time ($P < 0.01$) in the second stage compared with those of the first stage. In this model, the space of the left ventricle in porcine heart was highly similar to the space of prostatic urethra during the laser BPH treatment and it was very suitable for this particular training. This model showed that porcine heart is a simple, cheap and reproducible model for learning the basic skills of laser prostatectomy using laser before working on patients.

Pig is also widely used for laparoscopic training, mostly simulating the whole procedure such as laparoscopic nephrectomy, partial nephrectomy and pyeloplasty (Chiu


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et al. 1992; Barret et al. 2001; Yang et al. 2010; Gettman et al. 2002) (Fig. 2.3). The morphometric and anatomic of porcine kidney are greatly similar to human kidney (Sampaio et al. 1998) (Fig. 2.4).

Early in 1993, laparoscopic nephrectomy was performed in 15 male live pigs in Taiwan by Chiu et al. (1992). The average operation time was 200 min. The complications included renal vein tear in one case, mild subcutaneous emphysema in two cases.

In India, the crop and esophagus of a chicken were used to simulate the renal pelvis and ureter for laparoscopic pyeloplasty training (Ramachandran et al. 2008). This model was cheap, easily available and could provide a realistic feel to the tissue and anatomy of human. To assess the effectiveness of this model, three residents was chosen to complete laparoscopic pyeloplasty for four times in a period of 1 month. The operation time and quality of anastomosis were compared among the four attempts. For all the three trainees, the operation time showed remarkable reduction and the quality of anastomosis improved significantly from the first to the fourth attempt, suggesting a favorable trend in terms of learning curve.

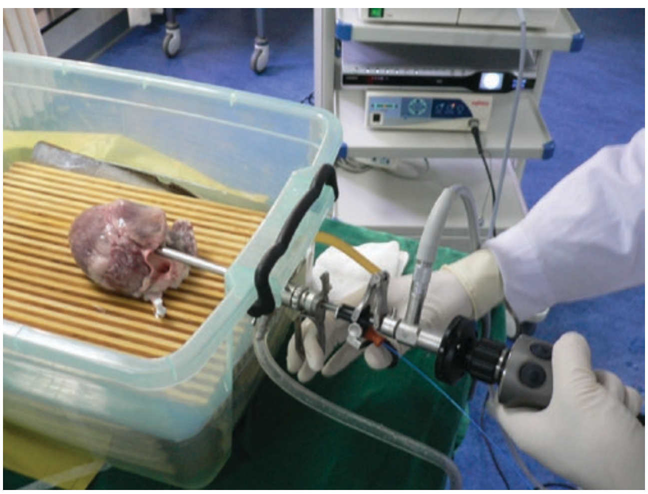


**Fig. 2.1** Instruments and porcine heart model

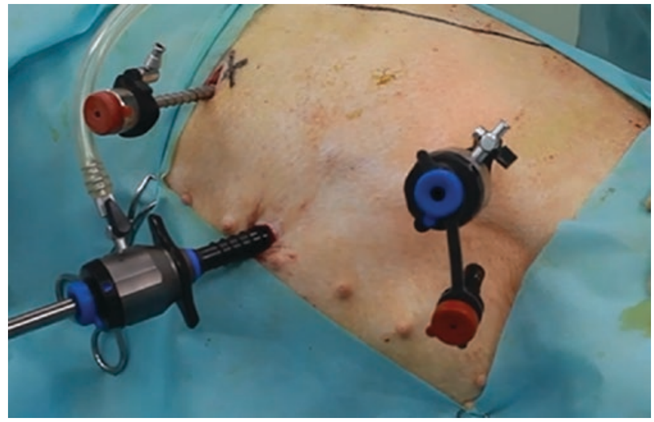


**Fig. 2.3** Live porcine model for laparoscopic training

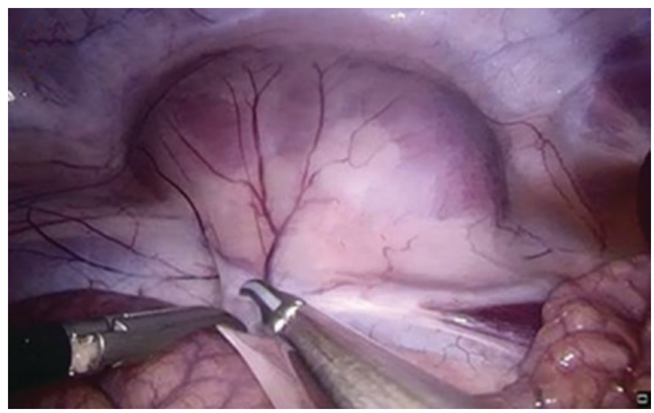
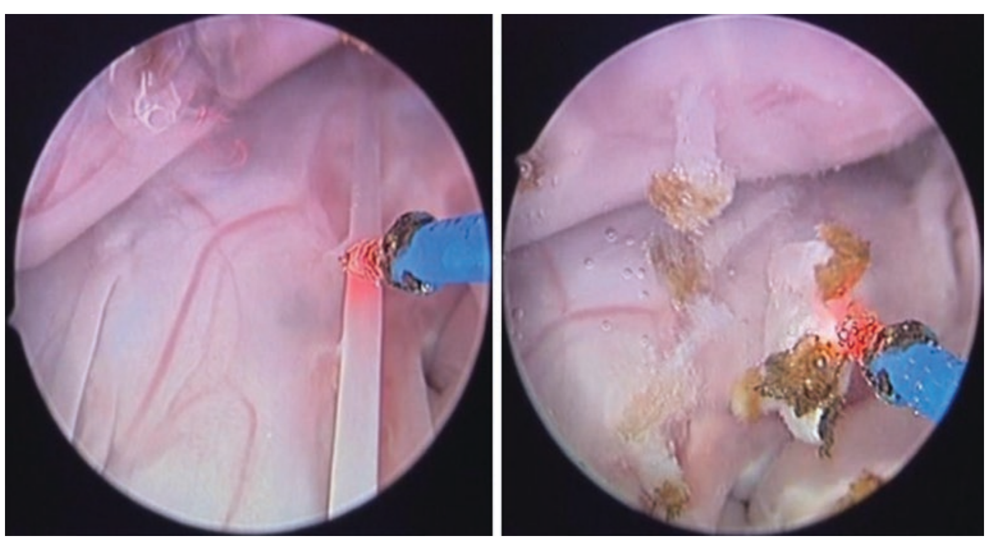


**Fig. 2.4** Live porcine kidney

**Fig. 2.2** Space of the left ventricle in porcine heart



In addition to transurethral and laparoscopic procedures, a number of models were created for training of ureteroscopy and PCNL (Soria et al. 2015; Mishra et al. 2013; Bele and Kelc 2016; Sinha and Krishnamoorthy 2015; Strohmaier and Giese 2009). A biologic bench model using a porcine kidney was reported to simulate intrarenal procedures in China (Zhang et al. 2008). The porcine kidney was wrapped with subcutaneous tissue and muscle in a thick skin flap. The whole model was fixed to a wooden board with nails and the radiologic contrast medium or normal saline could be injected into the kidney through ureteral catheter. Stones were placed inside the kidney through a small incision on the renal pelvis in advance. A total of 42 urologists with limited experience of endourology surgery attended this training, performing percutaneous renal surgery training under ultrasound guidance. At the end of training, 60.6% trainees could finish the whole procedure successfully and 85.7% trainees regarded this model for percutaneous renal surgery training "very helpful" or "helpful".

In general, animal and mechanical models are easily built and cost-effective, could provide realistic and reproducible practice for most endourology surgery. However, the validity varies among various models and standard evaluation system is still lacking.

**Fig. 2.5** TURPSim training system

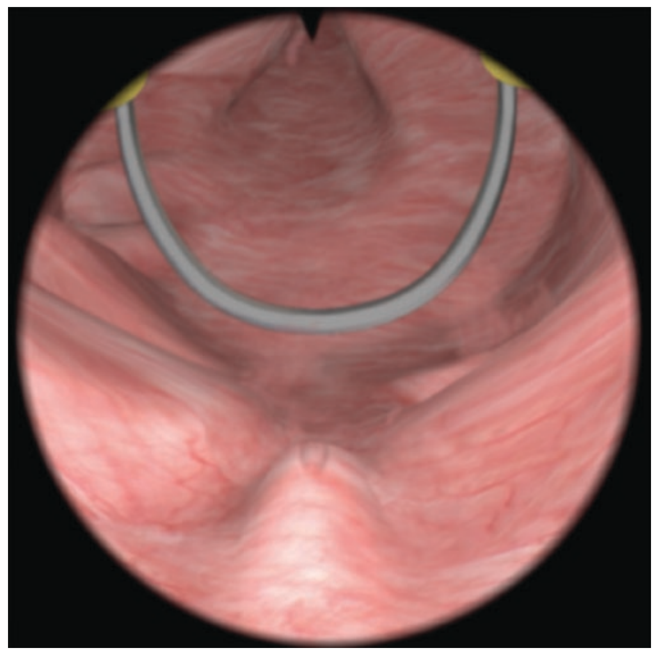


**Fig. 2.6** Virtual TURP surgery

## 2.2 Virtual Reality Training of Endourology

Virtual reality (AR) is defined as "Inducing targeted behavior in an organism by using artificial sensory stimulation, while the organism has little or no awareness of the interference" (Hamacher et al. 2016). The first VR simulator emerged in 1909 and was used for the training of aircraft pilots (Hamacher et al. 2016). Nowadays, an increasing number of validated VR simulators are widely used for endourology training (Aydin et al. 2016a; Phe et al. 2017; da Cruz et al. 2016; Noureldin et al. 2016; Tjiam et al. 2014).

In 1999, a VR simulator for transurethral resection of the prostate (TURP) procedures was first reported (Ballaro et al. 1999; Gomes et al. 1999). Software was developed to generate the images of urethral and prostate with using a magnetic sensor input device attached to a dummy resectoscope, which could help trainees be familiar with the TURP technique.

Zhu et al. (2013) investigated the utility of VR simulators in training of TURP in China. The TURPSim system was used and 38 trainees were randomly selected to take part in the training (Figs. 2.5 and 2.6). The global rate scale, rate of capsule resection, amount of blood loss, external sphincter injury was compared between the baseline and post-training levels. It showed that all the parameters improved remarkably after training and most trainees were satisfied with the TURP simulator. It is noteworthy that all the other parameters, except for the global rate scale can be objectively and accurately evaluated with this VR model.

In accordance with rapid and wide adoption of robot-assisted laparoscopic surgery in the last decade, robotic VR simulators emerged and were increasingly applied worldwide. At present there are five VR simulators: the Surgical Education Platform (SEP; SimSurgery, Oslo, Norway), the Robotic Surgical System (RoSS; Simulated Surgical Systems, San Jose, CA, USA), the dV-Trainer (Mimic, Seattle, WA, USA), the da Vinci Skills Simulator (dVSS; Intuitive Surgical), and the recently introduced RobotiX Mentor (3D Systems, Simbionix Products, Cleveland, OH, USA) (Moglia et al. 2016).

In Korea, the dVSS system was used to train 50 medical school students to perform 12 exercises with the aim to determine whether a robotic VR training enabled inexperienced trainees to complete a hands-on operation (Song and Ko 2016). The program was conducted in two parts. Firstly, 43 students received VR training for basic skills and advanced suture. Then a real robotic surgical system was applied to perform urethrovesical anastomosis on a hands-on model which was created using the proximal end of rectal tubes. In analysis, the console time of hands-on training was significantly associated with the total time and attempt of VR training, suggesting robotic VR training system could help beginners to acquire and improve robotic surgery skills.

In India, Mishra et al. compared the validation between a live porcine model and a VR simulation model for percutaneous renal access training (Mishra et al. 2010). In this study, a live anesthetized pig with a pre-placed ureteric catheter and a high-fidelity simulator (PERC Mentor, Simbionix; Lod, Israel) were used. A total of 24 urologists with experience of more than 50 cases of PCNL firstly performed percutaneous renal access with a real-time C-arm in the porcine model, then operated the same procedure on the simulator. In comparison, there was no statistical significant difference in overall usefulness. The simulator model came with a high price but was safer and easier to set up than live porcine model. However, the live porcine model was more realistic than the high-fidelity simulator model.

Cai et al. reported the value of VR simulator in the skill acquisition of flexible ureteroscopy (Cai et al. 2013). URO Mentor (Simbionix) VR model was used in this study. Thirty urologists took part in the study and received 1-h basic training for the instruments and the whole procedures, then followed by an assessment with task of seven programs. After another 4-h practice on the simulator, the participants performed the same task. It showed that most parameters including total procedure time, progressing time from the orifice to stone, time of stone translocation, fragmentation time, laser operate proficiency scale, total laser energy, maximal size of residual stone fragments, number of trauma from the scopes and tools and damage to the scope improved remarkably on the second assessment. This study illustrated that VR simulator could aid the trainees to enhance their flexible ureteroscopy skills in a short time.

Generally, the high-fidelity VR simulators usually seem a very high price. However, the running cost is very low once the models are installed. It can be easily set up, only a space and an electricity supply needed. Of the available VR simulators, some have held high level of evidence and recommendation, such as the UroSim and TURPsim for TUR surgery, the URO Mentor and PERC Mentor for urolithiasis, and the dv-Trainer for robotic surgery (Aydin et al. 2016b).

## 2.3 Evaluation of Training Effect

The main objective of endourology training is to shorten the time needed for clinical training and provide the residents or urologists with the possibility to gain experience and improve skills outside the operating room. However, the role of training in certification and credentialing of real surgery is still under investigation. There is limited data regarding whether training could affect actual performance in a hands-on setting.

In Japan, Fujimura et al. developed a mentoring system to balance training new surgeons while controlling medical quality (Fujimura et al. 2016). Novice surgeons with experience of radical retropubic prostatectomy and laparoscopic renal and adrenal surgery participated in the study (only one surgeon had experience of laparoscopic radical prostatectomy). They first underwent intensive dry and animal training and then observed 47 cases of robot-assisted radical prostatectomy performed by an experienced surgeon (Menon M, Henry Ford Hospital, Detroit, Michigan, USA). Moreover, in the first five cases of real operation, the new surgeons were supervised by a proctor who had enormous experience in laparoscopic and robot-assisted radical prostatectomy.

In the step-by-step procedures, time limits and blood loss was measured and ten checkpoints were set up during every operation in the mentoring program. The cut-off point was set at 70% of the time and blood loss limit. Once the time or blood loss limit was exceeded, a mentor would take over the operation or another new surgeon would replace the surgeon and finished the step. In this setting, the surgical quality and patient's safety could be controlled to the maximum extent.

In this study, a total of 242 patients underwent robot-assisted radical prostatectomy, with the median operative time 237 min and median perioperative blood loss 300 ml. 88% of new surgeons could finish the whole procedure after an average of 10.7 cases. There was no perioperative mortality and no conversion to open prostatectomy. Seven patients (2.8%) suffered from postoperative hemorrhage and one patient underwent emergent hemostatic surgery because of active bleeding of left epigastric artery. It is interesting to note that there was no statistically difference between the results of a mentor and those of new surgeons with a mentor in terms of median operative time, console time, blood loss, incidence of blood transfusion and duration of catheterization. One must admit that the majority of studies on endourology training merely compare the results between the baseline and post-training period on models or simulators. However, the ultimate goal of training is to improve the doctor's performance on real patients. This Japanese study provides us some enlightenment on how to investigate the effect of training in real clinic environment on the premise of ensuring medical quality and safety. Regrettably, there are too few data on this subject in Asia, even worldwide.

## 2.4 Training Organization in Asia

There are a lot of endourology training courses supported by local urology societies in Asian countries or Areas in the purpose of improving Asian urologist's endoscopic skills and techniques.

Asian Urological Surgery Training & Education Group (AUSTEG) was founded in Hong Kong, with the aim to enhance professional competencies to advance the standard of urological surgery in Asia through a comprehensive training platform for experience skill exchange, and hence, cultivate next generations in Asia. The members are all urological experts with a high reputation from China, Japan, Korea, Malaysia, Thailand and some other Asian countries and regions. There are extensive curriculums including laparoscopic upper tract surgery, endourology and stone management, lower tract surgery and urology nursing workshop (Figs. 2.7 and 2.8).

East Asian Society of Endourology (EASE) regularly has the pre-congress training program. Such as the EASE 2014 & The Sixth Hong Kong Congress of Endourology: The Next Generation in Endourology: Training, Technique and Technology.

Chinese Urology Association (CUA) has organized many training courses and provided support to local training centers in China. Usually the training centers were organized by each province and run by a local teaching hospital. There were regular courses, which have contributed to the development of Chinese Urology. There were also some collaborated international courses, such as the Endourology Society Global Education Initiative Skills Courses in Endourolgy, Laparoscopy and Robotics held in Chengdu, China, in March 2016.

In Korea, Yonsei University College of Medicine Department of Urology provided 1-year training program under the guidance of a urological surgeon. During the fellowship, the fellow will be exposed to different techniques and latest available instruments in endourologic, laparoscopic and robotic surgery.

In India, ceMAST organizes courses like two-day Upper Tract Endourology Course covering usage of semirigid ureteroscopes, flexible ureteroscopes, nephroscopes, etc.

**Fig. 2.8** AUSTEG model training for ureteroscopy

**Fig. 2.7** AUSTEG trainers and trainees

Japanese Urological Association and Japanese Society of Endourology have established a urologic laparoscopic skills qualification system called the Endoscopic Surgical Skill Qualification (ESSQ) System in 2004 to assess the techniques and skills of applicants in performing lap nephrectomy or adrenalectomy.

The Chinese University of Hong Kong (CUHK) Jockey Club Minimally Invasive Surgery Skills Centre (MISSC) has collaborations with the International Training Centre of Intuitive Surgical®. Intuitive Surgical® issues certifications for all courses in robotic assisted laparoscopic surgery conducted at the MISSC. CUHK MISSC runs courses covering the important clinical aspects of robotics as used in a wide variety of specialties, including urology. A similar International Training Centre of Intuitive Surgical® has just recently been established in Shanghai Changhai Hospital.

It is worth mentioning that, even with different organizers, all the courses combining academic lecture, model-based training and practice, case discussion, providing remarkable promotion not only on surgical skill, but also on professionalism of our future medical care providers to better serve our patients.

**Remark** Permission is obtained to show the human images in this article according to local regulation.

## References


Aydin A, et al. Simulation-based training and assessment in urological surgery. Nat Rev Urol. 2016a;13(9):503–19.

Aydin A, et al. Current status of simulation and training models in urological surgery: a systematic review. J Urol. 2016b;196(2):312–20.

Ballaro A, et al. A computer generated interactive transurethral prostatic resection simulator. J Urol. 1999;162(5):1633–5.

Barret E, et al. Laparoscopic partial nephrectomy in the pig: comparison of three hemostasis techniques. J Endourol. 2001;15(3):307–12.

Bele U, Kelc R. Upper and lower urinary tract endoscopy training on Thiel-embalmed cadavers. Urology. 2016;93:27–32.

Cai JL, et al. Proficiency of virtual reality simulator training in flexible retrograde ureteroscopy renal stone management. Chin Med J. 2013;126(20):3940–3.

Celia A, Zeccolini G. Ex vivo models for training in endourology: construction of the model and simulation of training procedures. Urologia. 2011;78(Suppl 18):16–20.

Chandrasekera SK, et al. Basic laparoscopic surgical training: examination of a low-cost alternative. Eur Urol. 2006;50(6):1285–90. 1290–1

Chiu AW, et al. Laparoscopic nephrectomy in a porcine model. Eur Urol. 1992;22(3):250–4.

da Cruz JA, et al. Does warm-up training in a virtual reality simulator improve surgical performance? A prospective randomized analysis. J Surg Educ. 2016;73(6):974–8.

Fujimura T, et al. Validation of an educational program balancing surgeon training and surgical quality control during robot-assisted radical prostatectomy. Int J Urol. 2016;23(2):160–6.

Ganpule A, Chhabra JS, Desai M. Chicken and porcine models for training in laparoscopy and robotics. Curr Opin Urol. 2015;25(2):158–62.

Gettman MT, et al. Transvaginal laparoscopic nephrectomy: development and feasibility in the porcine model. Urology. 2002;59(3):446–50.

Gomes MP, et al. A computer-assisted training/monitoring system for TURP structure and design. IEEE Trans Inf Technol Biomed. 1999;3(4):242–51.

Hamacher A, et al. Application of virtual, augmented, and mixed reality to urology. Int Neurourol J. 2016;20(3):172–81.

Mishra S, et al. Percutaneous renal access training: content validation comparison between a live porcine and a virtual reality (VR) simulation model. BJU Int. 2010;106(11):1753–6.

Mishra S, et al. Training in percutaneous nephrolithotomy. Curr Opin Urol. 2013;23(2):147–51.

Moglia A, et al. A systematic review of virtual reality simulators for robot-assisted surgery. Eur Urol. 2016;69(6):1065–80.

Noureldin YA, et al. Is there a place for virtual reality simulators in assessment of competency in percutaneous renal access? World J Urol. 2016;34(5):733–9.

Phe V, et al. Outcomes of a virtual-reality simulator-training programme on basic surgical skills in robot-assisted laparoscopic surgery. Int J Med Robot. 2017;13(2) https://doi.org/10.1002/rcs.1740.

Ramachandran A, et al. A novel training model for laparoscopic pyeloplasty using chicken crop. J Endourol. 2008;22(4):725–8.

Sampaio FJ, Pereira-Sampaio MA, Favorito LA. The pig kidney as an endourologic model: anatomic contribution. J Endourol. 1998;12(1):45–50.

Sinha M, Krishnamoorthy V. Use of a vegetable model as a training tool for PCNL puncture. Indian J Urol. 2015;31(2):156–9.

Song PH, Ko YH. The surgical skill of a novice trainee manifests in time-consuming exercises of a virtual simulator rather than a quick-finishing counterpart: a concurrent validity study using an urethrovesical anastomosis model. J Surg Educ. 2016;73(1):166–72.

Soria F, et al. Development and validation of a novel skills training model for retrograde intrarenal surgery. J Endourol. 2015;29(11):1276–81.

Strohmaier WL, Giese A. Improved ex vivo training model for percutaneous renal surgery. Urol Res. 2009;37(2):107–10.

Tjiam IM, et al. Evaluation of the educational value of a virtual reality TURP simulator according to a curriculum-based approach. Simul Healthc. 2014;9(5):288–94.

Yang B, et al. A novel training model for retroperitoneal laparoscopic dismembered pyeloplasty. J Endourol. 2010;24(8):1345–9.

Zhang Y, et al. Novel biologic model for percutaneous renal surgery learning and training in the laboratory. Urology. 2008;72(3):513–6.

Zhang K, Zhu G, Wan B, Wang JY. Application of porcine heart as animal tissue model for 2 micron continuous wave laser endoscopic technique training. Chin J Urol. 2009;30(9):627–9.

Zhu H, et al. Virtual reality simulator for training urologists on transurethral prostatectomy. Chin Med J. 2013;126(7):1220–3.

# 3 Laparoscopic Training Using Cadavers

Thomas Y. Hsueh

**Abstract**

Surgical education is the fundamentals of medicine and warrants experience transfer from generations to generation to achieve a better disease management. Laparoscopic procedure requires a steep learning curve compared to conventional open procedures due to two-dimensional vision, lack of tactile sensation and limited working space. The training curriculum in laparoscopic procedures includes not only didactic lectures but also hand-on surgical training lab. The application of computerized simulators, tissue analogue simulators and cadavers is proved to be efficient for surgical skills training in laparoscopy. The training in nontechnical surgical skills is found to have positive impact on surgical training, especially in interpersonal communication and team work during emergency scenarios in the operating room. This chapter will discuss the concept on surgical training, training curriculum design, the application of simulators in laparoscopic training and nontechnical training in laparoscopic surgery.

**Keywords**

Laparoscopy · Surgical training · Simulator

## 3.1 Introduction

Laparoscopic surgery was first introduced into urology in early 1990s. The advancement of technology, miniature of instruments and duplication of open surgical procedures are key elements for the revolution of minimal invasive surgery in the past 30 years. Robotic surgery, one of the revolutionary change of laparoscopic procedures, redefines the horizon of minimal invasive surgery and serves as the procedure of choice in complex urological surgical procedures. However, the evolvement of surgical training of laparoscopic procedures does not establish well as the development of laparoscopic procedures. Most urologists learned laparoscopic procedures just like the scenario about 40 years ago, as what we learned from our mentors. At that time, we learned the surgical procedures from our patients and from textbooks. In fact, the traditional training in surgery could be defined in the phrase, "see one, do one, teach one," as what surgeons learned for many decades (Halsted 1904). However, with the awareness of patient safety, financial constraints and medical legal issues in health care organizations, the training model used for many decades requires a fundamental renewal for urologists nowadays.

The advancement of computer science in the past 40 years and the widespread application of internet have changed people life in all aspects of our society. The use of smartphone, instant online communication and online video learning provide more chances for urologists to learn new surgical concepts. In international academic meetings, live demonstration of complex laparoscopic procedures via video streaming technology and real time communication with international experts deliver more opportunities for urologists in both step-by-step surgical illustrations and troubleshooting scenario in learning complex laparoscopic procedures. However, most complex laparoscopic procedures are associated with steeper learning curves compared to conventional open procedures. The restricted vision, lack of tactile perception, difficulty in handling endoscopic instruments and limited working space are main reasons for urologists to learn laparoscopic surgery. With the growing realization that most procedural learning curves do not require patients for skill acquisition, the implementation of training models in laparoscopic education has gained more and more attention in the past 20 years. Besides, the training program is more important than training models (Traxer et al. 2001). This chapter will focus on the discussion about

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training program for laparoscopic procedures and the validity of training models, so as to provide a panoramic view of current status of laparoscopic education.

## 3.2 Evaluation of a Training Curriculum

Surgical education is the long-standing responsibility for physicians as the clinical experience transferred for generations to generations so as to treat diseases in a better way. Continuous medical education is not only important for a surgeon to be competent in his specialty, but also provide a chance for patients to receive better medical treatment. In order to keep clinical competence, a well-designed training curriculum is required in all aspects of clinical practice, which would be more important in surgical field. Although the curriculum might change a lot as the alongside with the progression of computer science, the measuring tools remain constant in the past several decades. The validity test is the essential part to evaluate a training curriculum and will be discussed in the following parts.

### 3.2.1 Face Validity

Face validity refers to the measurement of a test in all aspects (Guion 1980; Holden 2010). It also means the transparency and relevance to test participants. In a simple word, face validity means how a test really "looks like" as evaluated by all faculties of a training curriculum.

### 3.2.2 Content Validity

Content validity is also known as logical validity, which refers to a measure on all aspects of the test (Lawshe 1975). It also needs to use a designed scale to evaluate the effectiveness of a test and a statistical test might be needed for further analysis. Content validity is most often used in academic and vocational testing and it might refer to the curriculum evaluation in clinical education.

### 3.2.3 Construct Validity

Construct validity is one of the three types of validity evidence, along with the content validity and criterion validity in traditional validity theory. It refers to the identification of appropriateness made on the basis of observations or measurements for a test. In 1955, Cronbach and Meehl reported that construct validity could be evaluated in the following three aspects, including the articulation of a set of theoretical concepts and their interactions, to develop ways to measure the hypothetical constructs for a theory and empirically testing the hypothesized relations. Construct validity is very important in social science, psychology and language studies and are one of the important measurements for a training curriculum of laparoscopy nowadays.

## 3.3 Training Curriculum

The training curriculum using cadaveric/animal models, high/low fidelity simulators and virtual reality simulators provide the possibility of getting knowledge-based behavior (Satava 2001). However, the course aiming to train new laparoscopic surgical procedures should focus on both technical and non-technical skills in handing various clinical scenarios. There are several issues needed to be addressed, such as length of the program, content of didactic courses, hand-on training materials and homogeneity of trainees (Vaziri 2013). It is reported that participants that are trained for more than 1 day interactive program might be more competent. In order to decrease the perioperative complication rate in laparoscopic procedures, the implementation of surgical volume after the training program is essential. Hence, an optimal course should include not only didactic lectures and interactive simulator training program, but also improve the performance of trainee (Kneebone 2003). The aim of the training course should focus on the decrease of possible complications and increase dexterity during laparoscopic procedures. In 1998, a guideline from society of American gastrointestinal endoscopic surgeons (SAGES) suggested the following rules for courses design in laparoscopic/robotic surgery. The principles were: (1) The objectives and the assessment methodology should be clearly illustrated, (2) the faculties should be qualified, (3) a fundamental knowledge, skills and clinical experiences should be identified in participants, (4) the facilities should be adequate. In 2006, Corica et al. reported the training experience of mini-residency program for laparoscopic procedures with more than 2-year follow-up period. A 5-day training program was conducted, including didactic lecture, hand-on training in dry lab and animal models and observation of live surgery in the operating room. The authors concluded that 5-day mini-residency program could encourage trainees to perform more complex laparoscopic procedures in their daily practice. The course coordinator needs to identify the requirement of trainees and tries to design a tailor-made content for all participants. The content of didactic lecture is another concern for a training course and should include fundamental knowledge of laparoscopic surgery, step-by-step laparoscopic surgical procedures and possible landmark identification during surgery, complications of laparoscopic surgery and future perspectives or current status of laparoscopic surgery. For participants who have certain level in laparoscopic procedures, the trouble-shooting lecture might be more helpful so as to provide experience sharing scenario in the course. Finally, the satisfaction survey of the training course is essential for course coordinators. It can provide not only the evaluation of the training course, but also provide suggestions for course refinement. To sum up, there is no perfect training curriculum, but a training curriculum can be refined to become perfect.

## 3.4 Training Models

There were several training models focused on laparoscopic surgical procedures. With the advancement of computer science and virtual reality, the application of computerized model has gained widespread acceptance in recent years. Besides, there were several validated models used for radical/partial nephrectomy, pyeloplasty, ureteral reimplantation, and urethrovesical anastomosis using analogue materials. The animal model was still the most common selection to simulate clinical scenario although fresh frozen cadaveric model might provide better experience in endoscopic dissection. The simulated training models will be discussed in the following section.

### 3.4.1 Computerized Simulators

As the development of imitative technology, application of augmented reality in real life and the widespread deployment of high definition video system, the use of virtual reality in educational training has gained popularity since early 2000s (Laguna et al. 2002). The computer-based design of a simulator mainly focused on the reproducibility of three-dimensional environment, tissue texture and the creation of force-feedback mechanisms. Besides, the possible smoke generation and tissue elasticity alongside the bleeding phenomenon during endoscopic dissection and vessel ligation is another consideration to be implemented in a computer-based simulator. In 2012, Matsuda et al. reported the experience in virtual reality simulator and compared to the videotape assessment from real laparoscopic procedures. They concluded that the basic skill training in virtual reality simulators might demonstrate the construct and concurrent validity to evaluate preclinical laparoscopic skills.

### 3.4.2 Analogue Training Model

#### 3.4.2.1 Partial/Radical Nephrectomy

There were several studies describing the application of training models in simulated training of partial nephrectomy. In 2010, the Procedicus MIST nephrectomy VR simulator was reported to have face, content and construct B validity (Brewin et al. 2010). Lee et al. (2012a) reported the partial nephrectomy model mimicking renal hilar injury, which demonstrated face, content and construct B validity. In 2012, Hung et al. reported another model using porcine kidney and styroform ball to mimic renal tumor requiring laparoscopic/robotic partial nephrectomy while face, content and construct B validity could be demonstrated in this study. In 2013, De Win et al. reported the animal model of porcine kidney, which found to have content and construct A validity. With the advancement in augmented reality, the computerized model was designed. In 2015, Hung et al. reported the application of dV-Trainer in robotic partial nephrectomy training and face, content and construct B validity was found in this training model. All four reported studies gained a level of evidence 2b.

#### 3.4.2.2 Pyeloplasty

There were two studies evaluating the application of pyeloplasty model. In 2013, Jiang et al. reported the use of chicken crop model to simulate clinical scenario of laparoscopic pyeloplasty which demonstrated construct B validity between experts, specialists and junior residents. In 2014, Poniatowski et al. reported the pyeloplasty simulator model by using a low-cost, high-fidelity tissue analogue. It was reported to have face, content and construct B validity (Poniatowski et al. 2014). Those two studies gained a level of evidence 2b.

#### 3.4.2.3 Ureteral Reimplantation

In 2013, Tunitsky et al. reported the use of hydrogel to simulate laparoscopic/robotic ureteral reimplantation. The model demonstrated to have face, content and construct B validity and gained a level of evidence 2b.

#### 3.4.2.4 Vesicourethral Anastomosis

There were several studies evaluating the training models of vesicourethral anastomosis. In 2006, Laguna et al. reported the chicken model to mimicking vesicourethral anastomosis and found to have construct B validity in this study with a level 2c evidence. In 2012, Sabbagh et al. reported the latex UV model to simulate vesicourethral anastomosis, which demonstrated face and predictive validity and a level 2a evidence was identified. In 2014, Kang et al. reported the use of tube3/dV-Trainer to simulated vesicourethral anastomosis. Face, content and construct B validity was found in this study while a level 2b evidence was identified. In 2015, Chowriappa et al. reported the use of augmented reality to simulate vesicourethral anastomosis in HoST/RoSS model. Face and concurrent validity were found in this study and a level 1b evidence was noted.

### 3.4.3 Animal Model

The use of animal to simulate real surgical scenario was a longstanding choice for surgical training, not only in conventional open surgery, but also in laparoscopic surgical procedures (Alemozaffar et al. 2014). The most commonly used animal is porcine model while canine or calf model was sporadically reported. The interactive training program can be divided to upper urinary tract and lower urinary tract. The trainees will be divided into several groups and about 2–3 trainees per group is the usual setting. Each group will be assigned to perform 2–3 procedures in about 4 h. Partial/radical nephrectomy, pyeloplasty and ureteroureterostomy are the usual procedures for upper urinary tract while ureteroneocystostomy, enterocystoplasty and radical cystectomy are usually conducted for lower urinary tract.

### 3.4.4 Cadaveric Model

The use of cadaveric model for surgical training may provide an ideal environment to realize real human anatomy and to simulate manipulations in laparoscopic surgery. It also serves as the transition to evaluate the surgical competence of trainees from simulation-based training model to real laparoscopic surgeries. In 2008, Giger et al. reported the experience using Thiel cadavers in laparoscopic training. They reported a high satisfaction scores were identified for the course and all participants were willing to recommend the course to their colleagues. In 2012, Sharma and Horgan reported the comparison between fresh frozen cadavers and high-fidelity simulators for laparoscopic training. They found that fresh frozen cadaver was perceived as a better tool for laparoscopic training. In 2016, Imakuma et al. reported the application of fresh frozen cadavers for laparoscopic training without pneumoperitoneum. They concluded that the use of fresh frozen cadavers could provide a promising model for laparoscopic training. However, the use of cadavers might raise several ethic and financial issues which limit the widespread use of cadaveric model.

### 3.4.5 Non-technical Skill Training

The nontechnical skill training was first reported in England, which refers to the evaluation of situation awareness, communication, teamwork and decision making and leadership. Lee et al. (2012b) reported the experience in high-fidelity simulation-based training for laparoscopic complication management. They concluded that the nontechnical training might improve the interdisciplinary communication skills.

## 3.5 Conclusion

With the advancement of optic technology, energy-based endoscopic equipment and computer science, the implementation of laparoscopic surgeries into surgeon's daily practice is essential nowadays. The introduction of laparoscopic training into continuous medical education could provide a solution to maintain clinical competency and to learn new endoscopic procedures in a safe environment. In the near future, laparoscopic simulation using computerized virtual reality model, animal model and cadaveric model might serve as the step-by-step learning protocol to deliver a new surgical technique from the experimental test into a practical procedure.

## References


Alemozaffar M, Narayanan R, Percy A, et al. Validation of a novel, tissue-based simulator for robot-assisted radical prostatectomy. J Endourol. 2014;28:995–1000.

Brewin J, Nedas T, Challacombe B, et al. Face, content and construct validation of the first virtual reality laparoscopic nephrectomy simulator. BJU Int. 2010;106:850–4.

Chowriappa A, Raza SJ, Fazili A, et al. Augmented-reality-based skills training for robot-assisted urethrovesical anastomosis: a multi-institutional randomised controlled trial. BJU Int. 2015;115:336–45.

Corica FA, Boker JR, Chou DS, et al. Short-term impact of a laparosocpic "mini-residency" experience on postgraduate urologists' practice patterns. J Am Coll Surg. 2006;203:692–8.

Cronbach LJ, Meehl PE. Construct validity in psychological tests. Psychol Bull. 1955;52:281–302.

De Win G, Van Bruwaene S, Allen C, et al. Design and implementation of a proficiency-based, structured endoscopy course for medical students applying for a surgical specialty. Adv Med Educ Pract. 2013;4:103–15.

Giger U, Fresard I, Hafliger A, et al. Laparoscopic training on Thiel human cadavers: a model to teach advanced laparoscopic procedures. Surg Endosc. 2008;22:901–6.

Guion RM. On trinitarian doctrines of validity. Prof Psychol. 1980;11:385–98.

Halsted SW. The training of the surgeon. Bull John Hopkins Hosp. 1904;15:267–75.

Holden RB. Face validity. In: Weiner IB, Craighead WE, editors. The Corsini encyclopedia of psychology. 4th ed. NJ: Wiley; 2010. p. 637–8.

Hung AJ, Ng CK, Patil MB, et al. Validation of a novel robotic-assisted partial nephrectomy surgical training model. BJU Int. 2012;110:870–4.

Hung AJ, Shah SH, Dalag L, et al. Development and validation of a novel robotic procedure specific simulation platform: partial nephrectomy. J Urol. 2015;194:520–6.

Imakuma ES, Ussami EY, Meyer A. Laparoscopic training model using fresh human cadavers without the establishment of pneumoperitoneum. J Minim Access Surg. 2016;12:190–3.

Jiang C, Liu M, Chen J, et al. Construct validity of the chicken crop model in the simulation of laparoscopic pyeloplasty. J Endourol. 2013;27:1032–6.

Kang SG, Cho S, Kang SH, et al. The Tube 3 module designed for practicing vesicourethral anastomosis in a virtual reality robotic simulator: determination of face, content, and construct validity. Urology. 2014;84:345–50.

Kneebone R. Simulation in surgical training: educational issues and practical implications. Med Educ. 2003;27:267–77.

Laguna MP, Hatzinger M, Rassweiler J. Simulators and endourological training. Curr Opin Urol. 2002;12:209–15.

Laguna MP, Arce-Alcazar A, Mochtar CA, et al. Construct validity of the chicken model in the simulation of laparoscopic radical prostatectomy suture. J Endourol. 2006;20:69–73.

Lawshe CH. A quantitative approach to content validity. Pers Psychol. 1975;28:563–75.
Lee JY, Mucksavage P, McDougall EM. Simulating laparoscopic renal hilar vessel injuries: preliminary evaluation of a novel surgical training model for residents. J Endourol. 2012a;26:393–7.
Lee JY, Mucksavage P, Canales C, et al. High fidelity simulation based team training in urology: a preliminary interdisciplinary study on technical and nontechnical skills in laparoscopic complications management. J Urol. 2012b;187:1385–91.
Matsuda T, McDougall EM, Ono Y, et al. Positive correlation between motion analysis data on the LapMentor virtual reality surgical simulator and the results from videotape assessment of real laparoscopic surgeries. J Endourol. 2012;26:1506–11.
Poniatowski LH, Wolf JS Jr, Nakada SY, et al. Validity and acceptability of a high-fidelity physical simulation model for training of laparoscopic pyeloplasty. J Endourol. 2014;28:393–8.
Sabbagh R, Chatterjee S, Chawla A, et al. Transfer of laparoscopic radical prostatectomy skills from bench model to animal model: a prospective, single-blind, randomized, controlled study. J Urol. 2012;187:1861–6.
SAGES. Guidelines for granting of privileges for laparoscopic and/or thoracoscopic general surgery. Society of American Gastrointestinal Endoscopic Surgeons (SAGES). Surg Endosc. 1998;12:379–80.
Satava RM. Surgical education and surgical simulation. World J Surg. 2001;25:1484–9.
Sharma M, Horgan A. Comparison of fresh-frozen cadaver and high-fidelity virtual reality simulators as methods of laparoscopic training. World J Surg. 2012;36:1732–7.
Traxer O, Gettman MT, Napper CA, et al. The impact of intensive laparoscopic skills training on the operative performance of urology residents. J Urol. 2001;166:1658–61.
Tunitsky E, Murphy A, Barber MD, et al. Development and validation of a ureteral anastomosis simulation model for surgical training. Female Pelvic Med Reconstr Surg. 2013;19:346–51.
Vaziri M. Laparoscopic surgical education. J Minim Invasive Surg Sci. 2013;2:1–2.

# 4 Simulation Training of Laparoscopy

Kazuhide Makiyama

**Abstract**

Simulators are often used as educational tools for training surgeons in laparoscopic procedures. Some surgical simulators have been proven to shorten clinical learning curves, and it was demonstrated that techniques learnt by using a simulator can be brought into the operation room. Laparoscopic surgical simulators can be classified into box and virtual reality type. Box-type simulators are cheaper and have a superior array of surgical tools. By using box trainers, trainees are able to use and become familiar with real surgical tools. Box trainers are perfectly suited for learning suturing and knot tying. Virtual reality simulators are generally more expensive than box trainers. The main advantage of virtual reality simulators is that every movement of the forceps is recordable in virtual space. Thus, the recorded data can be analyzed, and trainees' skills can be assessed objectively. Patient-specific simulators represent a new technological advancement. They provide patient-specific training, in which patients' three-dimensional imaging data are used to create virtual reality simulations.

It is necessary to evaluate the usefulness and adequacy of laparoscopic simulators. There are several ways to validate laparoscopic simulators, including both subjective and objective methods. Subjective simulator evaluations assess face and content validity, whereas quantitative evaluations examine construct, concurrent, and predictive validity.

**Keywords**

Simulator · Laparoscopy · Training

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## 4.1 Introduction

Surgical techniques have advanced in the past three decades. In the urological field, the majority of major surgical procedures that were performed using open methods have been replaced by laparoscopic and robotic techniques. Now, in high-volume centers, open surgery is only conducted in limited and complicated cases, for example, those involving bulky tumors or tumors affecting the major vessels, etc. When open surgery is performed by a trainee surgeon, a trainer will be in front of the trainee, both the trainer and trainee share the operative field and the trainer can freely manipulate and control the operation easily. On the other hand, in laparoscopic surgery the surgeon is basically alone, and scopists and assistants are supposed to concentrate on their own roles. When trainers want to manipulate and control such surgery, they have to remove the trainee from the surgeon's position. So, it is more difficult to teach surgery to trainees without sacrificing surgical "smoothness" in laparoscopic procedures. Thus, laparoscopic procedures are considered to be difficult to learn and teach. For this reason, trainees have to be well educated outside of the operative room before they perform laparoscopic surgery for the first time. In addition, surgeons are supposed to acquire most of the knowledge and skills required for a particular surgical procedure by themselves. Training outside of the operation room can shift the learning curve from inside to outside of the operation room and minimize the clinical learning curve. Simulations offer the opportunity for surgeons to improve their technical skills in a structured, low-pressure environment outside of the operation room without putting patient safety at risk (Gava 2004).

Surgical simulators are one of the tools used for training outside of the operation room. The need for surgical simulators has increased with the rise of surgical technology and so the market for them has expanded. Some surgical simulators have been proven to shorten clinical learning curves. In fact, it was demonstrated that techniques obtained from simulators can be brought into the operation room. In this chapter, we review laparoscopic surgical simulators.


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## 4.2 The Use of Simulators Laparoscopic Surgery Training

Training for laparoscopic surgery requires the trainee to acquire both knowledge and skills. At present, knowledge can be obtained from academic conferences, academic websites, textbooks, and videos. On the other hand, skill training is performed using simulators, animals, or cadavers. Although training using animals or cadavers is useful, it is expensive, and trainees have few chances to participate in such training. Conversely, simulator training can be performed repeatedly from day to day and is useful for skill acquisition. In the past two decades, the laparoscopic simulator market has expanded. As simulators are not affected by ethical or hygiene issues, it is expected that the need for surgical simulators will increase. By using laparoscopic surgical simulators, surgeons can train for laparoscopic surgery outside of the operating room. If simulators are appropriately incorporated into surgical training, they are considered to be a time-saving, cost-effective, and safe method of training (Le et al. 2007). In addition, some surgeons and urologists recognize simulators as important tools for laparoscopic surgical training (Le et al. 2007; Korndorffer Jr et al. 2006; Fried et al. 1999), and several randomized trials have reported that the use of virtual reality (VR) surgical simulators can improve performance in the operating room (Aggarwal et al. 2007; Grantcharov et al. 2004; Haque and Srinivasan 2006; Palter and Grantcharov 2014).

In the United States, FLS (Fundamentals of Laparoscopic Surgery) certification is required for American Board of Surgery Certification. The FLS process consists of hands-on manual skill practice and training via a box-type simulator. It was reported that undergoing FLS laparoscopic surgery training to proficiency levels can improve trainee performance (Sroka et al. 2010).

## 4.3 Classification of Laparoscopic Surgical Simulators

Table 4.1 shows a surgical simulator classification. As indicated in the table, part-task trainers are designed to train surgeons in the handling of tools during surgery. Box trainers are part-task trainers. Task trainers use virtual human bodies created by VR technology to train surgeons in surgical procedures and hand-eye coordination. VR-type simulators are task trainers. Mission rehearsal simulators are mainly used to determine the risks of surgery in advance via preoperative surgical training with a patient-specific model and to improve the surgeon's skills to minimize risks during the actual operation. Patient-specific simulators are mission rehearsal simulators. In general, the technical difficulty and cost of a system increase from classifications (1) to (3).

## 4.4 Box-Type Simulators (Box Trainer)

Box trainers are superior to other types of simulator in terms of their cost and surgical tools. Box trainers are relatively cheap. In box trainers, trainees are able to use and become familiar with real surgical tools. Box trainers are perfectly suited to basic training, e.g., learning suturing and knot tying. Although some VR simulators have suturing and knot-tying applications, box trainers seem to be the best type of simulator for training that requires fine manipulation and tactile sensation, especially for knot tying. Repeated training with a trainer could provide maximal benefits for trainees in terms of allowing them to acquire adequate suturing and knot-tying skills. Through such repetitive training, trainees obtain hand-eye coordination (Fig. 4.1).

Although box trainers are commercially available from a lot of companies, they can be "scratch built"(Aslam et al. 2016), which can be a cost-effective way of acquiring laparoscopic

**Fig. 4.1** Training using a box trainer

**Table 4.1** Classification of laparoscopic surgical simulators

| Classification | Typical example | Applications | Surgical tools | Basic training | Procedure-specific training | Patient-specific training |
|---|---|---|---|---|---|---|
| (1) Part-task trainers | Box trainers | Mechanical | Real | Possible | Possible with a good model | Impossible |
| (2) Task trainers | Common VR simulators | Virtual reality | Virtual | Possible | Possible | Impossible |
| (3) Mission rehearsal | Patient-specific simulators | Virtual reality | Virtual | Possible | Possible | Possible |

skills. Low-cost alternatives are needed to allow trainees to practice and develop their laparoscopic skills outside of the workplace (Li and George 2017). A portable bookbinder-sized box trainer that is used in combination with a smartphone has been developed (http://www.g-mark.org/award/describe/42712), and a box trainer that incorporates an iPad has been reported to be effective (Ruparel et al. 2014). As described above, trainees can create homemade box trainers by themselves, which can be beneficial in terms of cost and space.

Another important issue for box trainers is image quality. Recently, in response to surgeons' requests, it has become possible to obtain high-quality laparoscopic images. However, many box trainers still only produce low-quality images. Thus, it will be necessary to improve the image quality of box trainers in order to facilitate high-quality training. Achurra et al. (2017) reported that box trainer image quality is an important issue.

You can place any material in a box trainer and freely practice whatever skills you want. Traditionally, chicken meat and mandarin oranges are used for dissection training. Bimanual coordination skill can be obtained by trimming chicken skin from poultry or finding and dissecting nerves or blood vessels from poultry. In addition, trainees peel skin from mandarin oranges using laparoscopic forceps. During such skin-peeling training, rough dissection will cause the orange to rupture, leading to the release of juice. Therefore, trainees try to carefully dissect such oranges so that they do not release the juice. Sponge and rubber goods of moderate size and hardness can be used for suturing training. Thus, appropriate training can be conducted using everyday items. It is important to have an aim during training. Training for certain procedures or situations can also be conducted using ordinary goods. For example, Fig. 4.2 shows a vesicourethral anastomosis model composed of sponge, chicken, and rubber tubing. The sponge mimics the pelvic floor, anterior rectal wall, and deep dorsal complex; the chicken represents the bladder; and the rubber tube mimics the urethra.

Recently, with the rise of three-dimensional printers and advances in material engineering, three-dimensional training models have been developed, including models of the kidneys, stomach, lungs, liver, colon, and blood vessels, etc. By using such three-dimensional organ models in a box trainer, trainees can participate in more realistic training involving real surgical tools. Figure 4.3 shows examples of three-dimensional kidney models that are used for partial nephrectomy training. They can be cut and sutured freely. These three-dimensional organ models can be used to reduce and replace animal training. In addition, they might bridge the gap between real surgery and VR simulators.

Another recently developed technology is the suture evaluation system (https://www.kyotokagaku.com/products/detail01/m57.html). This system includes a personal computer, a camera, a suturing unit, and a suture pad with pressure sensors. It can evaluate a surgeon's skill, the procedure time, the force placed on a particular tissue, suture tension, stitch spacing, and stich equidistance (Ieiri et al. 2013). Although this product seems to be a bit expensive, an increase in demand might reduce the price, and it has the advantage of allowing objective assessments to be carried out.

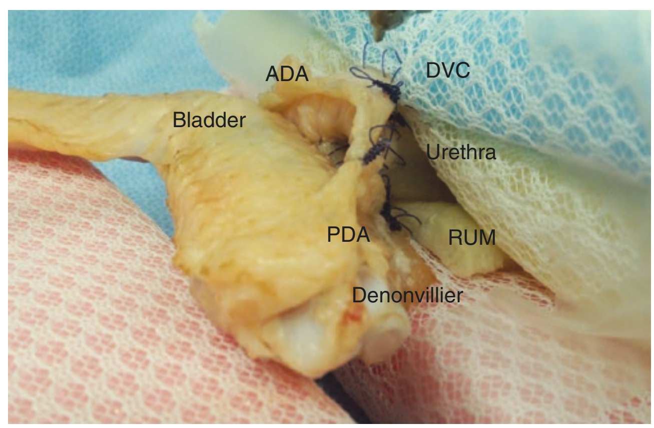
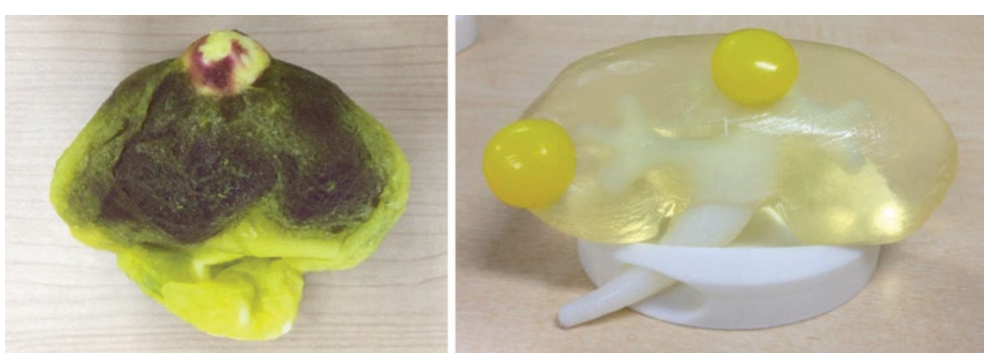



**Fig. 4.2** A vesicourethral anastomosis model. In this model, chicken meat, sponge, and rubber tubing are used to mimic the bladder, Denonvilliers' fascia, deep dorsal vein complex (DVC), anterior detrusor apron (ADA), posterior detrusor apron (PDA), rectourethral muscle (RUM), and urethra

**Fig. 4.3** Examples of three-dimensional kidney models used for practicing partial nephrectomy



## 4.5 Virtual Reality (VR) Simulators

Task trainers are training tools for specific tasks. In the laparoscopic field, VR simulators are used as task trainers. Figure 4.4 shows a VR simulator. VR simulators almost always include basic skill training software and procedure training software, and they are generally more expensive than box trainers. The main advantage of VR simulators is that every movement of the forceps or affected organs is recordable in virtual space. The recorded data can be analyzed, and trainees' skills can be assessed objectively (Fig. 4.5). Personal archival records might motivate trainees to continue training. Many pieces of surgical training software are commercially available, including software for general laparoscopic surgery and urological and gynecological laparoscopic procedures. Figure 4.6 shows a nephrectomy procedure performed on a simulator. Such simulators can be used to train surgeons in a particular procedure under various scenarios. During the procedure, trainees can experience the interaction between the forceps and the target organ; i.e., they can learn how to achieve good organ traction. They can also experience bleeding from blood vessels and learn how to achieve hemostasis. Some VR simulators have a haptic function, so the user can experience haptic feedback from the target organ. Many companies sell laparoscopic VR simulators, including the LAP Mentor (Simbionix Ltd., Airport City, Israel), LAPSIM (Surgical Science, Göteborg, Sweden), Simendo (Simendo B.V., Rotterdam, The Netherlands), LapVR (CAE Healthcare, FL, USA), and Lap-X (Medical X, Rotterdam, The Netherlands). Among these, the LAP Mentor and LapSim are available for nephrectomy training.

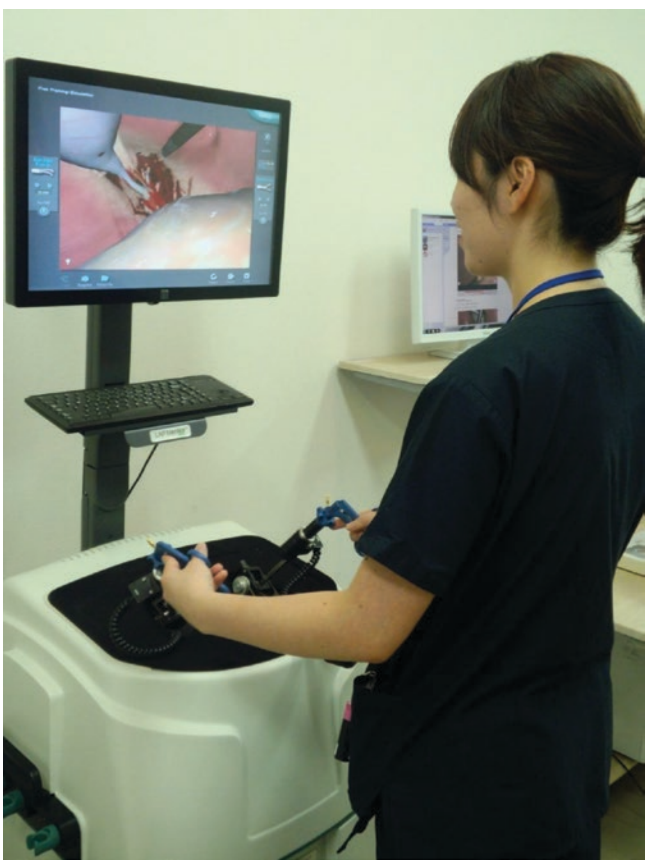


**Fig. 4.4** A VR-based laparoscopic surgical simulator

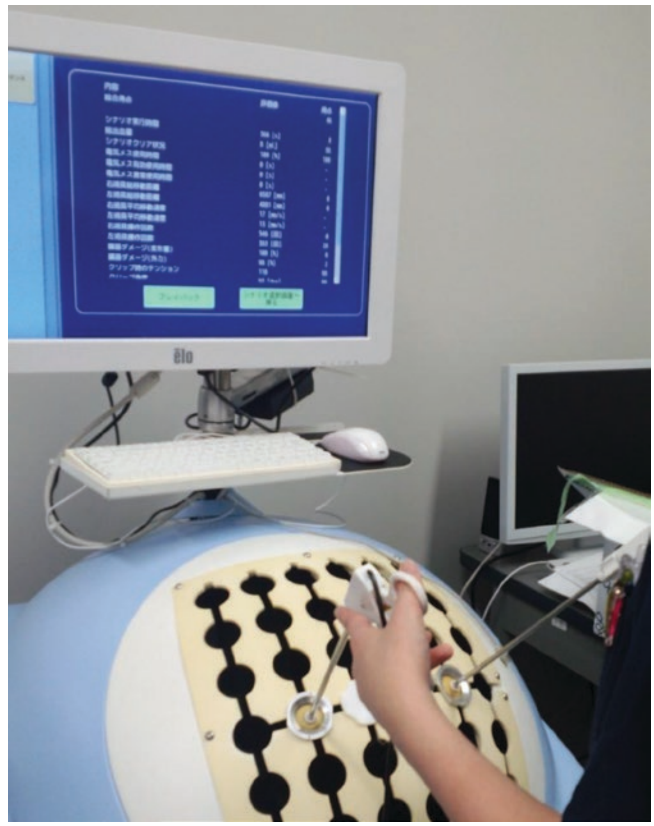


**Fig. 4.5** A score is displayed after each VR simulator procedure

**Fig. 4.6** A nephrectomy procedure performed on a simulator

A unique laparoscopic training system, the Nintendo Wii-U laparoscopic simulator, was described in a previous study. It includes a game named "Underground", which is specially designed for laparoscopic surgery (Jalink et al. 2015). The game is set in a cave and requires the player to use laparoscopic tools (e.g., to build roads and create paths). Although it does not involve anatomically relevant information, the game is useful for improving hand-eye coordination, which is essential for laparoscopic surgery. The total cost of this system is approximately €700 (825 USD), including the Wii-U, the controllers, the tool shells, and the game. It was reported that the game is suitable for use in introductory surgical courses. Thus, residents can improve their hand-eye coordination by playing the game at the beginning of their postgraduate training.

In sports, warming up before exercise has clear performance benefits. Likewise, some studies have found that warming up in VR simulators before going into the operating room has a beneficial effect on surgical performance (Lee et al. 2012; Da Cruz et al. 2016; Araujo et al. 2014; Calatayud et al. 2010; Moldovanu et al. 2011; Paschold et al. 2014). Lee et al. (2012) qualitatively evaluated the performance of residents in a total of 28 laparoscopic nephrectomy procedures, 14 of which involved a preoperative warm-up, and found that superior results were obtained when a preoperative warm-up was performed. Calatayud et al. (2010) compared the performance levels of eight experienced surgeons during laparoscopic cholecystectomy. Each surgeon performed two procedures—one involving a preoperative warm-up and another in which no warm-up was performed. The results suggested that a preoperative warm-up is beneficial. In a qualitative analysis, Moldovanu et al. (2011) examined the performance of a surgical team during laparoscopic cholecystectomies involving 20 patients. A preoperative warm-up was performed in a VR simulator before ten of the procedures. As a result, it was found that the team produced significantly better results in the cases involving preoperative warm-ups. Although Polterauer et al. (2016) reported that warming up before laparoscopic gynecological surgery does not increase psychomotor skills during surgery, conducting a preoperative warm-up using VR simulators generally seems to have beneficial effects on surgical performance. What is the ideal format for such warm-ups? In search of the ideal warm-up design, Willaert et al. (2012a) compared random basic exercise-based training with specific exercise-based training (procedure-related exercises) in VR simulators and found that performing a warm-up involving specific procedure-related tasks had beneficial effects on surgical performance.

Numerous studies have indicated that video game experience is related to good laparoscope surgical practice (Grantcharov et al. 2003; Van Hove et al. 2008; Nomura et al. 2008; Shane et al. 2007; de Araujo et al. 2016). In 2003, Grantcharov et al. (2003) reported that video game experience was positively correlated with laparoscopic simulator skill. Furthermore, Van Hove et al. (2008) detected a positive relationship between a history of video game use and laparoscopic skill levels in first-year residents. Gamers seem to have higher pre-laparoscopic training skill levels than non-gamers. Likewise, trainees who excel in sport seem to have higher pre-laparoscopic training skill levels. Although many investigators have reported that trainees with high baseline skill levels, such as gamers or athletes, tend to produce high scores during their first use of a VR simulator, very few studies have demonstrated that such advantages translate into performance improvements in the operation room. I emphasize that daily training will overcome any such initial advantages, and surgical simulators might be most beneficial for trainees who have no baseline advantage, although all trainees are supposed to undergo simulator training before they become surgeons.

## 4.6 Patient-Specific Simulators

Patient-specific simulations are an effective way of preoperatively practicing a procedure. They involve the use of patient-specific imaging data in a VR environment (Badash et al. 2016). Although many surgeons think over and plan procedures before performing them, the information acquired by such "mental simulations" is often not shared between team members, and important details can be unintentionally missed. Providing accurate patient-specific anatomical information is used, VR simulations reduce the risk of human error and allow visual surgical planning to be conducted by all team members (Endo et al. 2014).

The mission rehearsal type of simulator is a training tool for a specific "mission". In the laparoscopic field, patient-specific simulators are mission rehearsal-type simulators. Patient-specific simulators for laparoscopic surgery emerged relatively recently as a result of technological advancements, and a few investigators have described such systems (Makiyama et al. 2012a).

A laparoscopic colectomy simulator, involving a patient-specific model, was developed by Suzuki et al. (2007). Although various surgical maneuvers can be practiced in this prototype simulator, as far as I know, it has not been used in the clinical setting and does not seem to be up to scratch. Soler et al. also described a patient-specific laparoscopic simulator for liver surgery, named the ULIS (unlimited laparoscopic immersive simulator) (Soler and Marescaux 2008). To the best of my knowledge, a preoperative version of the ULIS that allows preoperative virtual liver resection to be performed has not been reported yet, and further improvements are awaited (Willaert et al. 2012b).

Makiyama et al. (2012a) developed a patient-specific simulator for laparoscopic renal surgery. The outline of this simulator is as follows. Using a model generation system, three-dimensional volumetric data are obtained for each patient who is scheduled to undergo renal surgery based on preoperative dynamic computed tomography. The patient-specific volumetric data for the kidneys and the surrounding anatomical structures are entered into the simulator. Then, the anatomical structures that are relevant to renal surgery are reproduced in the simulator on a patient-by-patient basis. Thus, this simulator allows surgeons to perform preoperative patient-specific simulations. In addition, surgical simulations can be conducted using either a laparoscopic or retroperitoneoscopic approach. Simulating both approaches might help surgeons to select the optimal approach for each case. This simulator also has a unique function named trocar simulation. In trocar simulation, the scope and other trocars can be located anywhere on the skin. The surgeon can then see the corresponding laparoscopic views and determine the optimal trocar positions for the real operation. In such surgical simulations, surgeons can use both hands and feel feedback forces from the virtual organs. The virtual surgical tools include scissors, several types of forceps, suction drains, clips, a stapler, entrapment bags, and others, and the surgeon can choose and change the tools during the simulation. By stepping on foot pedals, electrical cutting and coagulation can be achieved. The available surgical simulations include dissection of the renal hilus and mobilization of the kidney. Makiyama et al. validated this patient-specific simulator and concluded that anatomical structures were reproduced correctly. Based on its content validity, they also mentioned that the users felt that it was a useful preoperative training tool (Makiyama et al. 2015). It is commercially available as the Lap-PASS (Mitsubishi Precision Co. Ltd., Tokyo, Japan). Figure 4.7 shows the Lap-PASS.

**Fig. 4.7** Lap-PASS, a patient-specific simulator

Patient-specific laparoscopic simulators have greater potential than conventional VR simulators. While conventional non-patient-specific simulators seem to be useful for helping novices or trainees to improve their skills, patient-specific simulators have the potential to aid surgeons with varying degrees of expertise. As conventional VR simulators use fixed patterns or scenarios, training based on such simulators is restricted to basic skills or simple surgical procedures, which skilled surgeons do not need to learn. Using patient-specific simulators, surgeons are able to perform patient-specific preoperative rehearsals and to become familiar with patients' anatomies preoperatively, which might contribute to improving surgical outcomes. Expert surgeons can also try out or test new techniques using patient-specific simulators. Moreover, patient-specific simulators allow skilled surgeons to carry out preoperative rehearsals in cases involving patients with rare or complex anatomies, for example, situs inversus totalis (Makiyama et al. 2012b). Thus, patient-specific simulators have the potential to help surgeons of all levels of experience by facilitating preoperative rehearsals and/or planning. Surgeons might also be able to develop new surgical techniques using such simulators. As patient-specific VR simulators are a new technology, further improvement and development are expected, and additional studies to validate them will be required.

## 4.7 Validity of Simulators

There are various differences between real operations and simulations. So, it is necessary to test the usefulness and adequacy of laparoscopic simulators. In addition, validation studies are needed to confirm that such simulators are suitable for surgical training. For example, the validity of laparoscopic simulators has been examined in several studies (Brewin et al. 2010; Wijn et al. 2010; Seymour et al. 2002; Hamilton et al. 2002). As a result, some simulators have been successfully incorporated into training curricula (Seymour et al. 2002; Hamilton et al. 2002). On the other hand, other laparoscopic

**Table 4.2** Types of simulator validity

| Validity | Assessment type | Content |
|---|---|---|
| Face validity | Subjective | Realism for user |
| Content validity | Subjective | Usefulness for user |
| Construct validity | Objective | Ability to discriminate according to surgical experience |
| Concurrent validity | Objective | Correlation with established assessments |
| Predictive validity | Objective | Correlation with in vivo performance |

simulators have not demonstrated sufficient construct validity (Haque and Srinivasan 2006; Wijn et al. 2010). In this section, the validity of laparoscopic simulators is discussed.

There are several ways to validate laparoscopic simulators, including both subjective and objective methods. Subjective simulator evaluations include assessments of face and content validity, whereas quantitative evaluations examine construct, concurrent, and predictive validity (Wanzel et al. 2002). These five types of validity are summarized in Table 4.2.

Face validity is a measure of the realism of a simulator. Users are asked (via a questionnaire) whether, on the face of it, the simulator seems to be realistic or have the desired qualities. Content validity is a measure of the usefulness of a simulator. Users are asked (via a questionnaire) whether the simulator seems to be useful for training or education.

Construct validity assesses the discriminative ability of a simulator. For example, participants are divided into two or three groups according to their laparoscopic experience and perform a task using the simulator. When a significant difference in outcomes is detected between the groups, the construct validity of the simulator is confirmed. Many previous studies have tested the construct validity of laparoscopic simulators (Thijssen and Schijven 2010). In such studies, the subjects are typically categorized into novices, intermediates, and experts, which are normally based on experience in terms of the number of laparoscopic procedures a surgeon has performed or their professional seniority, e.g., whether they are a student, resident, or attending surgeon, etc. Among the various VR tasks, basic skill tasks, such as peg transfer, are more frequently employed during assessments of construct validity. Many VR metrics are used to assess subjects' performance. The typical metrics used to assess construct validity are the time to completion, the instrument path length, the number of errors, and composite scores.

Concurrent validity is a measure of the association between performance in a simulator and performance in an established skill assessment carried out around the same time. When a correlation is detected between these parameters, concurrent validity is achieved. Box trainer performance (Jalink et al. 2015; Madan et al. 2003), the aptitude test battery (Haluck et al. 2002) and the FLS program score (Ritter et al. 2007) are examples of established skill tests whose outcomes are compared with simulator performance. Predictive validity is achieved when there is a correlation between simulator performance and performance in the operation room. Although some predictive validity studies have been published (Seymour et al. 2002; Thijssen and Schijven 2010), more research is needed to prove that skills acquired from a simulator can be transferred to the operation room.

## 4.8 Conclusions

Surgical training has become more and more important with advances in surgical techniques. Laparoscopic surgery is difficult to learn. Simulators for laparoscopic surgery play an important role in training because they are hygienic, safe, and can be used repeatedly. The accumulation of more evidence concerning the efficacy of laparoscopic simulators would be expected to lead to them becoming an essential tool in training curricula all over the world. Box trainers seem to be the gold standard for learning laparoscopic skills. VR simulators are already used routinely for laparoscopic training in some academic institutions. Patient-specific VR simulators have recently emerged and need to be validated in further studies. At any rate, I hope that many affordable, realistic, useful, and effective training simulators for training surgeons in various laparoscopic procedures and skills will be developed.

## References

Achurra P, Lagos A, Avila R, Tejos R, Buckel E, Alvarado J, Boza C, Jarufe N, Varas J. Allowing new opportunities in advanced laparoscopy training using a full high-definition training box. Surg Innov. 2017;24:66–71.

Aggarwal R, Ward J, Balasundaram I, et al. Proving the effectiveness of virtual reality simulation for training in laparoscopic surgery. Ann Surg. 2007;246:771–9.

Araujo SE, Delaney CP, Seid VE, et al. Short-duration virtual reality simulation training positively impacts performance during laparoscopic colectomy in animal model: result of a single-blinded randomized trial: VR warm-up for laparoscopic colectomy. Surg Endosc. 2014;28:2574–54.

de Araujo TB, Silveira FR, Souza DL, et al. Impact of video game genre on surgical skills development: a feasibility study. J Surg Res. 2016;201:235–43.

Aslam A, Nason GJ, Giri SK. Homemade laparoscopic surgical simulator: a cost-effective solution to the challenge of acquiring laparoscopic skills? Ir J Med Sci. 2016;185:791–6.

Badash I, Burtt K, Solorzano CA, Carey JN. Innovations in surgery simulation: a review of past, current and future techniques. Ann Transl Med. 2016;4:453.

Brewin J, Nedas T, Challacombe B, Elhage O, Keisu J, Dasqupta P. Face, content and construct validation of the first virtual reality laparoscopic nephrectomy simulator. BJU Int. 2010;106:850–4.

Calatayud D, Arora S, Aggarwal R, et al. Warm-up in a virtual reality environment improves performance in the operating room. Ann Surg. 2010;251:1181–5.

Da Cruz JA, Dos Reis ST, Cunha Frati RM, et al. Does warm-up training in a virtual reality simulator improve surgical performance? A prospective randomized analysis. J Surg Educ. 2016;73:974–8.

Endo K, Sata N, Ishiguro Y, et al. A patient-specific surgical simulator using preoperative imaging data: an interactive simulator using a three-dimensional tactile mouse. J Comput Surg. 2014;1:1–8.

Fried GM, Derossis AM, Bothwell J, et al. Comparison of laparoscopic performance in vivo with performance measured in a laparoscopic simulator. Surg Endosc. 1999;13:1077–81.

Gava DM. The future vision of simulation in health care. Qual Saf Health Care. 2004;13(Suppl 1):i2–i10.

Grantcharov TP, Bardram L, Funch-Jensen P, Rosenberg J. Impact of hand dominance, gender, and experience with computer games on performance in virtual reality laparoscopy. Surg Endosc. 2003;17:1082–5.

Grantcharov TP, Kristiansen VB, Bendix J, et al. Randomized clinical trial of virtual reality simulation for laparoscopic skills training. Br J Surg. 2004;91:146–50.

Haluck RS, Gallagher AG, Satava RM, et al. Reliability and validity of Endotower, a virtual reality trainer for angled endoscope navigation. Stud Health Technol Inform. 2002;85:179–84.

Hamilton EC, Scott DJ, Fleming JB, et al. Comparison of video trainer and virtual reality training systems on acquisition of laparoscopic skills. Surg Endosc. 2002;16:406–11.

Haque S, Srinivasan S. A meta-analysis of the training effectiveness of virtual reality surgical simulators. IEEE Trans Inf Technol Biomed. 2006;10:51–8.

Ieiri S, Ishii H, Souzaki R, Uemura M, Tomikawa M, Matsuoka N, Takahashi A, Hashizume M, Taguchi T. Development of an objective endoscopic surgical skill assessment system for pediatric surgeons: suture ligature model of the crura of the diaphragm in infant fundoplication. Pediatr Surg Int. 2013;5:501–4.

Jalink MB, Goris J, Heineman E, Pierie JP, ten Cate Hoedemaker HO. Face validity of a Wii U video game for training basic laparoscopic skills. Am J Surg. 2015;209:1102–6.

Korndorffer JR Jr, Stefanidis D, Scott DJ. Laparoscopic skills laboratories: current assessment and a call for resident training standards. Am J Surg. 2006;191:17–22.

Le CQ, Lightner DJ, Vanderlei L, et al. The current role of medical simulation in American urological residency training programs: an assessment by program directors. J Urol. 2007;177:288–91.

Lee JY, Mucksavage P, Kerbl DC, et al. Laparoscopic warm-up exercises improve performance of senior-level trainees during laparoscopic renal surgery. J Endourol. 2012;26:545–50.

Li MM, George J. A systematic review of low-cost laparoscopic simulators. Surg Endosc. 2017;31:38–48.

Madan AK, Franzides CT, Shervin N, et al. Assessment of individual hand performance in box trainers compared to virtual reality trainers. Am Surg. 2003;69:1112–4.

Makiyama K, Nagasaka M, Inuiya T, Takanami K, Ogata M, Kubota Y. Development of a patient-specific simulator for laparoscopic renal surgery. Int J Urol. 2012a;19:829–35.

Makiyama K, Sakata R, Yamanaka H, Tatenuma T, Sano F, Kubota Y. Laparoscopic nephroureterectomy in renal pelvic urothelial carcinoma with situs inversus totalis: preoperative training using a patient-specific simulator. Urology. 2012b;80:1375–8.

Makiyama K, Yamanaka H, Ueno D, Ohsaka K, Sano F, Nakaigawa N, Yao M, Kubota Y. Validation of a patient-specific simulator for laparoscopic renal surgery. Int J Urol. 2015;22:572–6.

Moldovanu R, Tarcoveanu E, Dimofte G, et al. Preoperative warm-up using a virtual reality simulator. JSLS. 2011;15:533–8.

Nomura T, Miyashita M, Shrestha S, et al. Can interview prior to laparoscopic simulator training predict a trainee's skills? J Surg Educ. 2008;65:335–9.

Palter VN, Grantcharov TP. Individualized deliberate practice on a virtual reality simulator improves technical performance of surgical novices in the operating room: a randomized controlled trial. Ann Surg. 2014;259:443–8.

Paschold M, Huber T, Kauff DW, et al. Preconditioning in laparoscopic surgery – results of a virtual reality pilot study. Langenbecks Arch Surg. 2014;399:889–95.

Polterauer S, Husslein H, Kranawetter M, et al. Effect of preoperative warm-up exercise before laparoscopic gynecological surgery: A randomized trial. J Surg Educ. 2016;73:429–32.

Ritter EM, Kindelan TW, Micheal C, et al. Concurrent validity of augmented reality metrics applied to the Fundamentals of Laparoscopic Surgery (FLS). Surg Endosc. 2007;21:1441–5.

Ruparel RK, Brahmbhatt RD, Dove JC, Hutchinson RC, Stauffer JA, Bowers SP, Richie E, Lannen AM, Thiel DD. "iTrainers"—novel and inexpensive alternatives to traditional laparoscopic box trainers. Urology. 2014;83:116–20.

Seymour NE, Gallagher AG, Roman SA, et al. Virtual reality training improves operating room performance: results of a randomized, double-blinded study. Ann Surg. 2002;236:458–63.

Shane MD, Pettitt BJ, Morgenthal CB, et al. Should surgical novices trade their retractors for joysticks? Videogame experience decreases the time needed to acquire surgical skills. Surg Endosc. 2007;22:1294–7.

Soler L, Marescaux J. Patient-specific surgical simulation. World J Surg. 2008;32:208–12.

Sroka G, Feldman LS, Vassiliou MC, Kaneva PA, Fayez R, Fried GM. Fundamentals of laparoscopic surgery simulator training to proficiency improves laparoscopic performance in the operating room-a randomized controlled trial. Am J Surg. 2010;199:115–20.

Suzuki S, Eto K, Hattori A, Yanaga K, Suzuki N. Surgery simulation using patient-specific models for laparoscopic colectomy. Stud Health Technol Inform. 2007;125:464–6.

Thijssen AS, Schijven MP. Contenporary virtual reality laparoscopy simulators: quicksand or solid grounds for assessing surgical trainees? Am J Surg. 2010;199:529–41.

Van Hove C, Perry KA, Spight DH, Wheeler-Mcinvaille K, Diggs BS, Sheppard BC, Jobe BA, O'Rourke RW. Predictors of technical skill acquisition among resident trainees in a laparoscopic skills education program. World J Surg. 2008;32:1917–21.

Wanzel KR, Ward M, Reznick RK. Teaching the surgical craft: from selection to certification. Curr Probl Surg. 2002;39:573–659.

Wijn RP, Persoon MC, Schout BM, Martens EJ, Scherpbier AJ, Hendrikx AJ. Virtual reality laparoscopic nephrectomy simulator is lacking in construct validity. J Endourol. 2010;24:117–22.

Willaert WI, Aggarwal R, Daruwalla F, et al. Simulated procedure rehearsal is more effective than a preoperative generic warm-up for endovascular procedures. Ann Surg. 2012a;255:1184–9.

Willaert WI, Aggarwal R, Van Herzeele I, Cheshire NJ, Vermassen FE. Recent advancements in medical simulation: patient-specific virtual reality simulation. World J Surg. 2012b;36:1703–12.

# 5 Bridging the Gap Between Open Surgery and Robotics

Dennis P. Serrano and Sylvia Karina L. Alip

**Abstract**

The late twentieth century was a period of transition from purely open to minimally invasive to robot-assisted surgeries, accompanied by slow integration of these validated technologies into various training curricula, across Southeast Asia. For the individual surgeon, transitioning from open to robotic surgery include—developing technical proficiency in handling the robot complemented by the application of expected cognitive and skills mastery that comes with traditional open surgical training. This can be further facilitated by simulators, mentoring, dual-console training and credentialing; and team transitioning. Challenges in transitioning from open to robotic surgery will always be present, but they are predictable and programs are already in place to equip both novice and experienced surgeons with the tools they need.

**Keywords**

Robotic surgery · Laparoscopic surgery · Transitioning Team transitioning · Credentialing · Training

## 5.1 Robotic Surgery and the Asian Pioneers

In 2004, the western world braced itself for the global adoption of robotic surgical technology and the widespread installation of da Vinci units across the United States and Europe. It was only a matter of time before Asia would follow. Southeast Asian hospitals likewise posed to launch itself into this new era of surgical care.

Kwoh and colleagues with their robotic-assisted stereotactic brain surgery, the first robot-assisted surgery, heralded this era in 1988. Likewise, in the field of urology in 1989, Davies and colleagues performed the first robot-assisted transurethral resection of prostate in a human. The early 1990s to 2000s introduced two competing companies that pushed the development of minimally invasive and robotic surgery to the fore, *Intuitive Surgical* behind the 3-armed da Vinci system and *Computer Motion* behind the Zeus system. In 2000, both companies received U.S. FDA approval and the robotic surgical systems were made commercially available. These two leaders would then merge, bannering the da Vinci as the sole commercially available robotic surgical system (Yu 2007). In Asia, Singapore and Malaysia installed their first 3-arm Da Vinci units in the summer of 2004 and ventured into their maiden series of robotic assisted radical prostatectomies. In the same year, China, with their Zeus robot, started with robotic laparoscopic cholecystectomies.

For robotic assisted laparoscopic radical prostatectomy, (RALP), the Montsouris and the VIP (Vattikuti Institute prostatectomy) techniques were pretty much standardized at this point and this facilitated easier transitioning for the Asian pioneers. The instruments were already field tested and improved and they had the luxury of mentoring or dual console training from various centers in the US and Paris.

Learning always comes with a curve. While western centers had the luxury of large volumes of patients (from widespread screening and early detection) and reimbursement of hospitalization through managed care, Asian patients were more likely to be diagnosed at later stages of prostate cancer (hence no longer radical prostatectomy candidates) and usually had to pay out-of-pocket for their medical care. Coupled with the skepticism towards outcomes with a new technology and new techniques in the hands of "only recently trained" surgeons, case selection and finding were, understandably, difficult.

The Asian pioneers—Singapore General Hospital, Hospital Kuala Lumpur in Malaysia—posted an initial average of 4 h operating time in their first 10–20 cases later

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reducing this to 2.5 h. Positive margins were around 30% and post-operative potency at 50% in their first sub-50 patients (Sahabudin et al. 2006). This was not bad compared to western centers already doing hundreds of cases. They concluded that the future of robotics in Southeast Asia was promising, given adequate funding, extensive training and short-term proctoring for transitioning surgeons.

It wasn't long till other Southeast Asian countries joined the fold. Da Vinci installations followed in a year in Hong Kong, Indonesia, and in 2010 the Philippines. While many of the urologic training programs in the US had robotic surgery integrated into their curricula, the sparseness of robot installations in Southeast Asia limited minimally invasive urologic training to mostly laparoscopic procedures.

We can safely assume that transitioning from open surgery to robotics in that era took one of two pathways: (1) from open surgery to laparoscopic surgery to robotics for the younger urologists who have been trained in laparoscopy and minimally invasive urology; and (2) open surgery then straight to robotics for the other urologists who were bold enough to take the leap. For the first few years, Southeast Asia was (or may be, still is) in the "train the trainors" mode. Many of the centers are sending senior or "high - surgical volume" staff members and attending physicians to train in robotics either in short courses, or their young faculty to formal fellowship training programs. They are looking to them to start their own institutional robotics program henceforth. As the number of procedures and robot installations in Asia rise, and robotics programs are put into place, it is inevitable that the residents-in-training will have an easier time transitioning from open surgery to laparoscopic and robotic procedures as these are slowly integrated into their training curriculum.

## 5.2 Transitioning from Open Surgery to Robotics—Challenges and Solutions

Witte (2015) did an exhaustive analysis of the requirements for efficient robotic surgery training and transitioning from open surgery. Traditional open surgery was taught in an "apprenticeship manner". The set-up often consisted of a senior operator (trainer) being assisted by a junior operator (trainee) repeatedly in a series of pre-determined steps particular to each procedure. In the process, each step was ingrained to the trainee as a standard, only to be deviated from in cases of unexpected intra-operative findings or developments. The learning curve is often protracted and the success of the program hinged on the ratios of number of cases to trainees as well as trainers to trainees. The emphasis was both cognitive—in the areas of mastery of surgical anatomy as well as the goals and principles of surgery; and technical—how well one wields the scalpel or evenly places every stitch. Subsequently, a resident is allowed to graduate if he has fulfilled a set level of proficiency deemed mandatory to be a "safe" surgeon. The rest of his learning curve is conquered on his own thru repetition.

Robotic surgery likewise demands the same level of cognitive and technical proficiency. But, unlike open surgery, it puts a robot between the eyes and hands of the surgeon and the patient. This opens a new dimension of advantages and challenges for the operator. The 10×-magnification and three-dimensional, high-definition imaging of the robot enhances his mastery of anatomy. He is given better ergonomics, minute instruments with more degrees of freedom than the human hand, elimination of hand tremors, and negation of the fulcrum effect seen in conventional laparoscopy (Schreuder and Verheijen 2009). At the same time, he has to re-orient himself with the "new" field of vision lest he lose his plane of dissection in the magnified anatomy. His open surgical skills must be augmented with the knowledge of the basic principles of robotic movement, safety procedures, trocar placement, docking and undocking, patient positioning, responding to system errors and mastery of finger controls. The loss of haptic feedback forces him to visually infer tissue reaction and resistance thus making it necessary to develop new reflexes and alter tissue handling mechanics in the console. Hence, while the robot was meant to make surgery easier, the surgeon had the additional task of training further to master "robotic skills". The transition is heavily dependent on individual visual spatial perception and psychomotor skills.

Anderson (2004) proposed three levels of robotic skills acquisition: (1) the cognitive stage, (2) the associative stage, and (3) the autonomous stage. In the cognitive stage, the trainee masters the fundamental workings of the robot, simple procedures like docking and undocking and console controls. The associative stage allows him to use the cognitive knowledge and apply it to the surgical procedure, detect errors and correlate multiple elements of the surgery to one another. In the autonomous stage, the procedures become more rapid and automatic thus freeing the trainees mind to process more complex problems and adapt to variations in the surgical anatomy or conduct of the procedure. This allows for a greater degree of conscious deliberate analytical thinking which is often critical in intra-operative decision making. A transitioning surgeon must move through all these stages fairly rapidly after he has gained sufficient cognitive knowledge of the robots functions.

Transitioning to robotics for an experienced laparoscopist confers certain inherent differences as compared to transitioning from open surgery. Several studies have shown that a novice will likely perform better with the robot compared to laparoscopy. An experienced laparoscopic surgeon however will likely perform similarly with or without the robot

(Heemskerk et al. 2007; Kim et al. 2014; Nguan et al. 2008). Laparoscopists must acquire similar visual and sensorimotor skills that are necessary for robotic surgery.

Indeed, many open surgeons have shared the observation that robotic surgery is more easily "adoptable" as compared to laparoscopy. Barring the loss of haptic feedback, the improved visual input and the more versatile EndoWrist instruments vastly enhance the sensorimotor skills of the operator. Oftentimes, open surgeons can make Anderson's three-stage skills transition to robotic surgery without the need of exhaustive laparoscopic experience. Nonetheless there must be standards and proficiency measures that must be met before a surgeon, albeit experienced in open surgery, may be allowed to transition to robotics at the risk of a patient's morbidity or mortality. These benchmarks are often varied and depend on each institution's objectives and timelines in launching a robotics program. Hence as recognized by Schreuder et al (2012), designing a competency based robotic surgery training curriculum is a continuing challenge.

## 5.3 Tools to Bridge the Gap

There are several programs and tools that may facilitate this open to robotic surgery transition to aspiring applicants.

### 5.3.1 Virtual and Actual Training Modules

At present, Intuitive Surgical, Inc. the makers of the Da Vinci robot provides a modicum of standardized training before allowing an operator to utilize the robot. This consists of online training modules (*see DaVinci surgical community website*: davincisurgerycommunity.com), a structured 3 day hands-on course on familiarizing oneself with the robot's functions, docking, undocking and safety procedures and finally, on-site observation of robotic procedures done by an expert or at least an experienced robotic surgeon. All aspects are essential for an open surgeon to transition to robotics. But the most crucial part of this training is the mentoring of the trainee's first few cases by an expert. The required number of cases is often variable and usually determined as the proctor deems that the operator has demonstrated enough proficiency to be allowed to operate independently. After that, there is continuous re-evaluation of the surgeon, based on the continuity and number of cases and their outcomes, allowing him to graduate to more complex procedures or retaining (if not removing) him from his current level of credentialing. Most of the pioneer Southeast Asian robotic surgery programs went through this route before launching.

Currently, the strongest initiatives in the creation of a standardized robotics training curriculum are (1) the Fundamentals of Robotic Surgery (FRS) and (2) the ERUS robotic surgery training curriculum (Fisher et al. 2015).

The FRS curriculum has been validated by multiple experts from 14 international societies and consists of multiple modules using box trainers with the Da Vinci robot or virtual reality simulators. Patterned after the highly successful Fundamentals of Laparoscopic Surgery (FLS) course, the FRS is a short comprehensive version for robotics. It is often deemed as a starting point after which further training and accreditation may be based.

The ERUS training is a little bit more structured using four modules (1) e-learning, (2) simulation training with dry lab, virtual reality and wet labs (3) operating room training under supervision and (4) videotaped full procedure and trainer's report which will be used for certification (Ahmed et al. 2015). The last puts in place a regulatory parameter that may be exercised by a national or regional accrediting body.

The FRS curriculum emphasizes more of Anderson's cognitive stage learning whereas the ERUS model allows for more advanced transition to the associative and autonomous stages of skills acquisition.

### 5.3.2 Simulators

The success of training simulators has proven itself time and again most notably in the area of aviation where pilots' skills and off-the-cuff decision-making often translates into life-saving or life-losing outcomes. Robotic surgery mimics these conditions where an operator's sensorimotor skills coupled with his cognitive and associative knowledge of a complex machine, the robot, will determine life and death outcomes.

Rogula et al. (2015) reviewed the roles and availability of various simulators in robotics training. Robotic surgical simulators may be virtual reality simulators, in which the task is performed in a computer generated artificially virtual environment and mechanical simulators, in which the robot is connected to a box or dry lab trainer. They observed that the true test or validity of a simulator depends on how well it can mimic real life situations and test the trainee's performance in these situations. A 'valid' simulator must demonstrate face validity (how much the simulation resembles real-world situations), content validity (how the intended competency is measured by the exercise, thereby making it useful as a training tool), and construct validity (the ability to distinguish between a novice and expert user).

They (Rogula et al. 2015) summarily evaluated the several different robotic surgery simulators available on the market: da Vinci Skills Simulator® (dVSS, by Intuitive Surgical), Mimic dV-Trainer® (MdVT, by Mimic Technologies), Robotic Surgery Simulator (RoSS®, by

Simulated Surgical Systems), and SimSurgery Educational Platform® (SEP, by SimSurgery).

The da Vinci Skills Simulator® (dVSS) creates a computer generated case in a virtual environment where in the operator uses an actual da Vinci console to practice the designated operation. It also comes with a set of exercises which allow the trainee to gain familiarity with the machines capabilities and corresponding controls—specifically for camera management, EndoWrist manipulation, clutching and fourth arm maneuvers, dissection, suturing and energy device use. Rogula et al. (2015) has evaluated the dVSS and determined that it has proven face, content and construct validity.

The Mimic dV-Trainer® (MdVT) is a stand-alone simulator that essentially mimics the look and feel of the da Vinci system and also replicates its responses. It benchmarks trainee performance against a stored data bank of experienced users and generates a score based on time to completion of task, economy of motion, instrument collisions and other parameters. It comes with two sets of training modules—basic and advanced surgical skills training—the former allowing for surgeon familiarity with the console, EndoWrist manipulation, camera functions and clutching while the latter, for suturing, knot tying, application of monopolar and bipolar energy, and dissection.

The Robotic Surgery Simulator (RoSS®) offers the same features of a virtual reality platform as the two previous systems but with the added feature of a checklist based process guiding the trainee through the different steps of the real operation. It utilizes a stepwise process, which forces the trainee to complete one level before proceeding to the next. It has been validated for face, i.e., mimicking real life situations and for content in as far as but not so much for construct validity.

They cited the cost of the equipment as the main drawback of these simulators, with each running to an average of US$100,000.00. A cheaper alternative may be the SimSurgery Educational Platform® (SEP), a modified box simulator that can be fitted with EndoWrist manipulators and offers exercises on basic and advanced skills: tissue dissection and basic and advanced suturing. It has proven face, content and construct validity and may be more suitable for combined laparoscopic and robotic training programs. The ProMIS® simulator may also be a more affordable alternative but it requires a robot already installed in the institution. The system employs a mannequin that has a laparoscopic interface. The robot can be docked and the training maneuvers can be performed and recorded. This system analyzes time, path and smoothness of movement of the trainee.

The effectiveness of simulation training is widely held in the aviation industry where pilots rely heavily on simulators not just for basic training but also when transitioning to different equipment or aircraft. Muller and Patel (2012) showed similar efficacy for robotic surgery training, regardless of which simulator is used.

There have been no head-to-head trials pitting these simulators against each other. Most simulation models have proven useful in basic and some moderately complex skills training. However, it may not be the same for more advanced surgical procedures which require improvisation on the part of the surgeon. In these situations, traditional teaching, i.e., the apprentice model, may still be the most effective.

### 5.3.3 Mentoring

The direct supervision of a surgeon trainee by a more experienced surgeon in the performance of a surgical procedure offers a variation of this apprentice model of training. For the experienced open surgeon venturing into robotic surgery, mentoring can be done in phases, the first being the immersion of the surgeon in the review of numerous video recordings of a particular procedure to correlate how steps he has mastered in open surgery may be executed robotically. This may be followed by his scrubbing-in as a bedside assist for the more experienced robotic surgeon manning the console. Assisting in live robotic procedures gives the trainee the opportunity to demonstrate his working knowledge of the functions of the robot, his understanding of how the procedure will be done robotically, and enhance his experience with different strategies or maneuvers the console surgeon may employ in the performance of the surgery. The time or number of cases in this phase has not yet been collectively defined. Evidently, it is upon the discretion of the mentor when to allow the mentee to proceed to the last phase.

The last phase of course is with the trainee taking on the console and performing parts of the procedure the mentor will deem appropriate for his level of skill. This should steadily progress until he can be entrusted with the performance of the entire procedure with the mentor looking over his shoulder (or in this case, the monitors) all the time. The learning must be augmented by continuous review of the recordings of the procedure and identification of critical faults the trainee may have incurred. This is further enhanced by watching video recordings of the procedure done by more experienced surgeons over and over again to internalize the different steps and offer variations which the trainee can adopt according to his liking.

### 5.3.4 Dual Console Training

That only one surgeon can occupy the console at any given time poses a bit of a difficulty for the mentor. In the da Vinci system, the mentor is given the facility of writing gestures on the bedside monitor that can be seen simultaneously in the console in order to direct or guide the trainee. However, it does not give him the same degree of control over the operation as in the traditional open surgery set-up. *Intuitive Surgical* offers a dual console, which will allow the expert surgeon to direct and supervise a procedure without totally relinquishing control to the mentee. The teaching console has two collaborative modes: (1) swap mode allowing the mentor and mentee to operate simultaneously and alternately swap control of the robotic arms and (2) nudge mode which allows them to have simultaneous control, sharing the two robotic arms. Choosing a mode will depend on the degree of difficulty of a particular step of the procedure or the skill level of the trainee.

This three-phase pathway oftentimes is more suitable for the resident or fellow-in-training in a center with a robotics program in place, than for a certified attending urologist venturing to launch such a program for his institution for the first time. However, there will be a subset of surgeons—oftentimes already certified institutional faculty—who are already well versed with open urologic procedures and who will want to make a rapid transition to robotics within a short period of time. This will become all too common as more and more robots are installed in centers across Asia.

To the experienced open surgeon, direct transition from open to robotic surgery is feasible and effective. O'Brien and Shukla (2012) studied the learning curve in for robotic-assisted laparoscopic pyeloplasty (RALP) with and without the aid of the robot. They concluded that the learning curve for surgeons transitioning from open to robotic surgery is shorter from the one transitioning from laparoscopic to robotic, and that the former transition was possible without first learning classical laparoscopy. They echoed an earlier finding of Johnson and Wood (2010) that surgeons who are beginning to incorporate robotic surgery into their repertoire should expect outcomes to mirror their open results with no difference in complication rates and operative times. Even as early as 2003, Ahlering et al. noted that skills transfer from open to robotic can occur in as few as 8–12 cases for radical prostatectomy but that laparoscopic surgeons can only gain comparable performance outcomes after 100 laparoscopic radical prostatectomies.

This is most likely due to the fact that an experienced surgeon has already mastered the fundamental steps of the procedure and the utilization of the robot for him, only poses a variance on how the steps are to be executed. If we are to follow Anderson's model, much of his learning curve will be spent in the first or cognitive stage which is getting declarative knowledge on how the robot functions. Virtually everything in the associative and autonomous stage falls into place after that.

His first (cognitive) stage terminal competency is to get a comprehensive grasp of the fundamental functions of the robot. This would entail familiarization with docking and undocking procedures, mastery of the console controls and functions, execution of dissection, retraction and camera maneuvers, suturing and application of energy devices. Any of the aforementioned programs or simulators will be more than adequate for this stage. The key is to spend as much time on a dry run or simulator as necessary until he becomes fairly adept with working on the robot and integrates it into his rhythm. The robot essentially just becomes an extension of his eyes and hands.

Satava (2011) listed the top relevant tasks for robotic surgery training and their rank order as: (1) Situation awareness, (2) Eye-hand instrument coordination, (3) Needle Driving, (4) Atraumatic handling, (5) Safety of operative field, (6) Camera, (7) Clutching, (8) Fine and Blunt Dissection, (9) Closed Loop Communication, (10) Docking, (11) Knot tying, (12) Instrument exchange, (13) Cutting, (14) Energy sources handling and (15) Foreign body management. He continued to list other tasks which though low ranked, remain crucial in the training and proficiency of every emerging robotic surgeon.

The subsequent stage (associative) should see him perform the surgery in pretty much the same pathway as he would an open procedure but this time with the robot in between him and the patient. Experienced surgeons who have mastered open techniques and automatically know the different steps are more likely to breeze through this stage as it takes less conscious effort on their part to integrate the robot into the procedure. With increasing frequency of procedures, the surgeon's robotic movements become less self-conscious and more automatic. He finds better ways to do the same step, faster and more efficiently. He commits less errors and he is able to connect various stages of the procedure in a more fluid manner thereby achieving conservation of motion resulting in faster operating times. At this stage, the procedural knowledge builds up. For example, at this stage it is no longer required to rehearse the docking procedure before performing the task, because the declarative knowledge gradually converts to procedural knowledge (Witte 2015).

As he masters the associative stage and moves to the autonomous stage the cognitive workload is diminished and much of his mental processes during surgery is freed up to concentrate on situational analysis and surgical decision-making. He is then able to instruct his bedside surgeon on how to better assist during the surgery, concentrate on internal communications with anesthesia and educate the nurses better. He is able to perform situational analyses—assess variations in anatomy and unexpected intra-operative findings—and act accordingly. But the learning should not stop here. He must continue to practice with constant re-evaluation of his performance if he is to become an expert and not just an experienced robotic surgeon. For example, a study by Patel (2012), concluded that for robot-assisted radical prostatectomy (RARP), a basic proficiency learning curve requiring approximately 20 cases has been reported to occur before operative times and outcomes become consistent with a surgeon's prior laparoscopic or open surgery abilities.

## 5.4 Credentialing

Unlike laparoscopic surgery, which has the Fundamentals of Laparoscopic Surgery (FLS) curriculum that serves as a set of guidelines for laparoscopic surgery training—the completion of which is required by the American Board of Surgery for all general surgery graduates,—credentialing and validation of training is lacking for robotic surgery in Asia. Currently, there is no central governing body for robotic surgery credentialing, and standards are largely institution-based, relying on (1) formal subspecialty training, (2) training in robotic surgery including proctoring, (3) presentation and documentation of outcomes or clinical experience, and (4) assessment of competency usually through completion of procedures under the review of an expert mentor. The Society of American Gastrointestinal and Endoscopic Surgeons and the Minimally Invasive Robotic Association attempted to standardize training and credentialing with the SAGES-MIRA Consensus Document on Robotic Surgery (2007). Formal guidelines with recommendations that are backed-up by robust data, however, are still under way. Once credentialing is completed and competency has been determined, a period of provisional privileges is recommended as appropriate for each institution. After which, performance is monitored and competency is periodically evaluated for renewal of privileges.

## 5.5 Team Transitioning

As surgery is always a team effort, the success of a transitioning surgeon must always be accompanied by the same effective transition of his entire team. Nurses who are the backbone of any operating room must undergo robotic training of their own. There are various members of the robotic surgery nursing staff. Most teams are composed of (1) a nurse coordinator who is in charge of schedule and inventory management, as well as education and training (2) a scrub nurse in charge of aiding the surgeons in docking and undocking, robotic positioning and ensuring availability of instruments, and (3) a circulating nurse in charge of patient positioning, patient safety and instrument checking before, during and after the operation. Challenges in positioning, draping, system settings, preparation of robotic instruments, technical aspects of monitor placement and patient cart handling, as well as appropriate energy devices must be anticipated well in advance by competent circulating and scrub nurses. Francis (2006) outlined the general competencies of a robotics nurse specialist as an expert in: (1) minimally invasive surgery and (2) peri-operative nursing; and with (3) basic knowledge of research principles and computer software applications.

The phrase "one lives and dies by his assist" has often been used to emphasize the importance of the bedside surgeon assisting in any robotic procedure. It helps to have the same assist constantly as this facilitates the associative and autonomous stages of the learning curve. It also helps that the bedside assistants have robotic experience of their own whether in transition or as a full-fledged robotic surgeon. Situational analyses and critical decision-making can then be a shared responsibility especially in difficult situations or unexpected findings and events.

The anesthesiologist's expertise and experience must be underscored especially in urologic procedures where patients are peculiarly positioned (flank or extreme Trendelenburg) on top of the additional cardio-pulmonary stress imposed by pneumoperitoneum. Managing the patient's carbon dioxide retention is a major challenge in unduly prolonged procedures for the transitioning surgeon in the early flat slope of the learning curve.

As stressed by Satava (2011), closed loop communication among team members is of utmost importance in the conduct of the procedure. As the console surgeon moves to the autonomous stage of his learning, he should be able to communicate more freely and openly with his team in a manner that not only facilitates the current procedure but also teaches them nuances for future procedures as well.

## 5.6 Conclusion

Transitioning from open to robotic surgery has its share of challenges, but these challenges are predictable. We have gleaned from many studies prior that various tools such as simulators, dual consoles, and demonstration videos enable a smooth transition. Mentoring under an expert surgeon, however, is the most invaluable tool and is required for credentialing. We also stress the importance of a team approach to the transition. Members of the nursing, anesthesia and administrative services have their respective competencies that should not be overlooked.

## References

Ahlering TE, Skarecky D, Lee D, et al. Successful transfer of open surgical skills to a laparoscopic environment using a robotic interface: initial experience with laparoscopic radical prostatectomy. J Urol. 2003;170:1738–41.

Ahmed K, Khan R, Mottrie A, Lovegrove C, Abaza R, Ahlawat R, Dasgupta P. Development of a standardize training curriculum for robotic surgery: a consensus statement from an international multidisciplinary group of experts. BJU Int. 2015;116(1):93–101.

Anderson JR. Cognitive psychology and its implications. New York, NY: Worth Publishers; 2004.

Fisher RA, Dasgupta P, Mottrie A, Volpe A, Khan MS, Challacombe B, Ahmed K. An over-view of robot assisted surgery curricula and the status of their validation. Int J Surg. 2015;13:115–23.

Francis P. The evolution of robotics in surgery and implementing a perioperative robotics nurse specialist role. AORN J. 2006;83(3):629–50.

Davies L, Hibberd B, Coptcoat R, Wickham J. A surgeon robot prostatectomy–a laboratory evaluation. J Med Eng Technol. 1989;13:273–7.

Heemskerk J, van Gemert WG, de Vries J, Greve J, Bouvy ND. Learning curves of robot-assisted laparoscopic surgery compared with conventional laparoscopic surgery: an experimental study evaluating skill acquisition of robot-assisted laparoscopic tasks compared with conventional laparoscopic tasks in inexperienced users. Surg Laparosc Endosc Percutan Tech. 2007;17:171–4.

Johnson EK, Wood DP. Converting from open to robotic prostatectomy: key concepts. Urol Oncol. 2010;28(1):77–80.

Kim HJ, et al. Comparison of surgical skills in laparoscopic and robotic tasks between experienced surgeons and novices in laparoscopic surgery: an experimental study. Ann Coloproctol. 2014;30(2):71–6.

Kwoh YS, Hou J, Jonckheere EA, et al. A robot with improved positioning accuracy for CT guided stereotactic brain surgery. IEEE Trans Biomed Eng. 1988;35:153–61.

Müller S, Patel HRH. Lessons learned from the aviation industry: surgical checklists. In: Simulation training in laparoscopy and robotic surgery. London: Springer; 2012. p. 1–6.

Nguan C, Girvan A, Luke PP. Robotic surgery vs. laparoscopy: a comparison between two robotic systems and laparoscopy. J Robot Surg. 2008;1:263–8.

O'Brien ST, Shukla AR. Transition for open to robotic-assisted pediatric pyeloplasty: a feasibility and outcome study. J Pediatr Urol. 2012;8:276–81.

Patel VR. Robotic urologic surgery. London: Springer; 2012.

Rogula T, Acquafresca PA, Bazan M. Training and credentialing in robotic surgery. Essentials of robotic surgery XIII. 2015.

Sahabudin RM, Arni T, Ashani N, et al. Development of robotic program: an Asian experience. World J Urol. 2006;24(2):161–4. Epub 2006 Apr 11

Satava RM. Future directions in robotic surgery. In: Surgical robotics: systems applications and visions. NY: Springer; 2011. p. 3–11.

Schreuder HWR, Verheijen RHM. Robotic surgery. BJOG. 2009;116(2):198–213.

Schreuder HWR, Wolswijk R, Zweemer RP, Schijven MP, Verheijen RHM. Requirements for efficient robotic surgery training, time for a more structured approach: a systematic review. BJOG. 2012;119(2):137–49.

Society of American Gastrointestinal and Endoscopic Surgeons. A consensus document on robotic surgery. 2007. Available at: http://www.sages.org/publications/guidelines/consensus-document-robotic-surgery/.

Witte TEF. Requirements for efficient robotic surgery training. A master thesis. University of Twente. 2015.

Yu D-S. Emerging robot-assisted surgery: contemporary perspectives in Taiwan. JTUA. 2007;18:179–89.

# Development of Robotic Urologic Surgery in Asia

6

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**Abstract**

With the introduction of robotic-assisted surgical systems to surgical practice, there has been great progress and advancement in minimally invasive surgery (MIS). Robotic-assisted surgery (RAS) has proven useful in reducing the risks and complications associated with open surgical procedures, thereby extending the benefits of MIS to a broader population of patients. RAS has made its way into almost every surgical discipline. Urology has been in the forefront of employing and standardizing robotic-assisted procedures in fields such as oncologic and reconstructive urology.

Although the da Vinci surgical system has been available for 17 years, high cost and steep maintenance fees have been major hurdles to its widespread acceptance. The next generation of surgical robots are being designed to expand robotic surgery into areas that are currently underserved, such as general abdominal, gynecological, and urological procedures, to enhance cost-effective management of patients. With the recent development and advancements in robotic technologies, RAS will continue to grow because of its tremendous potential to offer better health care to patients. Here, the pioneers from leading Asian institutions describe the development and current state of robotic surgery in their respective countries.

**Keywords**

Robot · Urologic surgery

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## 6.1 Introduction

Modern day surgery has come a long way since the convergence of science and technology. Surprisingly, the history of minimally invasive surgery (MIS) based on laparoscopic principles is less than 30 years old. Laparoscopic procedures have been performed for the last 2 decades to treat various surgical conditions and provide the benefits of MIS while maintaining the principles of open surgery. The minimally invasive laparoscopic approach has been shown to be feasible in virtually all open surgical procedures. Laparoscopic surgery is preferred to the open approach because it is associated with shorter hospital stay, less pain, better cosmetic results, and faster recovery. However, despite the perceived advantages of the laparoscopic approach, conventional laparoscopy is limited by the need for dexterity and precision of the instruments, lack of tactile feedback, 2–dimensional view that necessitates the services of a camera-assistant, increasing fatigue and tremor over time, and a steep learning curve.

These limitations of conventional laparoscopy led to the development of more rigid, versatile, and dexterous surgical robots such as the Zeus and da Vinci surgical systems. The concept of a master-slave telemanipulation system was developed in the early 1990s at the United States Department of Defense. The army hoped to develop a robot that could remotely operate on patients in places such as outer space and battlefields (Satāba 1995) This led to the founding of the Stanford Research Initiative (SRI) which became Intuitive Surgical Inc. (Sunnyvale, California) in 1995 and comprised of a group of scientists from the SRI, International Business Machines, and the Massachusetts Institute of Technology. The company developed the system architecture of the da Vinci surgical system in 1999 which was approved by the Food and Drug Administration (FDA) in July 2000 after completing the first 200-patient trial of cholecystectomy and Nissen fundoplication.

It was not until the late 1990s that robotic-assisted surgery (RAS) was introduced into everyday surgical practice. The first application of robotics in surgery was in the Automated Endoscopic System for Optimal Positioning (AESOP) from Computer Motion, Inc. (Goleta, California) which was a camera-holding and guidance system. The advantage of AESOP is that it allows for a steady view of the operative field, eliminating the problem of assistant inexperience and fatigue which affect the smoothness of procedures (Sackier and Wang 1994; Schurr et al. 1999).

At about the same time, Computer Motion, Inc. developed a robotically enhanced laparoscopic surgical platform called the Zeus robotic surgical system which incorporated the existing AESOP robotic endoscope holder, the HERMES voice control system, and the SOCRATES telecollaboration system. The Zeus robotic surgical system made history in September 2001 during its first performance of telesurgery, known as the "Lindbergh operation," which was a cholecystectomy on a 68-years-old female patient across the Atlantic Ocean (the surgeon was in New York City and the patient was in Strasbourg, France). The demonstration of the trans-Atlantic procedure paved the way for the globalization of robotic surgical procedures, having proved that a surgeon could remotely perform an operation on a patient anywhere in the world. The FDA approved the da Vinci and Zeus surgical systems in July 2000 and September 2002, respectively. Sung et al compared the 2 systems in 2001 and concluded that the da Vinci surgical system had a shorter learning curve and allowed for considerably more intuitive execution of surgical maneuvers than the Zeus robotic surgical system. In June 2003, Intuitive Surgical Inc. acquired Computer Motion, Inc., and the Zeus robotic surgical system was discontinued.

Since then, the da Vinci surgical system has had five model upgrades with numerous state-of-the-art features, such as high-definition 3-dimensional (3D) and fluorescent-enhanced imaging, procedure-specific instrumentations, thinner robotic arms, and intelligent platforms. The installation of the da Vinci surgical system has grown exponentially each year despite its high cost of approximately 1.5–2.5 million US dollars, the steep annual maintenance fees, and concerns over low returns on the capital investment. The total number of installations worldwide as of March 2018 was 4528 units. This remarkable number shows its general acceptance by the public and hospitals worldwide. Robotic surgery clearly represents the pinnacle of minimally invasive surgical technology. It is a matter of pride and prestige for any institution with a high-end surgical robot and also reflects the institution's commitment and dedication to new surgical technology and state-of-the-art health care.

Urology has been in the forefront of employing and standardizing robotic-assisted procedures in fields such as oncologic and reconstructive urology. Advancements in robotic surgical technology and detailed understanding of surgical anatomy have revolutionized robotic surgery as the standard of care for many surgical procedures. Various robotic-assisted procedures for urologic diseases have been performed and compared with those performed using the traditional approach. The indications for robotic surgery have risen over the years and the volume of robotic surgical cases has increased dramatically. Relevant literature reported comparable clinical outcomes of robotic and open surgeries. Robotic-assisted radical prostatectomy (RARP) for prostate cancer, robotic-assisted partial nephrectomy (RAPN) for renal cell carcinoma, and robotic-assisted radical cystoprostatectomy (RARC) with urinary diversion for muscle-invasive bladder cancer are now more frequently offered to patients in major centers of excellence worldwide as replacements for their open surgery versions with comparable functional and oncologic outcomes.


**Fig. 6.1** da Vinci® System Installed Base 4528 systems as of March 2018

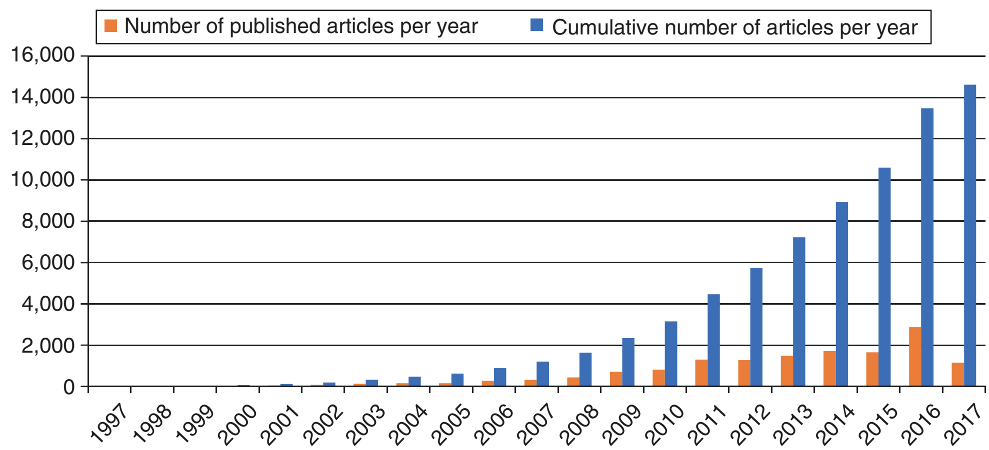



**Fig. 6.2** Yearly trend of publications on robotic-assisted surgeries

Asia has been a strong proponent of laparoscopic skills which utilizes the innate dexterity and agility of the hands. Within a few years of commercialization of the da Vinci system in USA, major centers of excellence in Asia established a comprehensive multi-subspecialty robotic surgery program with robotic surgical training and education offered as an integral part of the curriculum to physicians, residents, and clinical fellows. By June 2017, there were 2703 da Vinci units installed in USA, 698 in Europe, and 538 in Asia. In the first half of 2017, 17% of procedure growth was reported and of these, 14% was driven by general surgery growth in USA, while 25% was driven from outside USA, by Europe, China, and South Korea. This data shows the growth of the robotic surgery market in Asia.

Here, early adoptors from leading Asian institutions describe the development and current state of robotic surgery in their respective countries (Figs. 6.1 and 6.2).

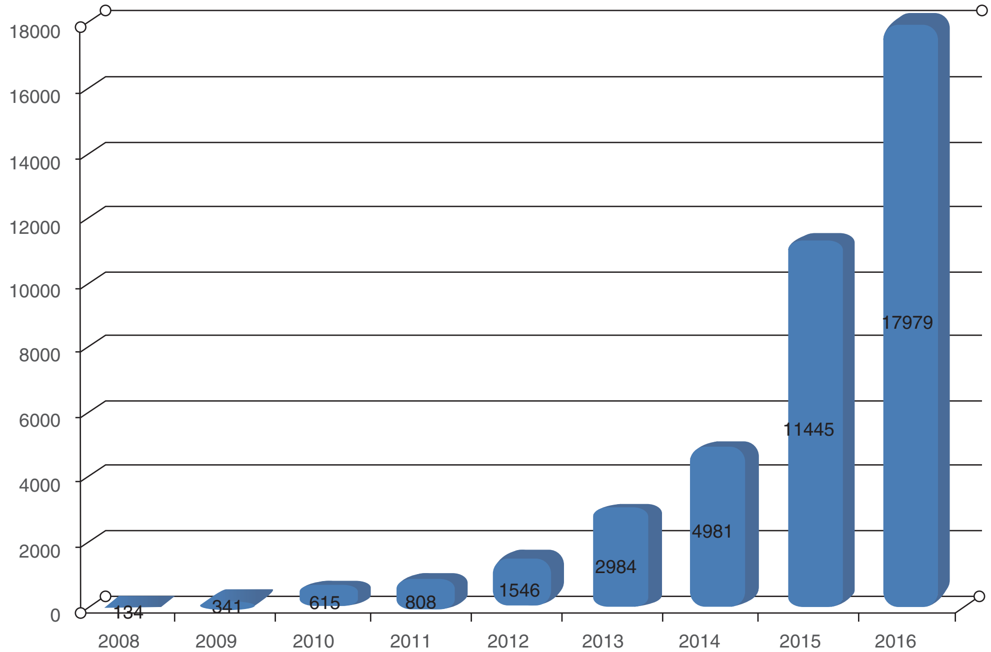
## 6.2 Robotic Urologic Surgery in China

Robotic devices have been used in several surgical specialities. The first application in urology was the clinical trial of performing transurethral surgery with the use of the PROBOT in 1988 (Harris et al. 1997). In 2000, the da Vinci robot was first used to perform robot-assisted radical prostatectomy in France (Abbou et al. 2000). From then on, a wide variety of urological procedures were performed by using the robotic platform, such as robot-assisted partial nephrectomy (RAPN) (Gettman et al. 2004), robot-assisted pyeloplasty (RAP) (Guillonneau et al. 2001) and robot-assisted radical cystectomy(RARC) (Menon et al. 2003). Here, we provide an overview of the development of urological robotic surgery in China since its first introduction in 2006.

### 6.2.1 Robotic Surgery in China

The da Vinci surgical system (Intuitive Surgical, Sunnyvale, CA, USA) was firstly introduced in China Mainland in 2006, and the first system was installed in General Hospital of People's Liberation Army in 2007. Since then, it has not only revolutionized minimally invasive techniques for many surgical procedures nationwide, but also has been adopted rapidly over the past decade (Fan et al. 2016), especially in urology. As of May 2017, 65 da Vinci surgical systems have been installed in China Mainland, with 53,101 robotic surgeries performed up to June 2017.

**Figs. 6.3 and 6.4** Robotic surgeries in 8 years





For the past decade (2006–2016), 40,896 robotic surgeries have been performed in China Mainland, 40% in urology, 32% in general surgery, 12% in thoracic surgery, and 11% in gynecology and obstetrics. As for urological surgeries, we performed 17,866 procedures. Among these cases, 6971 were radical prostatectomy, 4804 were partial nephrectomy, 1711 were radical cystectomy, 1210 were radical nephrectomy, 1102 were adrenalectomy, 1025 were pyeloplasty, and etc.

Regarding the total number of robotic surgeries (single system) in 2016, First Affiliated Hospital of Zhejiang University (888 cases), Zhongshan Hospital Affiliated to Fudan University (856 cases), and First Affiliated Hospital of Nanchang University (841 cases) were the top 3 in the world (Chindex Co., Ltd. n.d.) (Figs. 6.3 and 6.4).

The first surgery using single-port was reported by Hirano et al. (2005). In May 2017, the first single-port urological robotic surgery was performed in Changzheng Hospital affiliated to The Second Military Medical University (Figs. 6.5 and 6.6).

**Figs. 6.5 and 6.6** The first single-port urological robotic surgery was performed in Changzheng Hospital affiliated to The Second Military Medical University

### 6.2.2 Training

The first and only da Vinci Surgical robot international training center in China Mainland was established in Changhai Hospital affiliated to the Second Military Medical University. Up to date this center has trained 50 groups of healthcare providers (Chindex Co., Ltd. n.d.) (Figs. 6.7 and 6.8).

### 6.2.3 Current Status of Chinese Robotics

Currently, there are two major Chinese research teams focusing on surgical robotics. In 2010, Chinese medical robotics, Smarobot A, was developed by Tianjin University, Nankai University, and Tianjin Medical University General Hospital. Similar to the da Vinci surgical system, master-slave control system was applied. The system includes a console, image processing system, mechanical arms, and surgical instruments. It provides a 3-D surgical view, force feedback, and 6 degrees of freedom (Li et al. 2010). In 2014, the team developed a modified system featuring low cost, small size, modular assembly, named Smarobot S. This latest system has been applied in clinic (Bo et al. 2016) (Fig. 6.9).

In 2013, another surgical robot was developed by Harbin Institute of Technology, Nankai University, and General Hospital of People's Liberation Army, in which master-slave control system was also applied. The system consists of a doctor's console, an operating assistance system and an operating executive body. The doctor's console integrates the master manipulator, visual display system, and the functional control panel of entire robot system. The surgical assistance system mainly consists of 3D imaging equipment, coagulation and pneumoperitoneum machine, and etc. The operating executive body includes a laparoscope, medical instruments, and mechanical arms, which consist of active and passive joints (Ruqi 2013).


**Figs. 6.7 and 6.8** The first and only da Vinci Surgical robot international training center was established in Changhai Hospital affiliated to Second Military Medical University

**Fig. 6.9** Chinese medical robotics, Smarobot A, was developed by Tianjin University, Nankai University, and Tianjin Medical University General Hospital

## 6.3 Robotic Urologic Surgery in Hong Kong

The first robotic system, da Vinci standard version, was first installed in the Chinese University of Hong Kong in November 2005. With the increase in recognition of the benefit of the system in clinical management, more and more systems have been installed in the past years. Currently, there were five robotic system installed in five government public hospitals and also three more systems installed in private hospitals. There was also one system installed in the Chinese University of Hong Kong—Jockey Club Minimally Invasive Surgical Skill Centre for robotic surgical training for local and regional surgeons.

The introduction of RARP had completely changed the landscape of radical prostatectomy in Hong Kong. In the pre-robot era, majority of prostatectomy in Hong Kong was performed by open approach and only a few surgeons would use the laparoscopic approach. However, after 10 years of robotic surgery, more than 85% of radical prostatectomy in public hospitals were done by robotic approach (SOMIP 2016). In an earlier report of the prostatectomy performed by four public hospitals, about 75% of cases performed were stage T1 disease and 65% cases were belonged to D'Amico low risk category (Yip et al. 2012). However, with the increase in recognition of the potential benefit for symptom and disease control, more and more high-risk prostate cancer cases were performed recently.

Another important application for robotic system in Hong Kong is partial nephrectomy. With increase in detection of small renal masses, the number of partial nephrectomy was steadily increased over recent years, from 101 (2012–2013) to 161 (2015–2016) in public hospital (SOMIP 2013, 2016). In 2015–2016, 30% of partial nephrectomy was performed by robotic approach. In a retrospective comparison of the outcomes of robotic and laparoscopic partial nephrectomy, the warm ischemic time was significant shorter for robotic cases (31 min) when compared to laparoscopic cases (40 min) ($p = 0.032$) (Cho et al. 2011). With the more flexible instrument in robotic system, segmental artery branch dissection and selective artery clamping is current adopted by some surgeons to further improve the ischemic damage to patients during partial nephrectomy.

Cystectomy is another oncological application for robotic system. However, due to the technical demand and also concern in oncological outcomes, the development of RARC in Hong Kong is slower when comparing to prostatectomy and partial cystectomy. While for the standard, HD or Si system, most of the surgeon would use the central docking approach, side-docking approach might provide additional benefit for approaching the perineum for urethrectomy and vaginal closure (Chan et al. 2015).


**Fig. 6.10** Cake cerebration for the 1000th trained surgeon in the Chinese University of Hong Kong—Jockey Club Minimally Invasive Surgical Skill Centre for robotic surgery

Besides oncological application, robotic surgery is also used for various reconstructive procedures, from ureteric reimplantation to bladder augmentation in Hong Kong. With the more available of the system and the application should be widened more in future.

Hong Kong is also one of the earliest recognized robotic training center in Asia. Since the establishment of the robotic training program in the Chinese University of Hong Kong—Jockey Club Minimally Invasive Surgical Skill Centre in 2008, more than 1000 surgeons from different part of Asia had come to the centre for robotic training (Fig. 6.10). Also many advanced robotic training courses and conference had been held in Hong Kong. Therefore, Hong Kong will continue to contribute for the development of robotic surgery in greater China and also Asia.

## 6.4 Robotic Urological Surgery in India

Despite apprehensions about costs and sustainability (Nelivigi 2007), robotic surgery has been rapidly incorporated into urologic practice in India (Desai et al. 2015; Kumar and Hemal 2005). The first Indian robotic urological program was started at the All India Institute of Medical Sciences (AIIMS), New Delhi in 2006 and the first publication appeared in 2007 (Kumar et al. 2007). Unpublished data sourced from Intuitive Surgical shows that there has been a 62% increase in the installation rate for 2016 compared to 2015. Eighteen devices were installed in 2016 leading to a total of 52 robotic systems across the country while 30 more are planned by the end of 2017. Six installations are in the government funded hospitals while others are in the private sector. In 2016, 4960 robotic surgeries were performed and the numbers have crossed 4300 till July 2017.

The robotic program in India is driven by urologic oncology (Jain and Gautam 2015). While RARP was the initial driver, a number of additional procedures such as partial nephrectomies and cystectomies are now routinely performed with robotic assistance. Outcomes data is now available for RARP in the Indian population. Gupta et al. (2014) reported 94% continence rate at one-year follow-up in 150 patients undergoing RARP. Dogra et al. (2012a) also reported favorable perioperative outcomes in RARP in first 190 cases of RARP with six conversions and one rectal injury. Batra et al. reported clinical stage T2a as a significant predictor of lymph node metastasis in a study involving 100 patients undergoing RARP with extended lymph node dissection. Local data on robot assisted partial nephrectomy for patients with high renal nephrometry score has also been recently published (Bora et al. 2017). Expanding the indication for robotic assistance, robot-assisted radical nephrectomy has been shown to be feasible and safe in 23 patients (Dogra et al. 2012b). Similarly, robotic technology has been used to tackle complex situations in the ureteropelvic junction (UPJ) obstruction. Hemal et al. (2008a) reported successful outcomes of robot assisted laparoscopic pyeloplasty in nine patients with UPJ obstruction after failed prior surgical repair.

In India, the renal transplant program depends primarily on live related transplants and laparoscopic donor nephrectomy is a validated option for organ retrieval. The role of robotic technology is emerging in donor nephrectomies. A randomized controlled trial comprising of 45 living donors undergoing laparoscopic versus robotic donor nephrectomies showed significantly low pain scores and analgesic requirement in robotic group with longer graft arterial length for right side donors with the robot (Bhattu et al. 2015).

There is increasing use of robot assistance in radical cystoprostatectomy and Hemal et al. (2008b) reported the first case series of six patients with bilateral pelvic lymphadenectomy and urinary diversion. All the patients had negative surgical margins with the mean hospital stay of 9.2 days and favorable perioperative outcomes. Additional procedures reported from India include adrenal lesions (Pahwa et al. 2015), paraganglioma (Kumar et al. 2017a), and stone disease in complex anatomical situations (Kumar et al. 2017b).

Increasing availability of devices in coupled with increasing options for robotic training. Centres engaged in robotic surgery often train residents and also conduct stand-alone training programs and workshops for continuing education. International training continues to be a major option for many young urologists (Robotic Surgery Vattikuti Fellowship for 7 Indian Surgeons 2016) and fellowship training options have now been initiated within the country by the All India Institute of Medical Sciences (AIIMS), New Delhi.

## 6.5 Robotic Urological Surgery in Japan

In Japan, robot-assisted laparoscopic surgery started in 2000. A standard da Vinci surgical system was introduced to Keio University, Tokyo, in March, 2000, followed by Kyushu University, Fukuoka, in June, 2000. At that time, both of them were introduced as personal imports. Initially, the da Vinci surgical systems were mainly used in the field of general surgery procedures, including colon resection, distal gastrectomy, and splenectomy (Hashizume et al. 2002). They also performed a comparison of the da Vinci and the Zeus surgical system another robotic system at that time, using robotic laparoscopic distal gastrectomy (Kakeji et al. 2006). Although the number of operative cases was small, their results of operating time demonstrated the advantage of the da Vinci surgical system.

In urological fields, the first case of RALP using da Vinci surgical system was performed at Keio University in 2003, followed by Tokyo Medical University in 2006 (Yoshioka et al. 2008). On the other hand, we also started a laparoscopic radical prostatectomy (LRP) assisted by the ZEUS robotic surgical system in 2003 (Eto et al. 2005). A total of ten cases of LRP assisted by the Zeus robotic system was performed by single surgeon in our institute. The learning curve of vesico-urethral anastomosis using the Zeus system was shown in Fig. 6.11. In Fig. 6.11, we also demonstrated the learning curve of our initial eight cases of vesico-urethral anastomosis using the da Vinci surgical system, which were performed by another surgeon in 2007. Although we, of course, utilized the da Vinci system for all LRP procedures, we picked up the time of vesico-urethral anastomosis to compare the potential of the two robotic systems. As shown in Fig. 6.11, the learning curve of da Vinci surgical system was clearly better than that of Zeus implicating the fate of the two robotic systems.

In Japan, RALP using the da Vinci surgical system was initially covered with section 3 advanced medical care in January, 2009, followed by section 2 advanced medical care after the device approval of da Vinci S™ in November, 2009. RALP using da Vinci system was finally covered with health insurance in April, 2012. In addition, the device approval of

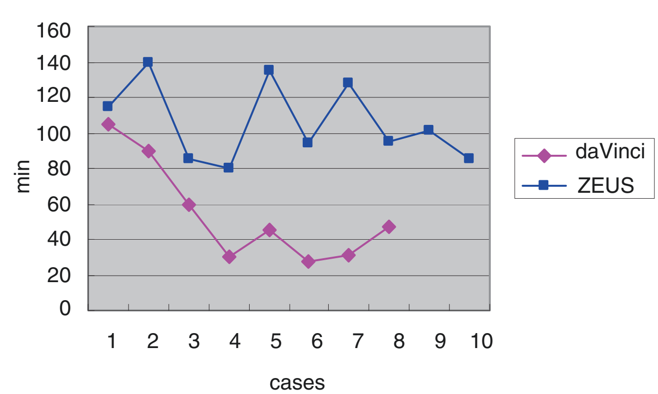



**Fig. 6.11** Comparison of vesico-urethral anastomosis time between the da Vinci and Zeus surgical systems. Single surgeon performed Zeus operations (diamond) in 2003, and another surgeon performed da Vinci operations (square) in 2007 in Kyushu University Hospital

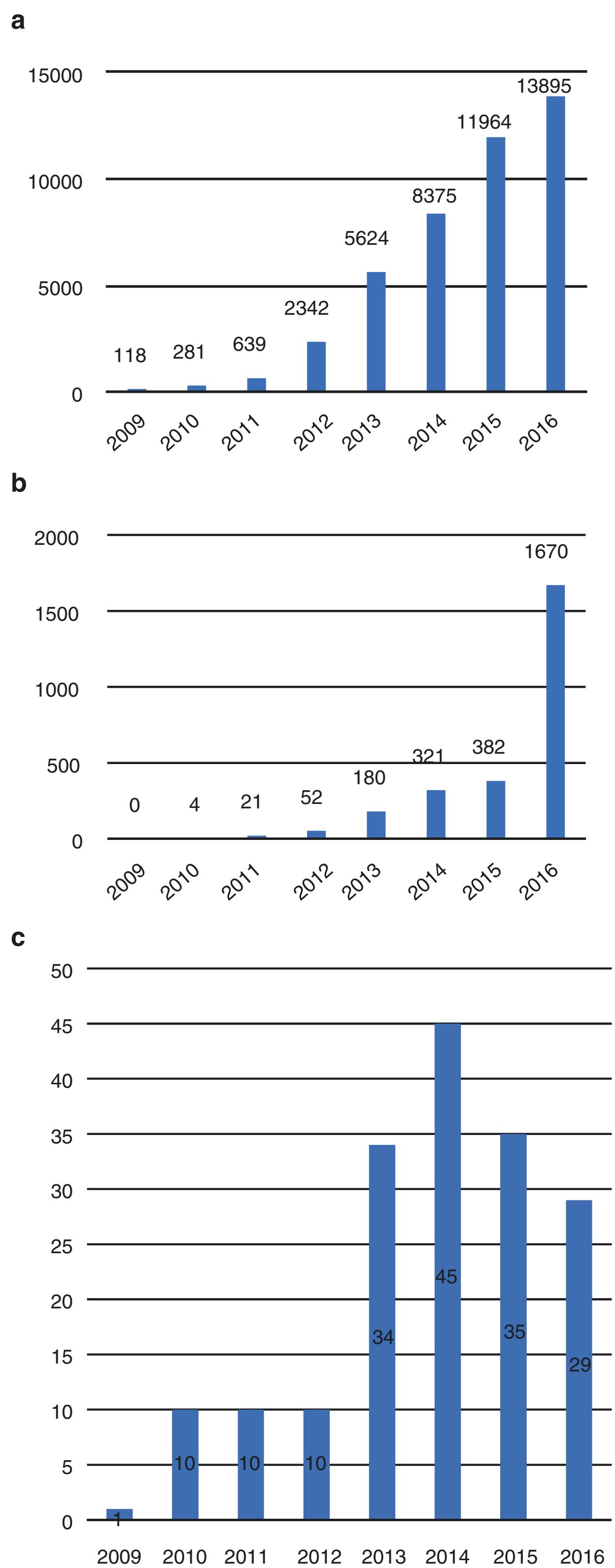



**Fig. 6.12** Changes of robotic surgery for urological cancers in Japan. (**a**) RALP, robot-assisted laparoscopic radical prostatectomy, (**b**) RAPN, robot-assisted laparoscopic partial nephrectomy, (**c**) RALC, robot-assisted laparoscopic radical cystectomy. Red arrows show the timing of national health insurance coverage

da Vinci Si™ was also done in October, 2012. As shown in Fig. 6.12a, the number of RALP using da Vinci system has been drastically increasing since the health insurance coverage in Japan. As a result, around 14,000 cases of RALP using da Vinci surgical system were performed in 2016.

Regarding RAPN using da Vinci system, the first case in Japan was performed at Fujita Health University in July, 2010. RAPN utilizing the da Vinci surgical system was initially covered by advanced medical care B in May, 2014 (Shiroki et al. 2016), followed by health insurance in April, 2016. The same was the case with RALP, the number of RAPN using da Vinci system has been explosively increasing since the coverage by health insurance (Fig. 6.12b). In case of RALC using the da Vinci surgical system, however, the trend is different from the former two robotic procedures. The first case of RALC using the da Vinci surgical system was performed at Tokyo Medical University in July, 2009 (Gondo et al. 2012). As shown in Fig. 6.12c, the number of RALC using the da Vinci surgical system has not been increasing, but decreasing in Japan recently, probably due to the fact that RALC using the da Vinci system is not covered by national health insurance system. To overcome this situation, the coverage of RALC using the da Vinci surgical system by advanced medical care seems to be indispensable. Furthermore, the device approval of the da Vinci Xi, a next generation the da Vinci surgical system, was also performed in March, 2015. Taken together, another new big wave for the da Vinci surgery seems to be coming in Japan in 2018.

## 6.6 Robotic Urologic Surgery in Korea

The first report on the da Vinci surgical system in Korea was by Sung GT and Kim HH and was published in the Journal of Korean Surgical Society in 2002. The feasibility of the da Vinci surgical system was evaluated by performing various general surgical laparoscopic procedures in an acute porcine model. The first 5 RARP procedures performed by Sung et al were on Korean patients with localized prostate cancer, with the collaboration of Dong-A University Hospital (DAUH), Korea and Singapore General Hospital (SGH), Singapore in 2004 (Kong et al. 2005). This historic endeavor between these 2 institutions was accomplished by 2 pioneers, namely Sung GT and Cheng C. The patients underwent surgery at the SGH and were transferred to DAUH, Busan, Korea on the first postoperative day where they stayed for an additional 6–7 days.

The da Vinci standard surgical system was approved as a medical device by the Korean Ministry of Health and Welfare in July 2005. The first da Vinci standard surgical system was installed at the Severance Hospital of Yonsei University in July 2005. From then to June 2017, a total of 65 da Vinci

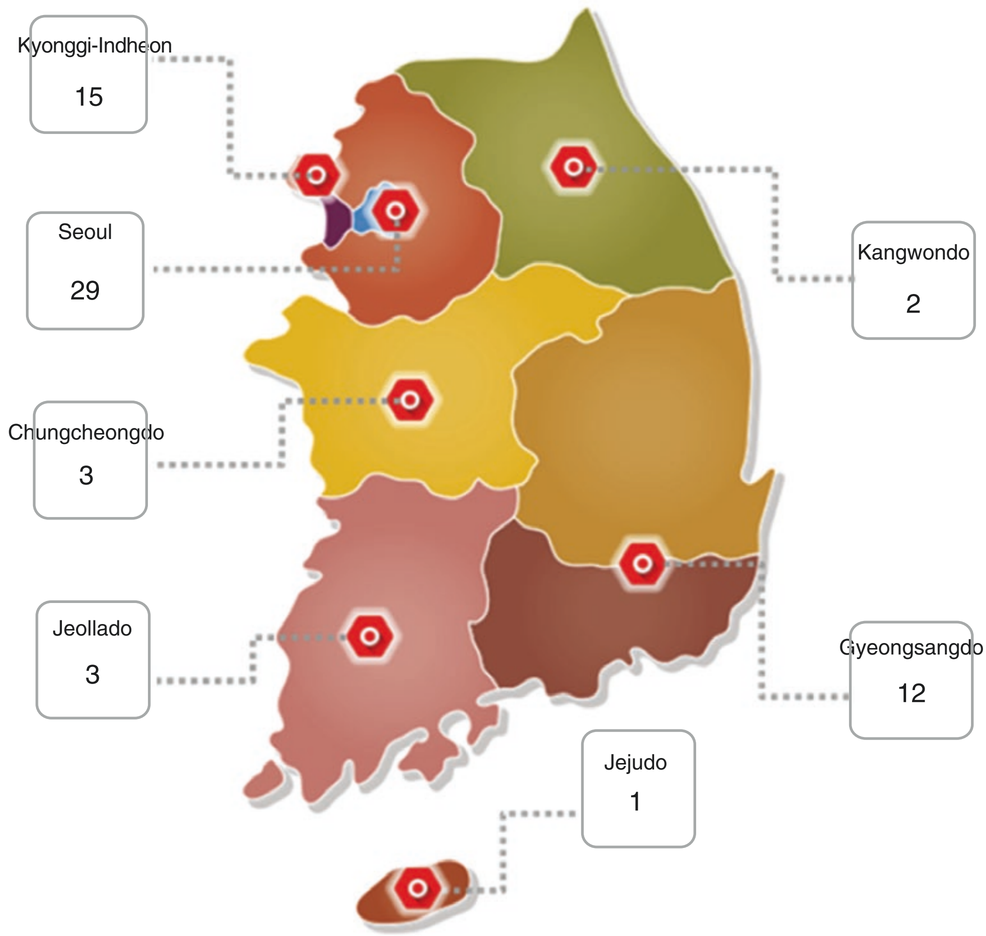



**Fig. 6.13** 2017 da Vinci system Installs in Korea

surgical systems have been installed in 49 institutions in Korea (Seo 2015) (Figs. 6.13 and 6.14).

The first robotic urologic procedure was a RARP performed by Rha et al. in July 2005 at the Severance Hospital (Lee et al. 2006). The first case of RALPN was performed in September 2006 by Park et al. (Park et al. 2008a). Park et al. (Park et al. 2008b) also successfully performed the first case of RALRC in March 2007. In the same year, the first case of robot-assisted laparoscopic radical nephrectomy and robot-assisted laparoscopic radical nephroureterectomy with bladder cuff excision were performed (Park et al. 2008c). The first case of robot-assisted laparoscopic pyeloplasty (RALPP) was reported in August 2007 (Kim et al. 2009). Subsequently, other robotic procedures including distal ureterectomy and ureteral reimplantation (Kang et al. 2009), partial cystectomy for urachal disease (Kim et al. 2010), adrenalectomy (You et al. 2013), and retroperitoneal lymph node dissection (Lee et al. 2015) started to be performed in the urologic field. The number of robotic urologic procedures has increased dramatically since 2008. In 2016, more than 5000 cases of urologic robotic procedures were performed in Korea.

The most commonly performed procedures up till now are RARP and RAPN (Fig. 6.14). Reports on the surgical

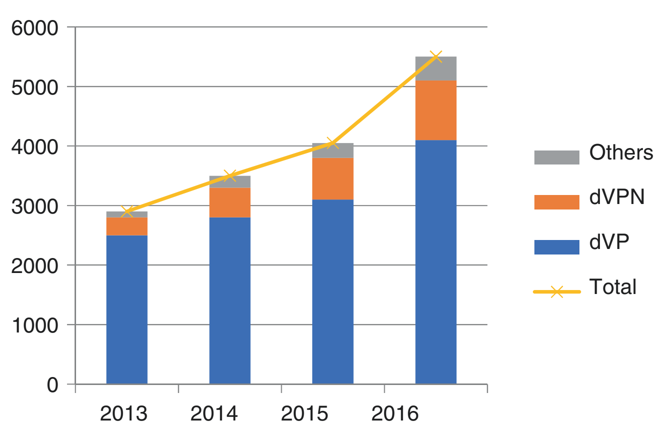



**Fig. 6.14** 2017 Korea da Vinci system Trend of URO

outcomes of these procedures show results comparable to those of open and laparoscopic surgeries. Robotic surgery is actively used in Korea, but its use is not widespread because of the high acquisition cost and substantial annual maintenance fees. Unlike laparoscopic and open surgeries, robotic surgery is not covered by the national health insurance system. If this problem is resolved, robotic surgery will be more widely used. In addition, approved guidelines for the use of the da Vinci surgical system and an accreditation system are necessary for the proper use of the robotic system by health care providers. These measures are important to minimize surgical complications and malpractice that can lead to medical lawsuits.

## 6.7 Robotic Urologic Surgery in Singapore

### 6.7.1 Funding for Robotic Surgery

The first robotic surgical system in Asia was installed in Singapore in 2002. Funding for the system came from Singapore Ministry of Health based on an S$2.52 million Health Service Development Programme for "A MIS Research Centre based on a robotic surgery unit (the da Vinci surgical system) and an image-guided intervention unit".

### 6.7.2 Dry Lab and Animal Training

A robotic surgical team, comprising urologists and OT nursing staff was assembled and site visits to Henry Ford Hospital and other centres were made to learn from pioneering robotic programmes in USA. Furthermore, team members underwent clinical attachments overseas to learn the intricacies of equipment setup and troubleshooting.

Once the da Vinci surgical system arrived in Singapore in 2002, experts in the field were invited to conduct dry lab and animal training. The first such training programme was held in Nov 2002 in Singapore General Hospital under the guidance of Dr. Mario Sung G.T. Animal training allowed the pioneer batch of robotic surgeons and scrub nurses to familiarise themselves with the robot setup, wrist controls, intracorporeal movement control and motion scaling, visual feedback and simple equipment troubleshooting.

### 6.7.3 Ramping Up the Surgical Volume

The first human case for robotic surgery was a radical prostatectomy that was performed in February 2003. The programme slowed during the SARS crisis in Apr 2003 but regained steam near the end of the same year. As the programme was government funded for the initial 30 cases, these patients need not be concerned about their bill size. Subsequent cases were spread over private patients and patients who received government subsidies based on their household income levels.

Robotic surgery remained financially challenging for many patients. It is known that centres with substantial volume can have the average cost brought down to more affordable levels (Yip and Sim 2009). In 2007, celebration of the first 200 patient journey of RARP was held in Singapore. In 2010, more than 500 cases of robotic radical prostatectomy were performed. In the same year, regional experts travelled to Singapore to support the Robotic Urology Masterclass Workshop. To date, more than 4000 cases have been performed in Singapore.

### 6.7.4 Current Scene

Robotic urologic surgery is now fully established and residents as well as OT staff are familiar with the device. The introduction of the da Vinci SI system in 2010 and XI system in 2015 in Singapore saw more centres adopting this technology.

The advantages of the robotic approach are best seen in high-volume centres where the surgical team manages large numbers of robotic cases with short setup times and mature trouble-shooting routines. Even in centres with modest volume of surgeries, a case can be made to embark on robotic surgery to improve on conventional laparoscopic or open surgery (Sim et al. 2004). A team-based approach to robot surgery helps to reduce the learning curve of the procedure for individual surgeons and team members compared to the equivalent open procedure (Sim et al. 2006). Using this approach in radical prostatectomy, good continence recovery and oncological outcomes can be expected in most patients undergoing RARP (Wang et al. 2011; Low et al. 2015).

### 6.7.5 Lessons Learnt from Two Decades of Robotic Urology

As an early adopter of robotic technology in urology, we have witnessed a whirlwind drive to re-imagine conventional open surgery in the robotic mould. This has catapulted clinical outcomes research in urology to the forefront in the pursuit of clinical evidence to back the adoption of robotic surgery. We became more acutely aware of the need for detailed unbiased charting and audit of perioperative, oncological and functional outcomes. Physician-centred functional outcome scores evolved into validated patient-centred self-reporting quality-of-life questionnaires. The importance of identical extent of dissection, standardised complications reporting, and caseload volume emerged as points of comparison between robotic and conventional laparoscopic and open approaches to achieve equivalent excellent outcomes. We have learnt that adopting a team-based strategy under the initial guidance of an experienced surgical proctor was invaluable in newly established robotic centres to help shorten the learning curve (Sim et al. 2006).

The experience drawn from our robotic experience led to more mature and insightful outcomes research techniques in other related fields, especially when correlating robotic surgery outcomes with pathological whole mount findings and fusion targeted prostate biopsies with our Biobot biopsy device (Ho et al. 2011). Following our footsteps, our colleagues in general surgery, ENT and gynaecology have also adopted robotic surgery in a similar fashion.

The journey to establish the first robotic programme in Asia has been an exhilarating ride. We are now ready for the next phase of the robotic evolution.

## 6.8 Robotic Urological Surgery in Taiwan

The first da Vinci robotic surgical system (da Vinci Standard 4-arm system) was set at the Tri-Service General Hospital (Taipei) in November 2004. The second and third system were set in the next year at the Cheng-Hsin General Hospital and Taichung Veterans General Hospital. So far, a total of 29 da Vinci surgical systems have been operating in 25 hospitals, including 16 systems in the north Taiwan, 6 in central Taiwan, 6 in the south Taiwan, and 1 in east Taiwan. By 2016, more than 20,000 robotic operations were completed in Taiwan. Urology accounted for 41% (n = 8486), following by gynecology (26%), general surgery (10%), cardiovascular surgery (8%), and colorectal surgery (6%) (Intuitive Surgical Inc. n.d.).

On 10 November 2004, Dr. Sheng-Tang Wu performed successfully the first RARP in Taiwan for a 75-year-old localized prostate cancer patient. A total of 5641 RARP procedures had been performed during 2004–2016. The next year, the first RAPN was completed by Dr. Yen-Chuan Ou. By 2016, 1340 RAPN procedures was completed in Taiwan (Intuitive Surgical Inc. n.d.).

In addition to prostatectomy and partial nephrectomy, the da Vinci surgical system was applied for many others urologic procedures, such as radical nephroureterectomy, radical nephrectomy, radical cystectomy, ureteral reconstruction, adrenalectomy (Table 6.1) (Intuitive Surgical Inc. n.d.).

**Table 6.1** Current status of robotic surgery in Taiwan

| Procedures | Case No. (%) |
|---|---|
| Radical prostatectomy | 5641 (66.5) |
| Partial nephrectomy | 1340 (15.8) |
| Radical nephroureterectomy and excision of bladder cuff | 323 (3.8) |
| Radical nephrectomy or nephrectomy | 290 (3.4) |
| Radical cystectomy | 165 (1.9) |
| Adrenalectomy | 150 (1.8) |
| Pyeloplasty | 104 (1.2) |
| Others | 373 (4.4) |
| Total | 8486 |

## 6.9 Conclusion

Nearly two decades ago, with the introduction of robotic-assisted surgical system into surgical practice, we have witnessed enormous progress and advances in MIS as well as in the operating room. The surgical robots have really advanced significantly and have become safer, more acceptable, and more versatile. Robotic-assisted surgery has proven benefits in reducing the risk and complications associated with open surgical procedures; thereby, extending the benefits of minimally invasive surgery to a broader population of patients. However, existing surgical robots have certain limitations. The robotic technology currently available is large and bulky that reaches into the body from outside the patient through multiport platform. Also, the system is cost prohibitive for secondary and tertiary hospitals and is mainly confined to a limited number of surgical procedures, such as radical prostatectomy, partial nephrectomy, cystoprostatectomy with urinary diversion and ureteral reconstruction in urology. High cost is certainly restraining the robotic application in developing countries in Asia, where hospitals do not have enough funds to accommodate the latest expensive technology. Furthermore, patients in developing and underdeveloped countries do not have the ability to pay for these expensive treatments, and hence, opt for cost effective surgeries. Furthermore, favorable reimbursement policies need to be implemented by the national health care system.

The next generation of surgical robots are being designed to expand robotic surgery into areas that are currently underserved, including general abdominal, gynecological and urological procedures, in a cost-effective manner. Furthermore, use of image guidance systems as well as 8K ultrahigh definition technology during robotic surgery has shown to improve the surgical accuracy levels, and thus, help in conducting surgeries efficiently. With recent advances and the development of robotic technologies, robotic-assisted surgery will continue to grow because of its tremendous potentials to offer better healthcare for the people. The da Vinci surgical system has only been commercially available for 17 years, a blink of an eye in the history of medicine. As newer and innovative surgical robots are expected to enter the surgical robotic market with a compelling economic value through reduced capital acquisition cost for the hospitals, robotic surgery will continue to grow in a more healthy and competitive environment.

## References

Abbou CC, Hoznek A, Saloman L, et al. Remote laparoscopic radical prostatectomy carried out with a robot. Report of a case. Prog Urol. 2000;10:520–3.

Bhattu AS, Ganpule A, Sabnis RB, et al. Robot-assisted laparoscopic donor nephrectomy vs standard laparoscopic donor nephrectomy: a prospective randomized comparative study. J Endourol. 2015;29:1334–40.

Bo Y, Juan J, Zhi S, et al. The first clinical application experience of domestic Smartbot S surgical robot. Chin J Gen Surg. 2016;31:512–3.

Bora GS, Mavuduru RS, Sharma AP, et al. Initial experience of robotic nephron sparing surgery in cases of high renal nephrometry scores. Indian J Urol. 2017;33:230–5.

Chan ESY, Yee CH, Chiu PKF, et al. Robot-assisted radical cystectomy using a side-docking technique. J Laparoendosc Adv Surg Tech A. 2015;25(3):207–11.

Data published by Chindex Co., Ltd. n.d.

Cho CL, Ho KL, Chu SS, et al. Robotic assisted versus standard laparoscopic partial nephrectomy: comparison of perioperative outcomes from a single institution. Hong Kong Med J. 2011;17:33–8.

Desai M, Chabra J, Ganpule AP. Robotic surgery is ready for prime time in India: for the motion. J Minim Access Surg. 2015;11:2–4.

Dogra PN, Javali TD, Singh P, et al. Perioperative outcome of initial 190 cases of robot-assisted laparoscopic radical prostatectomy – a single-center experience. Indian J Urol. 2012a;28:159–63.

Dogra PN, Abrol N, Singh P, et al. Outcomes following robotic radical nephrectomy: a single-center experience. Urol Int. 2012b;89:78–82.

Eto M, Yokomizo A, Koga H, et al. A laparoscopic radical prostatectomy assisted by the "ZEUS" robotic system: an initial case report. Fukuoka Igaku Zasshi. 2005;96(2):58–62.

Fan G, Zhou Z, Zhang H, et al. Global scientific production of robotic surgery in medicine: a 20-year survey of research activities. Int J Surg. 2016;30:126–31.

Gettman MT, Blute ML, Chow GK, et al. Robotic-assisted laparoscopic partial nephrectomy: technique and initial clinical experience with Da Vinci robotic system. Urology. 2004;64:914–8.

Gondo T, Yoshioka K, Nakagami Y, et al. Robotic versus open radical cystectomy: prospective comparison of perioperative and pathologic outcomes in Japan. Jpn J Clin Oncol. 2012;42(7):625–31.

Guillonneau B, Jayet C, Capelle O. Robotic-assisted laparoscopic pyeloplasty. J Urol. 2001;165:V75.

Gupta NP, Yadav R, Akpo EE. Continence outcomes following robotic radical prostatectomy: our experience from 150 consecutive patients. Indian J Urol. 2014;30:374–7.

Harris SJ, Arambula-Cosio F, Mei Q, et al. The Probot—an active robot for prostate resection. Proc Inst Mech Eng H. 1997;211:317–25.

Hashizume M, Shimada M, Tomikawa M, et al. Early experiences of endoscopic procedures in general surgery assisted by a computer-enhanced surgical system. Surg Endosc. 2002;16(8):1187–91.

Hemal AK, Mishra S, Mukharjee S, Suryavanshi M. Robot assisted laparoscopic pyeloplasty in patients of ureteropelvic junction obstruction with previously failed open surgical repair. Int J Urol. 2008a;15:744–6.

Hemal AK, Kolla SB, Wadhwa P. First case series of robotic radical cystoprostatectomy, bilateral pelvic lymphadenectomy, and urinary diversion with the da Vinci S system. J Robot Surg. 2008b;2:35–40.

Hirano D, Minei S, Yamaguchi K, et al. Retroperitoneoscopic adrenalectomy for adrenal tumors via a single large port. J Endourol. 2005;19:788–92.

Ho H, Yuen JS, Mohan P, et al. Robotic transperineal prostate biopsy: pilot clinical study. Urology. 2011;78(5):1203–8.

Statistical data from the Taiwan agents of Intuitive Surgical Inc. n.d.

Jain S, Gautam G. Robotics in urologic oncology. J Minim Access Surg. 2015;11:40–4.

Kakeji Y, Konishi K, Ieiri S, et al. Robotic laparoscopic distal gastrectomy: a comparison of the da Vinci and Zeus systems. Int J Med Robot. 2006;2(4):299–304.

Kang SG, Choi H, Ko YH, et al. Robot-assisted laparoscopic distal ureterectomy and ureteral reimplantation. Korean J Urol. 2009;50:921–4.

Kim SC, Kang T, Park H. Experience with laparoscopic pyeloplasty, including robot-assisted laparoscopic surgery, for ureteropelvic junction obstruction. Korean J Urol. 2009;50:996–1002.

Kim DK, Lee JW, Park SY, et al. Initial experience with robotic-assisted laparoscopic partial cystectomy in urachal diseases. Korean J Urol. 2010;51:318–22.

Kong GS, Seong YK, Sung GT. Robotic-assisted radical prostatectomy using da Vinci TM Surgical robotic system: initial Korean experience. Korean J Urol. 2005;46:353–9.

Kumar R, Hemal AK. Emerging role of robotics in urology. J Minim Access Surg. 2005;1:202–10.

Kumar R, Yadav R, Kolla SB. Simultaneous bilateral robot-assisted dismembered pyeloplasties for bilateral ureteropelvic junction obstruction: technique and literature review. J Endourol. 2007;21:750–3.

Kumar S, Pragatheeswarane M, Sharma AP, et al. Expanding the horizon of robotic surgery to large pelvic paraganglioma. J Robot Surg. 2017a;11:247–50.

Kumar S, Bishnoi K, Panwar VK, et al. Stone in ectopic pelvic pancake kidney: a surgical challenge overcome by robotic surgery. J Robot Surg. 2017b;12:181–3.

Lee YS, Han WK, Yang SC, et al. Robot-assisted laparoscopic radical prostatectomy. Korean J Urol. 2006;47:206–10.

Lee SH, Kim DS, Chang SG, et al. Robot-assisted laparoscopic retroperitoneal lymph node dissection for stage IIIb mixed germ cell testicular cancer after chemotherapy. Korean J Urol. 2015;56:540–4.

Li J, Wang S, Wang X, et al. Optimization of a novel mechanism for a minimally invasive surgery robot. Int J Med Robot. 2010;6(1):83–90.

Low AL, Sim HG, Huang HH, et al. Oncological outcomes following robotic-assisted radical prostatectomy in a multiracial Asian population. J Robot Surg. 2015;9(3):201–9.

Menon M, Hemal AK, Tewari A, et al. Nerve-sparing robot-assisted radical cystoprostatectomy and urinary diversion. BJU Int. 2003;92:232–6.

Nelivigi GG. Robotic surgery: India is not ready yet. Indian J Urol. 2007;23:240–4.

Pahwa M, Pahwa AR, Batra R, et al. Robotic assisted laparoscopic adrenalectomy: initial experience from a tertiary care centre in India. J Minim Access Surg. 2015;11:83–6.

Park SY, Kim HJ, Seo JW, et al. Robot-assisted laparoscopic partial nephrectomy. Korean J Urol. 2008a;49:387–91.

Park SY, Cho KS, Park KK, et al. Robot-assisted laparoscopic radical cystectomy with ileal conduit urinary diversion. Korean J Urol. 2008b;49:506–9.

Park SY, Cho KS, Ham WS. Robot-assisted laparoscopic nephroureterectomy with a bladder cuff excision. Korean J Urol. 2008c;49:373–5.

Robotic Surgery Vattikuti Fellowship for 7 Indian Surgeons. 2016. https://www.healthcareexecutive.in/robotic-surgery-vattikuti-fellowship-7-indian-surgeons. Accessed 18 Aug 2017.

Ruqi M. Development of a minimally invasive surgical robot executive system and study of its control algorithm. Harbin University of Science and Technology. 2013.

Sackier JM1, Wang Y. Robotically assisted laparoscopic surgery. From concept to development. Surg Endosc. 1994;8(1):63–6.

Satava RM. Virtual reality, telesurgery, and the new world order of medicine. J Image Guid Surg. 1995;1:12–6.

Schurr MO, Arezzo A, Neisius B, et al. Trocar and instrument positioning system TISKA. An assist device for endoscopic solo surgery. Surg Endosc. 1999;13(5):528–31.

Seo IY. Urologic robotic surgery in Korea: past and present. Korean J Urol. 2015;56:546–52.

Shiroki R, Fukami N, Fukaya K, et al. Robot-assisted partial nephrectomy: superiority over laparoscopic partial nephrectomy. Int J Urol. 2016;23(2):122–31.

Sim HG, Yip SKH, Lau WKO, et al. Early experience with robot-assisted laparoscopic radical prostatectomy. Asian J Surg. 2004;27(4):321–5.

Sim HG, Yip SKH, Lau WKO, et al. Team-based approach reduces learning curve in robot-assisted laparoscopic radical prostatectomy. Int J Urol. 2006;13(5):560–4.

Hospital Authority Surgical Outcomes Monitoring & Improvement Program (SOMIP) Report, vol 5 (July 2012–June 2013).

Hospital Authority Surgical Outcomes Monitoring & Improvement Program (SOMIP) Report, vol 8 (July 2015–June 2016).

Sung GT, Gill IS. Robotic laparoscopic surgery: a comparison of the da Vinci and Zeus systems. Urology. 2001;58(6):893–8.

Wang LS, Chung SFCM, Yip SKH, et al. The natural history of voiding function after robot-assisted laparoscopic radical prostatectomy. Urol Oncol. 2011;29(2):177–82.

Yip SKH, Sim HG. Robotic prostatectomy in East Asia: surgical results, development and challenges. Curr Opin Urol. 2009;20(1):80–5.

Yip SKH, Yee CH, Ng CF, et al. Robot-assisted radical prostatectomy in Hong Kong: a review of 235 cases. J Endourol. 2012;26(3):258–63.

Yoshioka K, Hatano T, Nakagami Y, et al. Robotic-assisted laparoscopic radical prostatectomy: initial 15 cases in Japan. J Robot Surg. 2008;2(2):85–8.

You JY, Lee HY, Son GS, et al. Comparison of robotic adrenalectomy with traditional laparoscopic adrenalectomy with a lateral transperitoneal approach: a single-surgeon experience. Int J Med Robot. 2013;9:345–50.

# 7 A Nation-Wide Laparoscopic Skills Qualification: A Thirteen-Year Experience in Japan

Tadashi Matsuda, Tomonori Habuchi, Hiroomi Kanayama, and Toshiro Terachi

**Abstract**

For laparoscopic and robotic surgeries, the surgeons' competency is important to keep high quality of surgical treatment. Japanese Society of Endourology (JSE) and the Japanese Urological Association established a urological laparoscopic skills evaluation system called the Endoscopic Surgical Skill Qualification (ESSQ) System in Urological Laparoscopy in 2004.

By 2016, a total of 1463 urologists had qualified from a total of 2561 applicants after skills assessment on non-edited videos by two referees, resulting in a pass rate of 57.1%. Details of the system and the skill assessment results are shown. Prospectively collected surgical outcomes of 2590 laparoscopic urologic operations performed by 130 qualified doctors 5 years post-qualification were excellent, demonstrating the good predictive validity of the ESSQ System. The reliability of video assessments by referees was analyzed statistically on 1220 videos which had fixed points by two referees. The results showed moderate reliability for the video assessments by the referees, but the final qualification rates showed no significant differences among the referees, which indicated that the video assessments by the referees were fair for all applicants.

In the 13 years since the launch of the ESSQ System, it has become the goal of young urologists in Japan who learn laparoscopic surgery. According to a nation-wide survey by JSE, open conversion rates and major complication rates have dramatically decreased during these 26 years since 1990.

**Keywords**

Urology · Laparoscopy · Skill assessment · Reliability

## 7.1 Introduction

For laparoscopic and robotic surgeries, the surgeons' competency is important to ensure the safety and quality of surgical treatment. There are many methods of skills assessment of surgeons, but a system which covers an whole country is rare. The Japanese Society of Endourology (JSE) and the Japanese Urological Association (JUA) started the Endoscopic Surgical Skill Qualification (ESSQ) System in Urological Laparoscopy in 2004 to promote wide and safe spread of urological laparoscopic surgeries (Matsuda et al. 2006), and have run the system for 13 years. The ESSQ System in Japan is an inter-institutional and nation-wide assessment system covering not only urologists but surgeons of other subspecialties including gynecologists, gastrointestinal, hepatobiliary, endocrine and pediatric surgeons (Mori et al. 2010; Iwanaka et al. 2011). The whole system is governed by the Japan Society for Endoscopic Surgery (JSES) and it is required for skill qualification to have the ability to complete common laparoscopic procedures in each field by applicants themselves. The skills assessment is done by the evaluation of an un-edited videotape of a surgery which entire procedure was completed by the surgeon in double-blinded way by two referees.

Herein, we summarize the system and the 13-year results of skills assessments of a total of 2561 urologists, together with the reliability and the predictive validity of the assessments.

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## 7.2 The Endoscopic Surgical Skill Qualification (ESSQ) System in Urological Laparoscopy

The ESSQ System in Urological Laparoscopy was established in 2003 according to formal agreements at the general assembly of the JUA and JSE. The system was designed and has been controlled by the ESSQ System Committee, and the members on this panel were selected by the Board Director Committee of the JUA and JSE.

In 2002, the JSE conducted a survey on the number of urological laparoscopic surgeries and estimated the possible number of applicants each year. Seven hundred and ten institutions (59.2%) responded out of 1199 hospitals that were certified as educational institutions by the JUA. The estimated number of applicants per year was about 300.

The ESSQ System started in 2004 and applicants are recruited in October every year. Video assessment is performed from November to the end of March. The final decision of the video assessments is made in April each year by the ESSQ System Committee and is approved by the JSE and JUA Board Directors Committees.

1. Requirements to apply for the ESSQ System
   To apply for skills qualification, surgeons are required to have more than 20 experiences of laparoscopic urological surgeries including adrenalectomies, nephrectomies, pyeloplasties, or radical prostatectomies as chief surgeon under the guidance of a supervisor, to attend a laparoscopy training course officially approved by JSE, and more than 2 years of laparoscopic practice after completion of the urological training program formally set by JUA of 6 years. The application must be supported by two supervisors who know the applicant's laparoscopic surgical skill personally. Applicants who failed in the video assessment are required to attend an educational program where a proper laparoscopic surgery is shown a video before re-application to the system. The applicant is required to pay an application fee of about 250 US dollars (30,000 yen).
2. Skills assessment
   The applicants submit un-edited videotapes which show the whole laparoscopic procedures of one operation, an adrenalectomy, a nephrectomy or a pyeloplasty, which was completed on their own. The applicants' skill is then evaluated on the un-edited videotapes according to the guidelines built by the Expert Referee Committee. The guidelines include a specific check-list which shows inappropriate maneuvers and points which should be deducted whenever an inappropriate maneuver is indicated on the video. The details of the skill assessment have been reported in a previous publication (Matsuda et al. 2006). A perfect procedure scores 75 points, and 1–5 points is reduced if there was a dangerous or inappropriate maneuver. More than 60 points (80%) is required to pass the skill assessment. The video assessment is conducted by two referees who do not have information on the applicant's name. When both referees score more than 60 points for the video, the applicant is qualified. If one of the referees disqualifies the video, then a third referee assesses the video and a final judgment is made by the Referee Committee. Videos disqualified by both referees are also discussed at the Referee Committee after discussion on the video. Referees write comments to the applicants indicating any inappropriate or dangerous performances shown in the video.
3. Qualification renewal
   Qualified doctors are required to renew the qualification every 5 years. Attendance at more than 20 urological laparoscopic surgeries as chief surgeon or as a supervisor is required for renewal during the qualification period of 5 years.
4. Referee Committee
   The referees should have more than 100 experiences of laparoscopic adrenal or renal surgeries, including adrenalectomies, nephrectomies, pyeloplasties or partial nephrectomies. At first, six expert referees were selected by the ESSQ Committee and they conducted video assessment by each other. Then 23 referees were selected by them out of 36 candidates who had more than 100 experiences in urological laparoscopic surgeries (Matsuda et al. 2006). In 2009, 2013, 2015 and 2016, 13, 8, 6, and 4 additional referees were selected, respectively, from among the doctors who had been qualified for more than 5 years. As of 2017, there are 51 referees currently working.

   The referees were trained in how to assess videos according to the guidelines at consensus meetings for 4–6 h before starting skill assessment. Every year, Referee Committee meetings are held on 5–6 times to make final decisions on those videos which were scored less than 60 points by referees. Five to seven referees including two expert referees attend each Referee Committee meeting where they review and discuss about 20 videos for 6 h. Particular attention is payed to the procedures listed in the check-list by the original referees. All referees are required to join a Referee Committee meeting at least once a year. The Expert Referee Committee meeting makes final decisions on videos where a Referee Committee meeting could not reach a consensus. Furthermore, all referees need to attend two additional meetings of 1 h, where the video assessment guidelines are discussed. Every year, the video assessment scores by each referee are evaluated in comparison to the final decision by the Referee Committee, and the results are informed to each referee.

## 7.3 Thirteen-Year Results of the ESSQ System in Urological Laparoscopy

The results of skills qualification from 2004 to 2016 are shown in Table 7.1, and the pass rate in each year is shown in Fig. 7.1. Thousand four hundred and sixty three urologists

**Table 7.1** The number of applicants and qualified doctors each year in the ESSQ System

| Year | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of applicants | 205 | 125 | 130 | 137 | 156 | 153 | 217 | 185 | 238 | 249 | 248 | 260 | 258 | 2561 |
| No. of qualified doctors | 136 | 79 | 79 | 83 | 96 | 91 | 122 | 101 | 140 | 124 | 143 | 137 | 132 | 1463 |

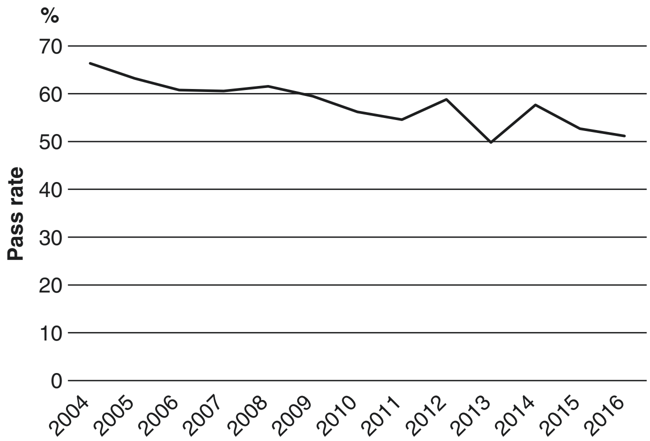


**Fig. 7.1** Pass rates of skills assessments each year. In 2004, the results of skills assessment of the referee candidates are included

**Table 7.2** Qualification rate of applicants including those who had not been qualified in previous applications

| | Initial apply | Second apply | Third apply | Fourth apply | Fifth apply | Sixth apply | Total |
|---|---|---|---|---|---|---|---|
| No. applicants | 1828 | 533 | 148 | 35 | 11 | 4 | 2561[a] |
| Qualified | 1045 | 300 | 90 | 20 | 4 | 2 | 1463[a] |
| Qualification rate (%) | 57.2 | 56.3 | 60.8 | 57.1 | 36.4 | 50 | 57.1 |

[a]Including two applicants who had video assessment due to lack of the renewal requirements at the renewal 5 years after the initial qualification

have qualified out of a total of 2561 applicants including re-applicants, resulting in a pass rate of 57.1%. Thousand forty five passed at the first application and the number of applicants who passed after the second, third, fourth, fifth, and sixth application are shown in Table 7.2 together with each pass rate.

## 7.4 Predictive Validity of the ESSQ System in Urological Laparoscopy

The predictive validity of the ESSQ System was evaluated in 2009, 5 years after the start of the system in 2004 (Habuchi et al. 2012). Hundred and thirty six urologists who were qualified in 2004 were prospectively asked to submit intra-operative and postoperative data of their 20 most recent consecutive cases at the end of 2009. The required data include type of surgery, role of the surgeon (main surgeon or mentor/instructor), operating time, amount of intraoperative bleeding, intraoperative or postoperative allogeneic blood transfusion, conversion to open surgery, and all intra- and post-operative complications. Complications were graded according to the Satava and modified Clavien classification.

Data of 2590 urologic laparoscopic surgeries performed by 130 surgeons were collected and analyzed. In 97 (3.7%) patients, complications occurred (Habuchi et al. 2012). Major intra-operative complications (grade II or III, Satava classification) were noted in 32 (1.2%) patients and major post-operative complications defined as grade III or higher (modified Clavien classification) in 24 (0.9%) patients. Conversion to open surgery, allogeneic transfusion and peri-operative mortality rates were 2.5%, 1.6% and 0%, respectively.

According to these results, the ESSQ System can ensure that urological laparoscopic surgeons with reasonable laparoscopic competency can perform various types of urological laparoscopic surgeries with good outcomes and a low prevalence of perioperative complications. This indicates good predictive validity of the ESSQ System.

## 7.5 Reliability of Video Assessments by Two Referees

To study the reliability of video assessments by referees, the results of the video assessments from 2004 to 2011 by each referee were evaluated on the following aspects: the average score made by each referee, the percentage of videos finally qualified at the committee among videos assessed by each referee, and the accordance rate of the referee's judgment and the final decision by the committee on each video (Matsuda et al. 2014).

The results from 2440 video assessments on 1220 videos by two referees were studied, after exclusion of 42 videos of referee candidates, and another 46 videos whose scores by the two referees were not fixed due to a variety of reasons. The average number of videos which each referee assessed was 58.1, ranging from 16 to 87. The accordance (pass or fail) rate of the results of the video assessment by the two referees was 68.9%. The average scores of the video assessment by each referee was 62.7 ± 2.4(SD). There was a statistically significant difference in the average video assessment score among the referees ($p < 0.001$), and 5 referees out of 42 referees showed significantly lower or higher average scores than the other referees. The percentage of videos qualified finally by the Referee Committee on the videos originally assessed by each referee showed no significant differences

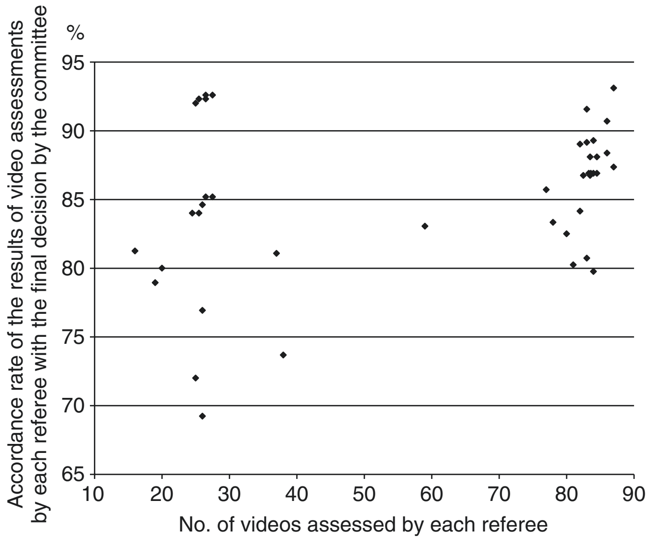


**Fig. 7.2** Correlation between the accordance rate of the results of the video assessments by each referee with the final decision by the committee (A rate), and the number of videos assessed by each referee (r = 0.404, p = 0.0080) (Matsuda et al. 2014)

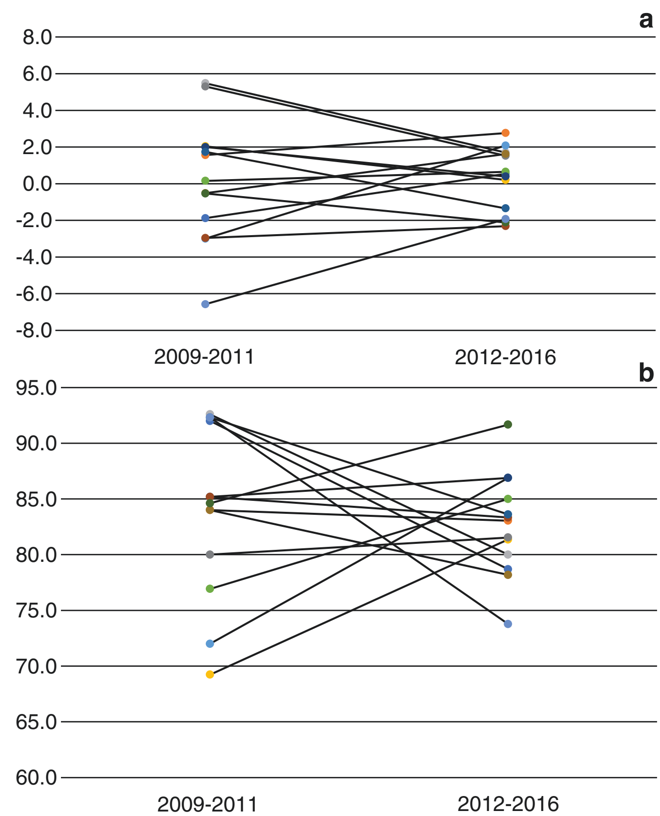


**Fig. 7.3** (**a**) Change of the average discrepancy of the video assessment point by one referee from the other referee on each video (D points) of 13 referees who joined the referee committee in 2009 from 2009–2011 to 2012–2016. (**b**) Change of the accordance rate of the results from the video assessment by each referee with the final decision by the committee (A rate) of 13 referees who joined the referee committee in 2009 from 2009–2011 to 2012–2016

among the referees. The accordance rate of the results of the video assessment by each referee with the final decision by the committee (A rate) showed a statistically significant positive correlation with the number of videos assessed by each referee (r = 0.404, p = 0.0080) (Fig. 7.2). The accordance of the video assessment by the two referees were shown in 68.4% (633/925) and 69.1% (204/295) of nephrectomies and adrenalectomies, respectively.

In 2017, further analysis was conducted to evaluate the reliability of video assessments, in particular to study whether increased experience of video assessments resulted in an improvement in the quality of video assessments. Two thousand five hundred and four video assessment points of 1252 videos by two referees from 2012 to 2016 were analyzed, and the discrepancy of the video assessment point by one referee from the other referee on each video (D points), and the A rate were studied. Among the 2504 points, the 783 video assessment points which were scored by the 13 referees who joined the referee committee in 2009 were evaluated on the above two issues. The average number of video assessments during this period by the 13 referees was 60.2. The D points ranged from +2.8 to −2.3. The A rate ranged from 73.8% to 91.7%. The D points and A rates from 2012 to 2016 were compared to those from 2004 to 2011 for the same 13 referees. From 2009 to 2011, the 13 referees scored 331 videos, and the average number of video assessments by each referee was 25.5. The D scores of each referee during each study period are shown in Fig. 7.3a, demonstrating the decrease of the D points after gaining experience of video assessments. On the other hand, the A rates improved in some referees but deteriorated in some of the others (Fig. 7.3b).

These results indicated that the ESSQ System showed moderate reliability of the video assessments by the referees. Because the final qualification rates showed no significant differences among the referees, we concluded that the video assessments by the referees were fair for all applicants. Further improvement in the reliability of video assessments is required in the ESSQ System.

## 7.6 Complication of Urological Laparoscopic Surgeries During the 26 Years

The JSE together with the JSES have conducted a nationwide survey on laparoscopic surgery performed in Japan biennially since 1991. The JSE sends a survey sheet to the members of the board of representatives of the JSE (300–400 doctors each survey) and asks them to complete the survey according to the data from their institution. The sheet includes the number of cases of each urological laparoscopic

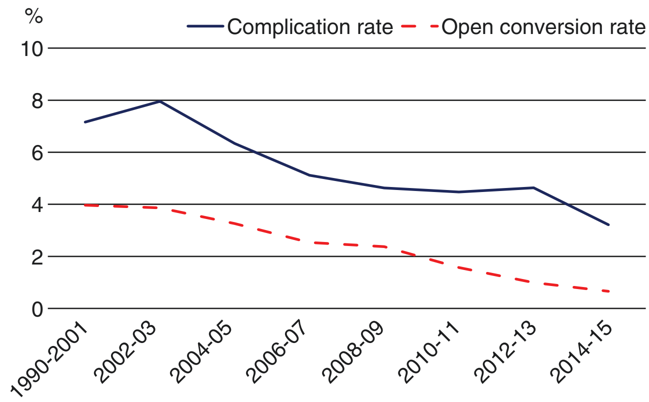


**Fig. 7.4** Open conversion and major complication rates of urological laparoscopic surgery according to the nation-wide survey in Japan

procedure in each year, the number of open conversion cases, the complications, and cases of death related to laparoscopic surgery.

A total of 105,807 urological laparoscopic and robotic assisted surgeries were recorded over the 26 years according to the responses from the institutions (Japanese Society of Endoscopic Surgery 2016). The number of procedures for each year showed a rapid and exponential increase in cases. Open conversion and major complication rates are shown in Fig. 7.4 according to the date of surgery. Both rates decreased significantly over the 26-year period.

## 7.7 Discussion

During the past 13 years, the ESSQ System in Urological Laparoscopy has provided a variety of benefits. These include the setting of appropriate standards for urological laparoscopic surgery, an improvement of the skills of each applicant by feedback on the results of the skill assessment with comments, and promoting an equalization of skill levels from different institutes across Japan. The main goal, that is to reduce complications due to laparoscopic surgeries, has been partially achieved by reducing the open conversion rate of 4.0% and complication rate of 7.2% among 7237 surgeries between 1990 and 2001 to 0.7% and 3.2% among 28,969 surgeries in 2014–2015, respectively according to the nation-wide survey of laparoscopic surgeries in Japan.

A skills assessment system requires fairness, reliability and good validity. If it covers the whole nation such as the ESSQ System, feasibility and cost are also important. To make the assessment feasible, cost effective and fair, the ESSQ System uses video assessment in a double blinded fashion, reviewing videos without knowledge of the applicant's and reviewers' names.

Good predictive validity was shown as described above. The qualified surgeons worked not only as good surgeons but also as good educators of laparoscopy yielding reasonable outcomes of the operations which they attended.

The most difficult aspect of the ESSQ System was the forming of a consensus among the societies to start the system. We started discussion on this system in 2001 at the Executive Committee of the JUA and JSE. It took 2½ years for our societies to reach a consensus and to prepare the system.

Another difficulty of the system was to ensure good reliability of video assessments. It is difficult to do reliable skills assessment, in particular when complicated procedures such as an adrenalectomy or nephrectomy performed using different surgical instruments and different surgical techniques, are evaluated. Furthermore, in the ESSQ System, it is necessary to judge by the skills assessment whether the applicant is competent enough as an established laparoscopic surgeon. Such surgical skills assessment system (a pass-or-fail type) with good validity and reliability has never been reported. The reliability of this type of skills assessment should be a matter of discussion.

**Acknowledgements** Sixty referees, including the authors and the late Drs. Yoshinari Ono and Kazuo Suzuki, spent a lot of time to assess the videos every year. Ms. Keiko Iijima, the chief secretary of the JSE, performed all the clerical works on the system.

All authors contributed to this chapter as the chair of the ESSQ System.

*Remarks*: Ethical approval is granted for the studies involved in this article according to local regulations.

*Disclosures*: Drs. Tadashi Matsuda, Tomonori Habuchi, Hiroomi Kanayama, and Toshiro Terachi have no conflicts of interest or financial ties to disclose.

## References

Habuchi T, Terachi T, Mimata H, et al. Evaluation of 2,590 urological laparoscopic surgeries undertaken by urological surgeons accredited by an endoscopic surgical skill qualification system in urological laparoscopy in Japan. Surg Endosc. 2012;26:1656–63.

Iwanaka T, Morikawa Y, Yamataka A, et al. Skill qualifications in pediatric minimally invasive surgery. Pediatr Surg Int. 2011;27:727–31.

Japanese Society of Endoscopic Surgery. Results of 13th nationwide survey of endoscopic surgery in Japan. J Jpn Soc Endosc Surg. 2016;21:772–96.

Matsuda T, Ono Y, Terachi T, et al. The Endoscopic Surgical Skill Qualification system in urological laparoscopy: a novel system in Japan. J Urol. 2006;176:2168–72.

Matsuda T, Kanayama H, Ono Y, et al. Reliability of laparoscopic skills assessment on video: 8-year results of the Endoscopic Surgical Skill Qualification System in Japan. J Endourol. 2014;28:1374–8.

Mori T, Kimura T, Kitajima M. Skill accreditation system for laparoscopic gastroenterologic surgeons in Japan. Minim Invasive Ther Allied Technol. 2010;19:18–23.

# Part II

# Endourology Techniques

# Multiple vs. Single Access PCNL

**8**

Michael Alfred V. Tan and Dennis G. Lusaya

**Abstract**

Percutaneous nephrolithotomy (PCNL) is the standard of care for large renal calculi which are no longer suitable for extracorporeal shockwave lithotripsy. The key to success depends on the urologist's choice of instruments, preoperative and intraoperative access planning, patience, perseverance, skill and training. Percutaneous renal access is a crucial early step that may ultimately influence outcomes of PCNL in terms of overall stone-free rate and complications. Several techniques for access and tract dilatation are described in this chapter. Prone, supine or lateral positioning during renal access have inherent advantages and disadvantages. Similarly, various adjunct imaging modalities and instrumentation are available to increase success and decrease the risk of complications. Nonetheless, the most practical and effective approach still depends heavily on stone burden and renal anatomy, available instrumentation and equipment, and the surgeon's expertise and level of training.

**Keywords**

Percutaneous nephrolithotomy · PCNL · Stone

The 2005 American Urological Association guidelines on the management of staghorn calculi has recommended percutaneous nephrolithotomy (PCNL) for treatment of renal calculi 2 cm and larger. Success of a PCNL procedure depends on several factors which include: preoperative planning, the correct choice of puncture site and access technique, and efficacy of tract dilatation, nephroscopy, stone fragmentation, extraction and drainage. Planning of tract placement could never be overemphasized. Meticulous evaluation of preoperative imaging will dictate the choice of access site and the intrarenal endoscopic route that would yield high stone free rates with minimal morbidity. Access to the kidney is arguably the most crucial step in PCNL as the site of entry will determine the approach and equipment needed for stone clearance. If done properly, it can maximize the efficiency of rigid and flexible instruments, minimize morbidity and allow for execution of adjunctive procedures.

## 8.1 Positioning the Patient

Fluoroscopy-guided percutaneous access requires opacification of the renal collecting system. This is achieved by injecting radiographic contrast medium through a ureteral catheter with one end externalized through the urethra. This can be easily performed using rigid instruments with the patient in a dorsal lithotomy position. In certain instances, flexible cystoscopy with the patient supine or prone may also be done for ureteral catheter placement and retrograde pyelography. Following ureteral catheter placement, a Foley catheter is also routinely placed. The exposed caudal segment of the ureteral catheter is secured to the Foley catheter to prevent misplacement of the cephalic segment inside the collecting system as the patient is re-positioned and re-draped for percutaneous access.

The patient can be positioned either prone, supine or laterally (with further variations such as split-leg, slightly oblique, etc.) for percutaneous renal access depending on the preference of the surgeon. The prone position offers direct and shorter access to the collecting system with minimal interference from other intraabdominal organs. It also potentially exposes multiple calyces for easier percutaneous access. These may be circumvented in supine and lateral

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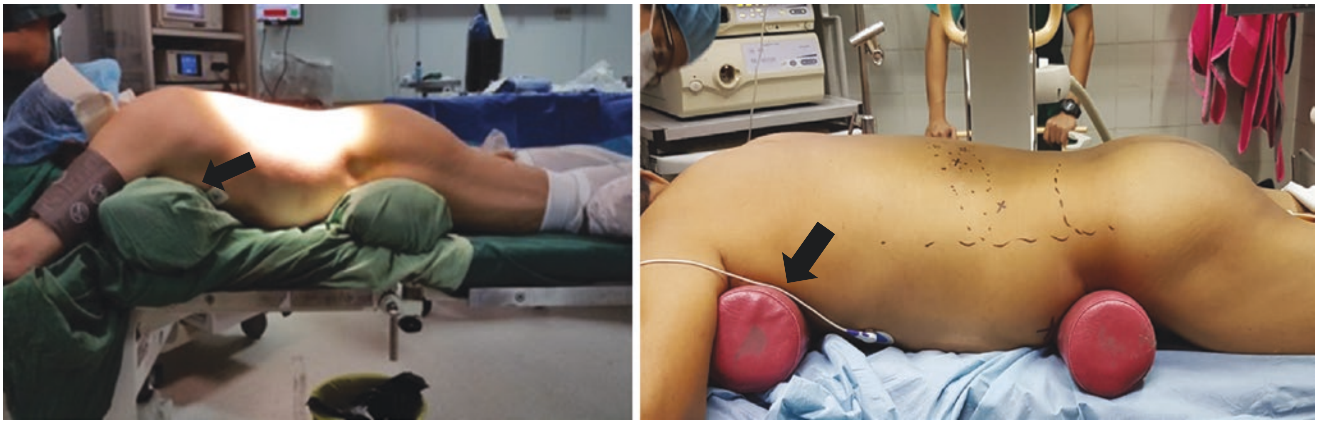


**Fig. 8.1** Patient is placed prone on the operating table for PCNL. The patient's neck is placed at a neutral position, pressure points are padded and a chest roll is placed (black arrow) to facilitate ventilation

positions by judicious use of fluoroscopy and ultrasound during punctures (Lojanapiwat 2013). In the prone position, the stone containing side is slightly elevated on a foam pad. This maneuver brings the posterior calices into a more vertical position facilitating subsequent percutaneous access. The patient's neck is carefully placed in a neutral position, and a chest roll is positioned accordingly to facilitate ventilation (Fig. 8.1). The ipsilateral arm may be secured at a 90° flexion while the contralateral upper extremity is tucked at the side to allow the C-arm to be positioned as close to the patient as possible (Miller et al. 2007).

## 8.2 Choosing the Access Site

A single access site that would result in complete stone clearance is desirable in most cases however collecting system anatomy, stone location, and stone burden dictate location and number of percutaneous access. Oftentimes during preoperative planning (which includes intraoperative retrograde pyelogram), the site which would maximize movement and utilization of rigid instruments is selected. The posterolateral calyces are preferred because they are oriented along the line of puncture and the access would generally pass through line of Brodel, which would minimize risk of parenchymal bleeding. Puncture lateral to the mid scapular line at full expiration avoids entry into the visceral and parietal pleurae. Colonic segments are usually found anterior or anterolateral to the lateral edge of the kidney. The posterior axillary line is considered as the lateral boundary of access puncture as risk of colon injury increases as you go beyond this line (Fig. 8.2) (McCallister et al. 2011; Lingeman 2011).

Access to majority of stones may be achieved via a single tract, upper pole approach which would also offer a straighter line of access to the ureter. The upper pole may be accessed via a supracostal, intercostal or subcostal approach (Fig. 8.3) (Lingeman 2011). Supracostal access facilitates guidewire passage and rigid nephroscopy due its alignment with the long axis of the kidney. McCallister et al. reported on key anatomic relationships pertinent to PCNL access, particularly the location of the intercostal nerves and vessels in reference to the 11th and 12th ribs. They suggest that the supracostal access be placed immediately lateral to the paraspinous muscles and in the lower half of the 11th IC space, but at least 5 mm above the 12th rib, to decrease the potential for pain, bleeding and need for transfusion while at the same time minimizing the risk of difficult insertion due to the sheath catching on the 12th rib (McCallister et al. 2011).

**Fig. 8.2** Landmarks and anticipated puncture sites (x marks) are identified on the patient in prone position

Upper pole access especially the supracostal approach may be associated with possible morbidities such as injury to the intercostal vessels and nerves, injury to adjacent organs such as the liver and spleen, and development of pneumo/hemothorax (McCallister et al. 2011; Tomaszewski et al. 2010). While these complications are rare, even for upper

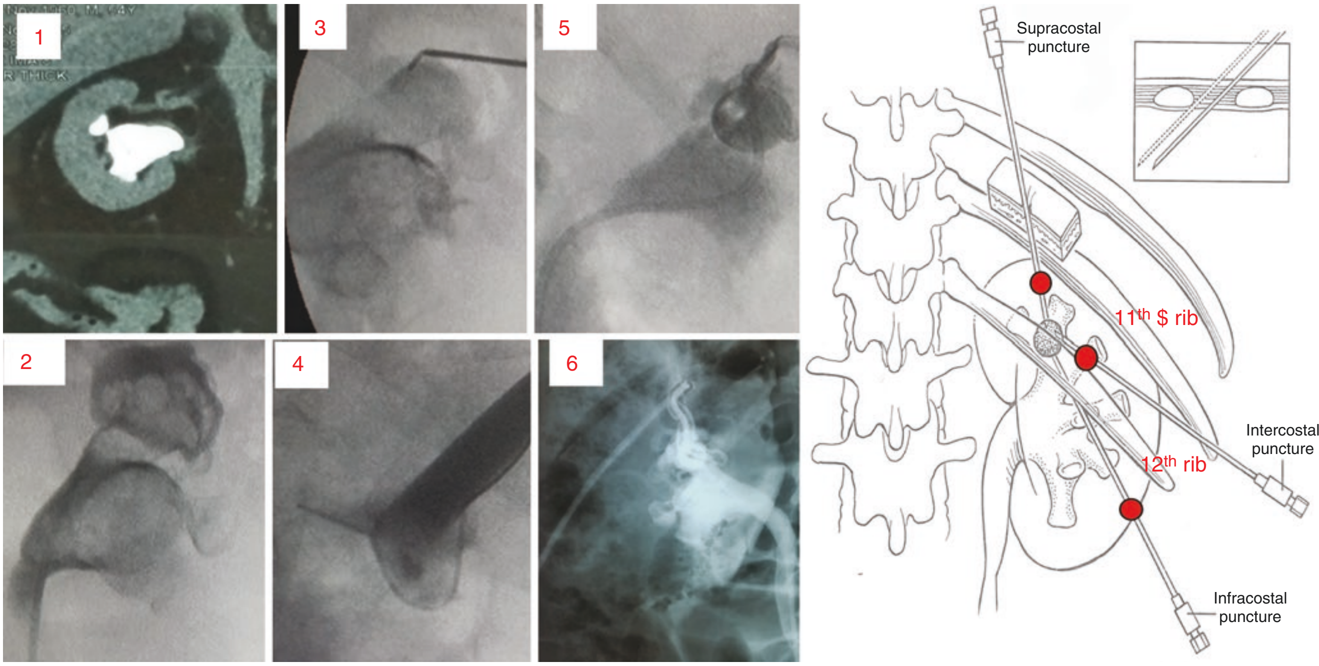
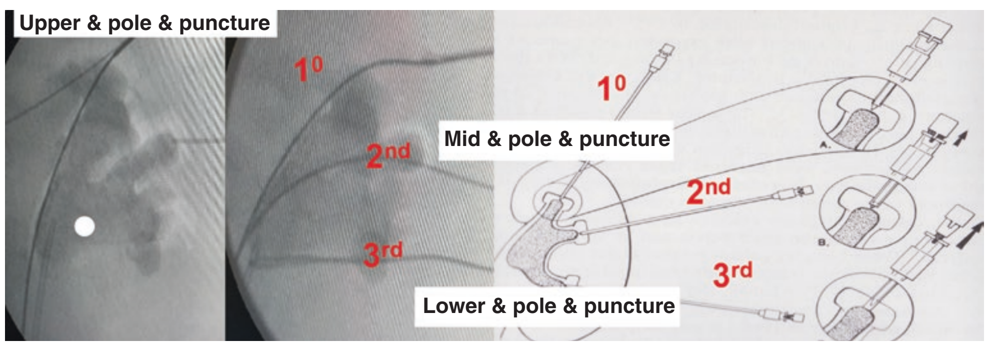



**Fig. 8.3** Basic steps in PCNL include: (1) ensure availability of imaging for pre- and perioperative evaluation, (2) retrograde pyelogam to opacificy collecting system, (3) imaging-guided percutaneous access of the desired calyx with a precutaneous needle, (4) placement and securing of guidewire down into the collecting system, preferably down the ureter, (5) placement of DJ stent and nephrostomy tube (if needed), (6) antegrade pyelogram if nephrostomy tube is placed. Diagram on the right shows different puncture approaches in reference to the 11th and 12th ribs

**Fig. 8.4** Actual fluoroscopic images (**a**) and diagram (**b**) of the multiple access or "multiperc" approach showing access to upper pole, mid pole and lower pole calyces




pole access, some urologists would prefer a lower pole access which affords less morbidities but may sacrifice optimal stone clearance. Nevertheless, regardless of the chosen access site, precise puncture is still necessary to avoid possible bleeding from peri-infundibular vessels.

Multiple access tracts can be used especially in cases with complex stones and multiple branch staghorn calculi. The "multiperc" or the multi tract approach offers clearance of stones without the added cost of advanced instrumentation. It entails creation of a main tract through which maximum stone burden can be removed. Secondary access punctures are made to address the remaining calyceal stones. The secondary access tracts are similarly secured with guidewires and subsequently dilated once majority of the stone burden has been removed and remaining stones could not be accessed through the main tract (Fig. 8.4). Monotherapy with PCNL utilizing multiple percutaneous tracts is highly effective in the treatment of staghorn and other large-volume renal calculi. This approach has been reported to achieve stone clearance rates of more than 80% (Miller et al. 2007; Ganpule et al. 2009). The multiperc procedure may obviate the use of flexible devices with its concurrent learning curve, and in certain instances, prohibitive costs. Along this line, multiperc may also preclude the use of second look or staged procedures and "sandwich therapy" to render the patient stone free. While proper head-to-head studies comparing multiperc with single-tract PCNL are lacking adequately powered prospective studies to provide valid conclusions, initial reports have so far shown the apparent inferiority of multiperc in terms of bleeding, transfusion rates and hospital stay (Miller et al. 2007; Ganpule et al. 2009).

## 8.3 Imaging

Knowledge of renal anatomy is essential for a safe and successful PCNL especially during access creation. Nonetheless intraoperative imaging adjuncts including plain xrays, ultrasound and CT scan are rather indispensable tools for a safe and effective procedure. Historically, access to the renal collecting system was done by or with the aid of interventional radiologists. While this practice is still seen in some centers, urologists have since been accustomed to the procedure and reports have shown improved outcomes in terms of stone clearance. There were also less access-related complications in urologist acquired percutaneous access (Miller et al. 2007; Tomaszewski et al. 2010). Biplanar fluoroscopy is presently more commonly used, however, other imaging tools may be used as adjuncts or as the main imaging guidance modality during percutaneous access.

Ultrasound may be used solely or as an adjunct in guiding percutaneous renal access with excellent clinical outcomes. Its main advantage over the conventional biplanar fluoroscopy include is reduction in overall radiation exposure (for everyone in the operating room) during the procedure, furthermore real-time imaging of the renal collecting system and parenchyma including vascular structures with the use of Doppler can be done and the cost is significantly less. Ultrasound can help delineate the anterior and posterior calices, outline adjacent viscera, and show the presence of radiolucent stones (Chu et al. 2016). It has been used for renal collecting system access with a success rate of 88–99% and a complication rate of 2–4% depending on the procedure done (Chu et al. 2016; Pedro and Rodriguez 2009). With the patient in the prone position, a curved array ultrasound transducer set to 3.5 MHz range is used to outline the renal parenchyma and collecting system. Saline may be injected through an externalized ureteral catheter to further help visualization of the target by dilating the renal calyces. The target calyx is chosen and a 18- or 24-gauge needle is used to puncture the skin in front of, or behind the probe, parallel to the probe's long axis. Keep the needle visualized at all times while as it is advanced towards the intended calyx. Puncture is further simplified in some ultrasound units with a needle-guidance system attached to the side of the probe. Once access is established tract dilation may also be done under ultrasound guidance depending on the level of comfort of the surgeon. A novel application of ultrasound for complex nephrolithiases is ultrasound-guided repositioning or "pushing" of residual stones into an accessible calyx using an access needle, although the extra puncture comes with possible attendant morbidities (Chu et al. 2016). Success in terms of stone free rate, hospital stay and transfusion rates was found to be similar compared with fluoroscopic access in several reports. The Clinical Research Office of the Endourological Society (CROES) reported higher transfusion rates for fluoroscopy-guided percutaneous access, however, this was attributed to larger access sheaths used compared to those in the ultrasound group (Lojanapiwat 2013).

CT scan-guided percutaneous access was first reported in 1977 and may be considered in patients with anatomical difficulties such as spinal dysraphisms, morbid obesity, presence of retrorenal viscera, abnormal renal anatomy (multiple cysts, angiomyolipoma), ectopic/transplanted kidney and those who failed standard fluoroscopy-guided access because of a non-dilated collecting systems with poor anatomic definition due to a ureteral stricture, or those at high risk for contrast-induced nephropathy (Ghani et al. 2009). The procedure is done in a conventional CT scan room, with intermittent localizing scans during different stages of access creation to decrease radiation exposure. Access can be done using local anesthesia and once access is established, a nephrostomy tube is placed and the patient is transferred to the operating room for subsequent PCNL. Success rates for percutaneous access are reportedly as high as 100% with only minor complications ranging from 1% to 14% (Ghani et al. 2009). The labor intensive conduct of CT scan guided access renders it a less attractive but still effective option for percutaneous access guidance.

Biplanar fluoroscopy is still the most common imaging method used, especially with improvements in image quality and more importantly, familiarity to operators (Urologists and technicians), and ease of use. Renal collecting system anatomy, stone burden and PCNL equipment are visualized in detail during fluoroscopy. It is an essential tool for PCNL and is used throughout the whole procedure, from initial ureteral catheter insertion to monitoring of stone clearance at the end of the procedure. One concern therefore, is the amount of radiation exposure, and a full array of protective equipment such as lead impregnated goggles, lead gloves, thyroid shields and lead aprons is highly recommended (Lojanapiwat 2013; Pedro and Rodriguez 2009). An antegrade percutaneous access into the collecting system is achieved via fluoroscopy-guided needle puncture using the "eye of the needle" and/or triangulation technique. A guidewire is threaded through the lumen of the percutaneous access needle and into the collecting system and (ideally) all the way down to the ipsilateral ureter to secure the access. Retrograde percutaneous access can also be done and may prove to be helpful in certain instances such as mobile or malrotated kidneys. This technique involves placement of a ureteral catheter retrogradely, followed by the passage of a sharp wire through the catheter and out of the desired calyx for access. Several techniques and equipment have already been described to achieve retrograde percutaneous access. Retrograde percutaneous access however, has not been found to offers any advantage over antegrade percutaneous access, which enables more accurate and controlled creation and eventual dilation of the nephrostomy tract (Lojanapiwat 2013).

## 8.4 Accessing the Collecting System

Fluoroscopic assessment of caliceal orientation, and selection of the optimal calyx for entry, is done with the use of a C-arm. During actual puncture, the image of only one plane is provided in real time. Familiarity with the location of renal and perirenal neurovascular structures and peripheral organs in relation to the renal collecting system will decrease the risk problematic hemorrhage and other complications (Miller et al. 2007). The preferred point of entry into the collecting system is along the axis of the calyx, and through the papilla. Aligning the access and eventual tract with the adjacent infundibulum would allow for the most efficient use of a rigid nephroscope and decrease the need for excessive torque on the instruments—which may lead to parenchymal trauma and bleeding. The posterior calyx is the preferred access target as negotiation of a guidewire into the ureter is easier compared to and anterior calyx access. Direct puncture through the infundibulum or into the renal pelvis increases the risk of vascular injury (Miller et al. 2007).

### 8.4.1 Percutaneous Access Technique: Eye of the Needle

As previously mentioned, percutaneous access using the eye of the needle technique requires fluoroscopy. The patient is initially placed in a dorsal lithotomy position and a ureteral catheter is retrogradely placed well within the ipsilateral collecting system. The externalized ureteral catheter is secured and the patient is then positioned for percutaneous access, and prepped and draped accordingly. The C-arm is initially oriented in a 30° angle towards the surgeon. Under fluoroscopy, an 18-gauge diamond tip access needle is carefully positioned in such a way that the targeted calyx, needle tip and needle hub are in line with the image intensifier. If properly executed, a "bull's-eye" image can be observed on the monitor (Fig. 8.5). With this approach, it is as if the surgeon is virtually looking down through the "eye of the needle" and into the targeted calyx, hence the technique is aptly named as such. Once proper needle direction is achieved, the C arm is rotated 15°–20° away from the surgeon. This view will allow and monitor needle alignment and depth as it is advanced towards the appropriate calyx while maintaining its orientation. Real-time fluoroscopic monitoring is needed as the needle is advanced to ensure that proper trajectory is maintained. As the needle enters the renal capsule or parenchyma, a certain give is noted and movement of the needle will be observed with the patient's breathing. Controlled pressure is also applied during advancement of the needle as inadvertent puncture beyond the anterior aspect of the collecting system risks injury to the segmental vessels (Miller et al. 2007). Once the desired calyx is entered, the urologist should be able to aspirate urine from the collecting system, confirming proper positioning. Alternatively, saline may be pushed from the ureteral catheter and outflow of urine is noted to overflow from the access needle. A 0.035 in. guidewire is then threaded through the access needle into the renal pelvis and as far down the length of the ureter as possible to secure the access tract. The access is then dilated using a Fr10 fascial dilator to allow for insertion a safety wire introducer. A second guidewire is inserted through the introducer and into the collecting system. This safety wire is secured to the drapes once the introducer is removed.

### 8.4.2 Percutaneous Access Technique: Triangulation

As with the "eye of the needle technique", the triangulation technique starts off by fluoroscopic identification of the targeted calyx. The collecting system is opacified and dilated by instilling contrast dye through the ureteral catheter. The C-arm is moved back and forth between two positions as the access needle is being adjusted to the target, that is—parallel and oblique to the line of puncture. When the C-arm is oriented parallel to the line of puncture (usually 15°–30° towards the patients head), the needle is moved in the medial-

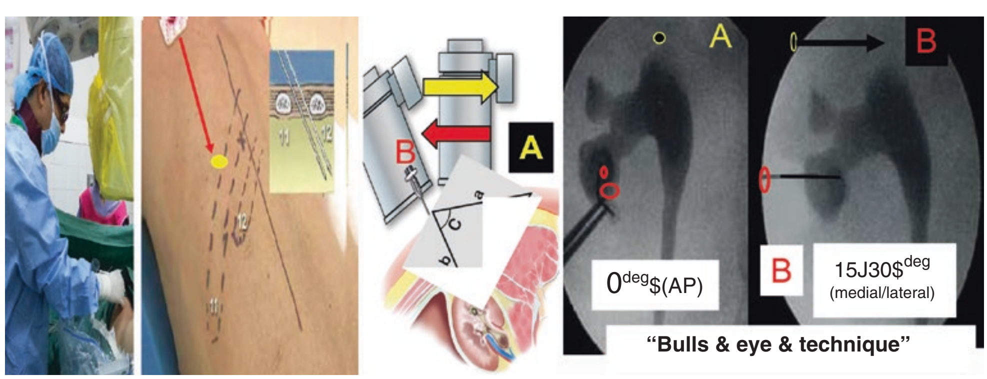



**Fig. 8.5** The "Bull's eye" or "Eye of the Needle" technique

lateral (or left-right) direction in the anterior-posterior plane to acquire a straight line of puncture towards the targeted calyx. The C-arm is then rotated to the oblique position (15°–30° towards the surgeon, while maintaining the previous angle parallel to the line of puncture) and adjustments are made cephalad-caudad (or up-down) relative to the sagittal plane, with care taken not to alter the previously established mediolateral orientation of the needle. Target acquisition and determination of the needle trajectory depends on the maintenance of needle orientation in one plane while simultaneously making adjustments in another plane. The surgeon may rest his/her forearm on the torso of the patient to help maintain the line of puncture when the needle is advanced. This technique demands more concentration, hand-eye coordination and grasp of spatial orientation from the surgeon, as well as proper coordination with the C-arm operator.

After obtaining the proper orientation of the line of puncture, ventilation is suspended in full expiration to elevate the diaphragm as the needle is advanced. The 18-gauge diamond tipped needle is carefully advanced toward the desired calyx in the oblique position taking note of the orientation and depth of puncture. As the needle is advanced further into the retroperitoneum, fine adjustments are made before entering the renal capsule. The needle is then carefully advanced towards the desired calyx. Needle trajectory should be maintained at all times as manipulating the needle after it has entered the renal parenchyma is may displace the kidney and alter the position of the targeted calyx. Successful entry into the collecting system is confirmed as described earlier. The access is secured by placing a guidewire through the needle into the collecting system (Fig. 8.6).

### 8.4.3 Tract Dilatation and Establishment of Access

Aspiration or egress of urine from the access needle verifies proper caliceal puncture. Initially, a 0.038-in. hydrophilic nitinol core glidewire is used to secure the access tract, threading it through the needle and into the collecting system. The nitinol core glidewire for obtaining initial access is preferred because it is quite maneuverable and resists kinking. Other guidewire types may also be used as long as the atraumatic tip is advanced first and care is taken that the collecting system is not punctured. Some operators elect to obtain access using a 21 gauge puncture needle that accepts a 0.018-in. wire for initial access, however, if this is used, transition dilators are necessary to accommodate a proper working wire of a larger diameter. We prefer to use an 18-gauge access needle, which can be torqued, within the kidney and easily accommodates a suitable working wire.

Careful attempts to guide and pass the glidewire through the access needle all the way down the length of the ureter, under fluoroscopic guidance, should be done whenever possible. If the wire does not pass easily into the ureter, allow for a significant length of wire to be coiled in the renal pelvis. Carefully remove the access needle and pass a 8 Fr fascial dilator over the glidewire into the calyx. Afterwhich, the dilator is removed and a 5 Fr Cobra tipped angiographic catheter may then be passed over the glidewire and used to direct the glidewire toward the UPJ, facilitating placement of the wire down the ureter. The tract is further dilated to 10 Fr to allow for the passage of a safety wire introducer (coaxial dilator or a dual lumen catheter). A second wire (safety wire), usually a 0.035-in. wire is introduced into the collecting sys-

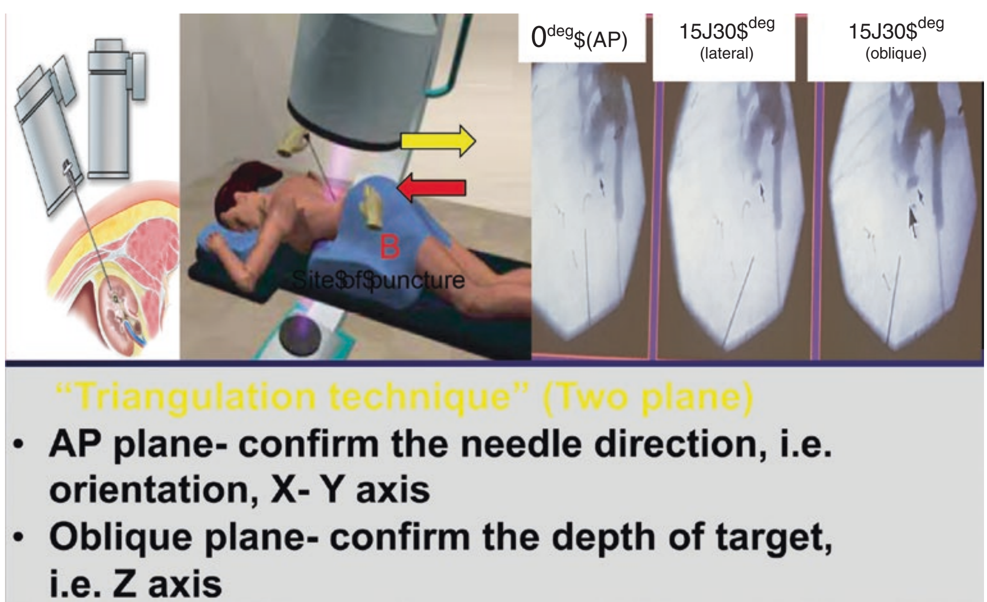



**Fig. 8.6** The Triangulation technique

tem and preferably into the ureter. Placement of safety wire is highly recommended prior to percutaneous dilation of the tract. The glidewire is also replaced with a stiffer polytetrafluoroethylene (PTFE)-coated working wire, such as an Amplatz super-stiff wire. The glidewire should not be used as a working wire because as it is prone to displacement.

Once a stable working wire is established, and a safety wire is secured, dilation of the tract may be done via Seldinger method over the working wire using metal telescoping dilators or semirigid Amplatz dilators. Alternatively, balloon dilators may be used. The radial force generated by balloon dilators which is used to spread the renal parenchyma is less traumatic than the shearing or cutting action of sequential Amplatz dilators or metal telescoping dilators and leads to decreased risk of parenchymal bleeding. Nevertheless, in the setting of extensive perirenal or retroperitoneal fibrosis (e.g. Post-op patients), sequential Amplatz or telescoping metal dilators may be effectively utilized. Alternatively, a 4.5 mm fascial incising needle (Cook Urological, Spencer, Indiana) can be placed over the working wire to facilitate balloon dilation.

After dilation of the tract to 30 Fr, an Amplatz working sheath maybe placed. When properly placed, the Amplatz sheath would tamponade parenchymal bleeding resulting from tract dilation. Nevertheless, care should be taken however, to use steady rotational force as the sheath is advanced as haphazard introduction of the sheath may also cause bleeding and trauma to the renal parenchyma or collecting system. A large diameter Amplatz sheath is always preferred because it creates an open, low pressure (below 16 cm $H_2O$) system during nephroscopy. This decreases the risk of excessive absorption of irrigant into the circulation. Use of isotonic irrigating fluid further decreases the risk of absorption. Easier insertion and removal of different equipment as well as the evacuation of larger stone fragments is also possible with larger diameter sheaths.

The Pathway™ balloon expandable percutaneous access sheath (Boston Scientific, Natick, Massachusetts) allows simultaneous balloon tract dilation and access sheath placement. This leads to decreased operative time and tissue trauma, however, more data are needed to support these conclusions.

### 8.4.4 Access Complications

An upper pole access particularly the supracostal approach increases the degree of difficulty of PCNL and also increases the risk of patient morbidity. Injury to the renal and perirenal vessels, adjacent organs, the pleura and viscera is always a concern. Nevertheless, this approach is still used especially in cases of staghorn stones, upper pole stones, impacted UPJ stones and upper calyx diverticula, as the normal renal anatomy favors access through this tract (Pedro and Rodriguez 2009).

Compared to a lower pole access, Pedro and Rodriguez report a higher rate of complication (mainly intrathoracic) with upper pole supracostal access (18.2% vs. 4.4%) (Pedro and Rodriguez 2009). Complication risks increase further when the desired upper pole calyx lies above the 11th rib. To avoid these complications, a thorough evaluation of preoperative imaging is done. Choosing the desired calyx for access is done when the patient is in full expiration. Needle puncture is likewise done in the same manner. In the event of acute bleeding, occluding the Amplatz sheath with the pad of the urologist's finger for about 5–10 min may be done to tamponade the bleeders. Alternatively, the corresponding Fr28 or Fr30 Amplatz dilator over the sheath may be used. If bleeding persists despite these maneuvers, a large bore foley catheter (Fr20–Fr22) is placed through the tract and kept under gentle traction and an endovascular embolization may be indicated (McCallister et al. 2011). Injuries to the pleura may be managed expectantly with no further interventions if patient is clinically stable. Closed-tube thoracostomy is recommended however for large volume pneumo- or hemothorax. In these cases, the chest-tube should be placed in a new tract above the nephrostomy site. The chest tube may be withdrawn usually within 24–48 h when the lungs are fully expanded. Routine postoperative chest x-rays are not recommended especially for non-complex procedures unless there is a high suspicion of significant injury (Pedro and Rodriguez 2009). Standard treatment for delayed post-PCNL bleeding is selective renal artery angiography with embolization (McCallister et al. 2011).

## References

Chu C, et al. Ultrasound guided access for percutaneous nephrolithotomy a description of three novel ultrasound-guided needle techniques. J Endourol. 2016;30(2):153–9.

Ganpule A, et al. Multiperc versus single perc with flexible instrumentation for staghorn calculi. J Endourol. 2009;23(10):1675–8.

Ghani K, et al. Computed tomography for percutaneous renal access. J Endourol. 2009;23(10):1633–9.

Lingeman JE. Lecture: PCNL access. Indianapolis, IN: Indiana University School of Medicine; 2011.

Lojanapiwat B. The ideal puncture approach for PCNL: fluoroscopy, ultrasound or endoscopy? Indian J Urol. 2013;29(3):208–13.

McCallister M, et al. Intercostal nerves and vessels are at risk for injury during supracostal percutaneous nephrostolithotomy. J Urol. 2011;185:329–34.

Miller NL, et al. Techniques for fluoroscopic percutaneous renal access. J Urol. 2007;178:15–23.

Pedro R, Rodriguez N. Upper-pole access for percutaneous nephrolithotomy. J Endourol. 2009;23(10):1645–7.

Tomaszewski J, et al. Renal access by urologist or radiologist during percutaneous nephrolithotomy. J Endourol. 2010;24(11):1733–7.

# 9 Retrograde Intra-Renal Surgery (RIRS)

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**Abstract**

Retrograde intrarenal surgery (RIRS) has markedly evolved and now plays an important role in the first-line treatment of renal calculi of less than 20 mm. RIRS is a delicate operation that uses a lot of miniaturized instruments including flexible ureterorenoscope (FURS). Understanding characteristics of instruments and surgical techniques is important for safe and effective operation. A variety of FURS is on the market and has various functional distinctions. Image transfer technology, number of working channel, and durability are important issues for proper selection of FURS. There is a learning curve to be familiarized with FURS. Understanding basic principles of FURS manipulation will shorten the learning time and reduce the maintenance cost of FURS. Currently, three stone-breaking methods are widely used. Fragmentation with basketing is optimal in the treatment of small hard stones. Dusting makes large stones to tiny pieces by low pulse power laser. It eliminates the necessity of stone basket use. Stone debris that is not suitable for basketing or dusting can be treated by popcorn method that utilizes whirlpool phenomenon. Various combination of stone breaking/removal strategy may be applied to achieve good surgical outcomes.

**Keywords**

Retrograde intrarenal surgery · Urinary stone · Flexible ureterorenoscopy · Renal stone · Ureteroscopy · Flexible Laser

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## 9.1 Introduction

As a minimally invasive treatment modality of renal calculi, retrograde intrarenal surgery (RIRS) has markedly evolved. With the advancement of technology and accumulation of clinical experience, the indications are constantly expanding as the morbidity constantly became low and the surgical outcomes became high. RIRS is now accepted as the first-line treatment of renal calculi of less than 20 mm regardless of stone location, composition, and renal anatomy (Turk et al. 2016). RIRS is now widely used not only for small kidney stones that are difficult to be resolved with ESWL but also for large and complicated stones that were managed by percutaneous nephrolithotomy in the past.

RIRS is a very delicate operation that uses a lot of miniaturized instruments including flexible ureterorenoscope (FURS). Understanding characteristics of various instruments needed for RIRS is important for safe and effective operation. There are clinical issues that need to be taken into consideration for successful RIRS. This chapter outlines the necessary considerations with several tips for the safe and effective implementation of RIRS.

## 9.2 Preoperative Considerations

### 9.2.1 Flexible Ureterorenoscope

The FURS is a key device in RIRS. Since its first introduction by Marshall (1964), the FURS has undergone dramatic improvements in performance over the last two decades. The latest FURSs enable bidirectional active deflection of more than 270° and allow sufficient deflection even with various working instruments. In addition, with the advent of the digital video endoscope, the imaging quality has been markedly improved. The outer diameter of RIRS has been drastically decreased below 9 Fr. without reducing the size of the working channel. Currently, FURSs that have two working channels are available. The durability of FURS has also been


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**Table 9.1** Specifications of latest flexible ureterorenoscopes

| Model | Company | Angle of view (degrees) | Field of view (degrees) | Length (mm) | Shaft diameter (F) | Tip diameter (F) | Channel size (F) | Channel number | Active deflection up (degrees) | Active deflection down (degrees) |
|---|---|---|---|---|---|---|---|---|---|---|
| Fiber optic type | | | | | | | | | | |
| URF-P6 | Olympus | 0 | 90 | 670 | 7.95 | 4.9 | 3.6 | 1 | 275 | 275 |
| Flex-X$^2$ | Karl Storz | 0 | 88 | 670 | 8.4 | 7.5 | 3.6 | 1 | 270 | 270 |
| Viper | Richard Wolf | 0 | 86 | 680 | 8.8 | 6 | 3.6 | 1 | 270 | 270 |
| Cobra | Richard Wolf | 0 | 85 | 680 | 9.9 | 6 | 3.3 | 2 | 270 | 270 |
| Digital video type | | | | | | | | | | |
| URF V2 | Olympus | 0 | 80 | 670 | 8.5 | 8.4 | 3.6 | 1 | 275 | 275 |
| Flex-X$^c$ | Karl Storz | 0 | 90 | 700 | 8.5 | 8.5 | 3.6 | 1 | 270 | 270 |
| Cobra vision | Richard Wolf | 0 | 90 | 680 | 9.9 | 5.2 | 3.6/2.4 | 2 | 270 | 270 |

significantly improved, and the latest FURSs endure more than 50 cases of RIRS. Recently a disposable FURS was introduced that is expected to reduce the economic and labor burden on maintenance.

#### 9.2.1.1 Determination of FURS

Currently, a variety of FURS is on the market and has various functional distinctions (Table 9.1). In performing RIRS, selection of FURS is one of the most important steps for a successful surgery. There are some issues that are needed for the selection of the FURS.

##### Fiberoptic Type vs. Digital Video Type

Traditionally, the FURS was developed in a fiberoptic manner. The images from all fibers are merged to form a single reconstructed image and transferred to independent camera system through the eyepiece. FURS has been used for decades as an only option. As digital technology evolves, digital sensors such as CCD (charge-coupled device) and CMOS (complementary metal oxide semiconductor) have been applied to FURSs. These digital sensor FURS provides better resolution, contrast, and color discrimination than fiberoptic ureterorenoscope (Borin et al. 2006; Quayle et al. 2005). The bigger image size and reduced weight of FURS by using fewer cables are additional advantages. Traxer and Thomas (2013) compared the clinical outcomes of fiberoptic and digital FURS. They showed the operation time was significantly lower in digital video group although did not demonstrate better stone clearance rate. With the advantage of the superior image quality, the digital video FURS is expected to supersede the fiberoptic FURS in the near future. Nevertheless, a fiberoptic FURS still has several merits. It is less expensive than digital video FURS. The maintenance cost is an important issue when choosing an endoscope because FURS is not only expensive, but it also has a limited lifespan. Compatibility is also a useful advantage of fiberoptic fURS because fURSs from any company can be used by attaching independent camera without changing whole image control system.

The fiberoptic FURS is also useful for understanding orientation especially for beginners of RIRS. Unlike the bladder or ureter, the pyelocaliceal system has a complex three-dimensional structure. So, the learning curve is needed to be familiar with the position and direction of the endoscope during operation. During RIRS with digital video FURS, when the endoscope is rotated to approach a target location, the image sensors on the tip rotates together. So, the orientation recognized by the monitor screen does not coincide with the actual movement of FURS. In the case of fiberoptic FURS, since an independent endoscope is combined with the camera through an eyepiece, the operation can be performed without rotating the camera body and the image sensors on it. In this manner, the orientation of the monitor screen can be maintained. It makes easier to understand the movement of the tip of the endoscope during operation.

The Larger diameter of digital video FURS was a demerit compared to fiberoptic FURS. However, latest digital video fURSs are miniaturized further and have similar outer diameters with fiberoptic FURSs (Table 9.1).

##### Single Working Channel vs. Dual Working Channel

During RIRS, clear visibility is essential for safe and efficient operation. A clean field of view during operation can be achieved by maintaining constant irrigation flow. Continuous irrigation removes bleeding, stone dust, and air bubbles that are developed during operation. Traditionally, a FURS has a single working channel with a small diameter (3.6 Fr.). When this working channel is shared with working instruments such as laser fiber, basket, and forceps, the irrigation flow rate is significantly decreased (Fig. 9.1). Paffen et al. (2008) evaluated the change of irrigation flow rate when working instruments were placed. They demonstrated that the place-

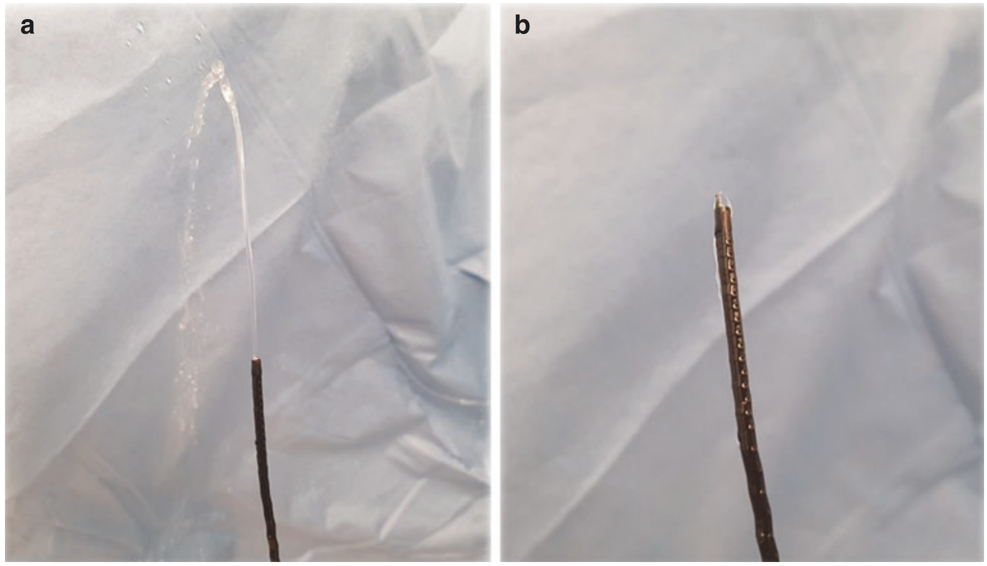


**Fig. 9.1** Flow of saline with the pressure of 200 $cmH_2O$ in single-channel ureterorenoscope (Flex-X$^c$, Storz) (**a**) with the empty working channel, (**b**) with 1.9 Fr. stone basket

ment of a 200 μm laser fiber resulted in approximately a 50% reduction of the flow rates on single-channel FURS.

Recently, dual channel FURS became commercially available. Cobra (Richard Wolf, Germany) has two working channels with the same diameter (3.3 Fr.). This allows one working channel to be used by a working instrument while another working channel is used for irrigation. There are a variety of applications to use this equipment: A laser fiber and basket can be used simultaneously. Both working channels can be used for irrigation if higher irrigation flow is necessary. That enables to double the flow rate theoretically if adequate drainage is possible. Simultaneous suction for active drainage during infusion is also available. Simultaneous infusion and drainage by two channels can make efficient constant flow even without ureteral access sheath (UAS). The dual-channel FURS has some disadvantages. Cobra has a large outer diameter (9.9 Fr.) that is significantly bigger than latest fiberoptic FURSs. It necessitates the use of UAS that is 12/14 Fr. or bigger. The smaller size of each channel (3.3 Fr.) is a potential disadvantage compared to the regular single-channel endoscope. Recently, dual-channel digital video FURS with a same outer diameter became available on the market.

Depending on operator's stone breaking strategy and pelvocalyceal anatomy, single-channel or dual-channel FURS can be selected. If a surgeon plans to perform stone dusting (see Sect. 9.4.2) without basketing, single-channel FURS is a good option. However, if a surgeon intends to use a stone basket or forceps, dual-channel FURS will make the operation easier. Haberman et al. (2011) compared the irrigation flow rates depending on the number of working channels. They demonstrated that in dual-channel FURS, the placement of working instruments did not affect the irrigation flow and the flow rates were up to 37 times (×1.5–37) higher than single-channel FURS depending on instrumentation. They also showed that dual-channel endoscope provided similar deflection characteristics to the single-channel ureterorenoscope.

#### Reusable Type vs. Disposable Type

Although RIRS has been proposed as a first-line treatment for renal calculi, the cost issue is a major obstacle to the implementation of RIRS. The latest FURSs have improved dramatically in durability and greatly reduced the cost burden. However, the high initial cost for scope acquisition and necessity of enough backup equipment for unexpected failures of FURS is a significant economic burden. Several disposable or single-use instruments have been developed to replace conventional FURS (Emiliani and Traxer 2017). However, most of those devices were not evaluated enough for clinical uses. Recently, LithoVue™ (Boston Scientific, USA), a single-use, disposable FURS was introduced to markets. It provides 270° of deflection and offers digital video imaging. Usawachintachit et al. (2017) published a prospective case-control study data comparing 115 cases of Lithovue with 65 cases of reusable FURSs. They showed that scope failure rate and hospital stay were similar in both groups. In stone patients, the stone-free rate was also similar, but operation time and complication rate were significantly lower in Lithovue group (70.3 min vs. 57.3 min, 18.0% vs. 5.4%, respectively).

A disposable FURS is expected to play an important role as a backup instrument when reusable ureterorenoscope is not available. It will also be useful in patients with high-risk infection. Patients with a technically demanding case that may markedly decrease a lifespan of FURS will be a good indication. As clinical experience accumulates with disposable FURSs, the utilization is expected to increase gradually.

#### 9.2.1.2 Manipulation of FURS

FURS can approach the desired location by several maneuvers including rotation, advance/retreat, and deflection. Generally, rotating the body of FURS and deflecting are performed by operator's dominant hand that grasps the proximal body of FURS. Toward and backward movement of FURS is performed by operator's non-dominant hand that holds the flexible distal body of FURS. Because the angle of view of flexible ureterorenoscopes is zero degree (Table 9.1), a target point should be kept in the center of the imaging field to approach that location.

To approach the desired location by FURS, understanding the deflecting plane on the monitor screen is important. In fiberoptic FURS, there is a small triangular mark around the circle of the visual field (Fig. 9.2). That guides the direction of upward and downward deflection. There is a virtual line passing the mark and a center of the circle of the visual field. When deflecting lever is manipulated, the tip of FURS moves along this virtual line. When a target point is located on the virtual line, the target point can be moved to the center of the imaging field simply by deflection. That means the tip of FURS was moved to the target direction. When a target location is not on the virtual line, the target point can be moved toward the virtual line by rotating the body of FURS. Once the target location is located on a virtual line, the target point is also moved to the center of the imaging field by deflection (Fig. 9.2). In digital video FURS, there is no triangular mark. But, there is also a virtual deflecting line. A line that passes 6 and 12 o'clock is the virtual line. A target location can be approached in the same manner as fiberoptic FURS.

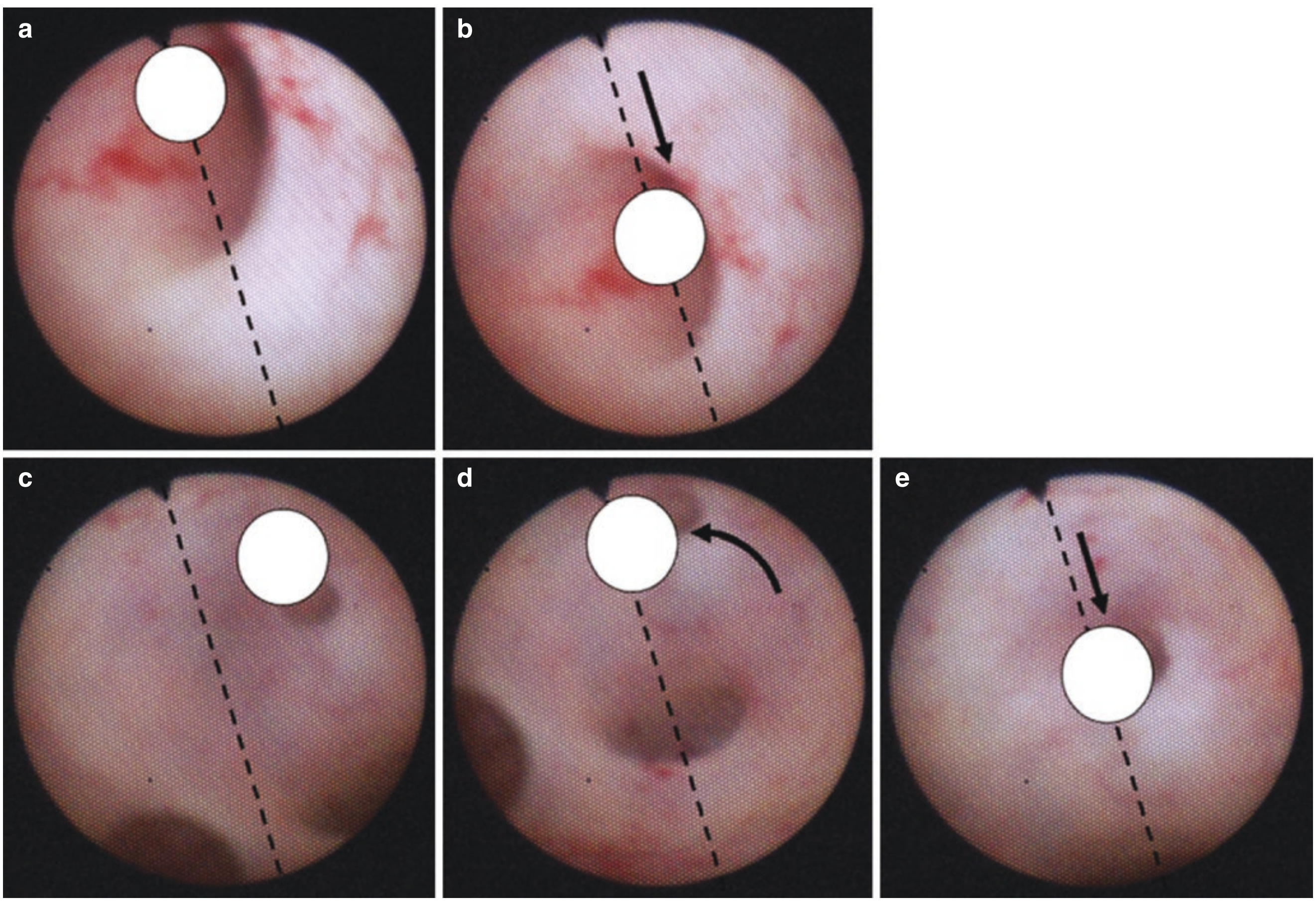


**Fig. 9.2** Aligning flexible ureterorenoscope in the desired direction when target point is on deflecting plane (**a** and **b**) and when target point is outside deflection plane (**c**–**e**). (**a**) Target point (*white circle*) is on virtual deflecting plane (*black dotted line*), (**b**) target point moves to center of image by deflecting maneuver, (**c**) target point is outside virtual plane, (**d**) target point moves toward virtual plane by rotating maneuver, (**e**) target point moves to center by deflecting maneuver

## 9.3 Access to Kidney

### 9.3.1 Access into Ureter

Before ureteral access, systemic evaluation of bladder by cystoscope to rule out coincidental bladder pathology is necessary. Retrograde pyelography provides valuable information about the ureter. The luminal width and existence of narrow ureteral segment are assessed. If there is a suspicious ureteral stricture, the location and length are remembered and recorded for proper access.

As an initial guidewire, the nitinol-cored hydrophilic wire is beneficial. It can navigate to the renal pelvis quickly with minimal trauma to the ureteral wall. If the guide wire does not advance because of ureter kink, narrowing, and ureteral pathology, a curved tip hydrophilic guide wire, and curved tip open-end catheter are used to find the way to the renal pelvis. If the operation is not expected to be simple, safety guide wire should be kept in place because it would be useful for placing a ureteral stent or regaining ureteral access when there is much bleeding or significant ureteral injury.

Initial access to the ureter can be done by either semi-rigid ureteroscope or FURS. But, semi-rigid ureteroscope is preferred because of several reasons. The beveled and beaked tip of semi-rigid ureteroscope enables endoscope to enter the ureter more easily. The assessment of ureter to rule out incidental ureteral pathology can be done more quickly. If a stone is accessed by semi-rigid ureteroscope, the stone can be managed more efficiently because semi-rigid ureteroscope provides larger image and a bigger and straight working channel.

### 9.3.2 Ureteral Access Sheath

#### 9.3.2.1 Advantage vs. Concern

UAS enables FURS to access the ureter and renal pelvis directly. It can save procedural time by facilitating re-entry of FURS by passing urethra, bladder and ureterovesical junction. Many advantages of UAS have been suggested. It provides increased irrigation flow during RIRS. Because the visual field of FURS is much smaller than other endoscopes, constant irrigation to flush out bleeding, stone dust, and evaporation bubbles induced by the laser are very important in RIRS. For constant flow to be maintained, effective drainage channels are needed as well as infusion channels. If there is not enough space around FURS at any level of the ureter, irrigation will be significantly decreased without UAS. UAS also reduces the intrarenal pressure that is potentially hazardous to kidney when it is high. Auge et al. (2004) compared intrarenal pressure through percutaneous nephrostomy tube during routine flexible ureteroscopy with and without UAS. They showed that the pressure in the renal pelvis was significantly lower in cases with UAS than cases without UAS. The intrarenal pressure was from 60 to 94.4 mmHg without UAS, and it was from 15 to 40.6 mmHg with a UAS depending on the location of the ureteroscope. UAS also has a protective role to the FURS by reducing resistance with the ureteral wall. UAS also prevents the ureteral wall injury induced by the sharp irregular surface of stone fragments.

However, there are concerns about the routine use of UAS. Traxer and Thomas (2013) evaluated the acute ureteral injury induced by UAS immediately after RIRS. The showed that ureteral injury was found in 46.5% of patients. The also demonstrated that severe injury involving the smooth muscle layers was observed in 13.3% of patients and absence of ureteral stent was the most significant predictor of severe ureteral injury. There are also concerns about the risk of ureteral stricture by UAS-induced injury. However, there is no proven evidence about this potential risk.

#### 9.3.2.2 Technical Considerations

The insertion of UAS should proceed over a strong guide wire with a steel core such as Amplatz super-stiff wire. If a hydrophilic soft guide wire is used, the risk of UAS-induced ureteral perforation will be increased because UAS is relatively rigid and it has tapered narrow tip for ureteral dilation. Adequate placement of the working guide wire is also important. The rigid segment of guide wire should be completely placed in the renal pelvis or preferably in the upper calyx. If a proximal rigid segment of the guide wire is not properly located in the kidney, ureter can be injured by the tip of UAS because the guide wire may not support the UAS adequately into the safe direction.

Theoretically, benefits of UAS would be greater when the diameter is bigger, and the tip location is higher to the renal pelvis. If the UAS is placed lower in the ureter during RIRS, uncovered segment by UAS can increase resistance to drainage flow resulting in a decrease of irrigation flow and an increase in intrarenal pressure. If there is a narrow ureteral segment, it is recommended to located UAS higher than the narrow segment to facilitate irrigation flow (Fig. 9.3). Rehman et al. (2003) evaluated the effect of the size of UAS on urodynamic features including intrarenal pressure, flow rate, and the amount of fluid absorbed by the kidney. As the size of UAS increased from 10/12 Fr. to 14/16 Fr., intrarenal pressures gradually decreased. As the size of UAS increased, irrigation flow tended to increase. But, the flow rate with 12/14 Fr. sheath was nearly equivalent with 14/16Fr. sheath. The intravasation volume was gradually decreased as the size of UAS increased. In summary, 12/14 Fr. or larger size of UAS could provide maximal flow while maintaining a low intrarenal pressure. In the same study, the effects of the location of the UAS were also evaluated. When UASs were located in the renal pelvis, intrarenal pressures and extravasation volumes were much lower than in lower and mid ureter. Irrigation flow rates were also higher with UASs in the renal pelvis.

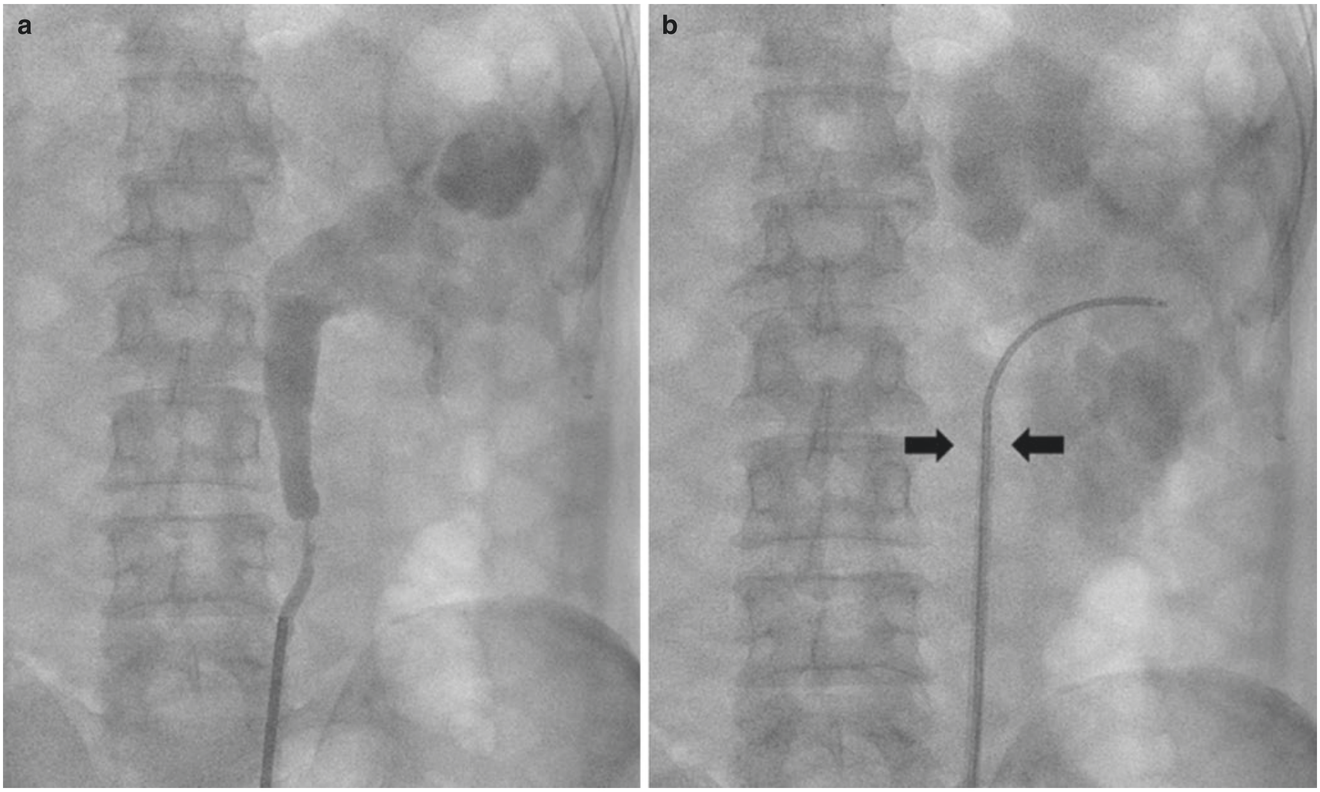


**Fig. 9.3** Placement of ureteral access sheath. (**a**) A narrow segment in upper ureter, (**b**) ureteral access sheath (*black arrow*) placed higher than the narrow segment

Placement of UAS may be difficult because of ureteral stricture or narrow. When UAS does not proceed in lower ureter, UAS can be reinserted after balloon dilation. When UAS does not proceed in upper ureter, it is generally recommended to place a ureteral stent and perform staged operation 1 or 2 weeks later. There is a concern that upper ureter is more vulnerable to ureteral stricture after balloon dilation than lower ureter. However, no study showed the balloon dilation before UAS placement in upper ureter increases the risk of ureteral stricture.

During operation, UAS can migrate downward. When it occurs, UAS should not be advanced upward alone. It can cause significant ureteral injury or bleeding. The Proper guide wire and obturator of UAS should be placed again before pushing up the UAS.

## 9.4 Stone Breaking/Retrieval

### 9.4.1 Assessment of Entire Pyelocaliceal System

Once ureterorenoscope is engaged into intrarenal space, the first step is a careful observation of the renal pyelocaliceal system. Incidental pathology in the kidney can be found. Understanding pyelocaliceal anatomy prior to stone breaking or retrieval is an essential part of RIRS. And incidental pathology in the kidney may be found during this assessment. Stone dust, bleeding, and mucosal swelling can obscure visual field during breaking stone. So, it is much easier to examine renal anatomy under clear visual field before the active operation. During the navigation in the pyelocaliceal system, the operator obtains much valuable information including number, size, and shape of each calyx. Information about the anatomical feature of each infundibulum and accessibility of each calyx were also obtained. The size, number, and location of renal calculi are evaluated simultaneously. A surface feature of renal calculi is also examined to predict the hardness of the stone.

Sometimes—frequently after placement of UAS to a ureteropelvic junction or after ureteral ballooning—there may be some retrograde bleeding that makes it hard to assess the kidney. In this case, if constant irrigation is kept, visual field becomes better soon. Moderately increased intrarenal pressure prohibits additional bleeding, and constant irrigation washes out bloody urine in the kidney. This assessment enables operators to have an individualized plan for stone breakage and retrieval. Understanding pyelocaliceal system will guide an operator through the entire procedure.

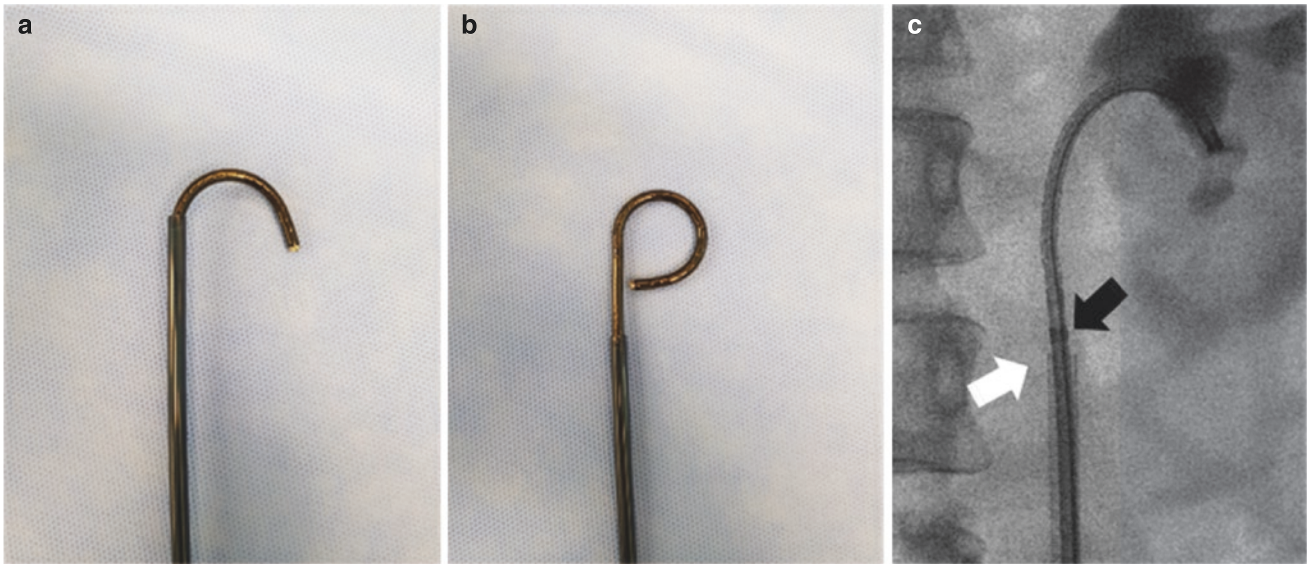


**Fig. 9.4** Effect of ureteral access sheath on a deflection of flexible ureterorenoscope. (**a**) Ureteral access sheath placed too proximally with limiting deflection, (**b**) placed properly without affecting deflection. (**c**) Fluoroscopic image during operation. Radiopaque marker of flexible ureterorenoscope (*black arrow*) indicates the end of deflecting segment. Tip of ureteral access sheath is visible (*white arrow*)

### 9.4.2 Optimization for Stone Breaking

The location of UAS needs to be adjusted before active breakage of renal calculi. As mentioned above (see Sect. 9.3.2), the higher the UAS is placed, the better it is to maintain the constant flow. However, when UAS is placed too high, it restricts the movement of FURS because the deflection of FURS is limited when the active deflection segment is inside the UAS (Fig. 9.4). If an operator does not recognize this situation and continue to attempt deflection, it will shorten the lifespan of the FURS.

The insertion of a laser fiber into FURS also needs caution. An operator always is sure that the body of FURS is straightened during placement of a laser fiber. The tip of reusable laser fiber has an irregular surface, and this can cause microdamage on the wall of the working channel. If the damage is accumulated, this will cause malfunction of FURS. The use of single-use, disposable laser fibers is helpful to lower the risk of laser-induced working channel damage (Chapman et al. 2014).

Latest FURSs can access lower pole calyx even with laser fibers in the working channel. So, lower pole calculi can be managed by in situ breakage. However, there are several disadvantages. The manipulation of laser and basket is more difficult than in upper or mid pole calyx because of changed orientation and less deflection ability in the calyx. The stiffness of working instruments affects the lifespan of FURS with acute deflection. So, the transposition of calculi to preferred calyx—generally, upper pole calyx—is recommended before active stone breaking (Fig. 9.5). For this step, the selection of basket size is important. Generally, for stone removal, miniaturized baskets are preferred because those provide more space for irrigation in the working channel. However, a miniaturized basket tends to have a smaller size of the cage. If the cage is not big enough to catch the calculi, transposition can be technically demanding. The Larger basket is also better for freeing calculi in a preferred location. So, the transposition of a lower pole stone is planned, the basket should be selected according to the size of the stone.

### 9.4.3 Breaking Strategy

#### 9.4.3.1 Fragmentation, Dusting, and Popcorn Effects

During the last two decades, stone breaking techniques using a laser have evolved greatly. And currently, three stone-breaking methods are widely used. Traditionally, the urinary stone was retrieved with a basket after broken into smaller extractable pieces. This *fragmentation method* is a great way to eliminate all stone burden in small stones. If a stone is split into pieces about 3 mm in size, those fragments can be easily removed by a basket (Fig. 9.6). To do this procedure, a laser with moderate pulse power (0.6–1.2 J) with moderate frequency (5–30 Hz) is useful. However, in large stones, this fragmentation method has critical limitations. To split a large stone to adequate sizes of pieces, it needs much longer fragmentation time. And it also needs much more basket use to remove the numerous pieces. If high pulse power energy is used, fragmentation time can be reduced. But, it makes a variety size of stone pieces and makes it more difficult to remove stone pieces by using a basket. Theoretically, when

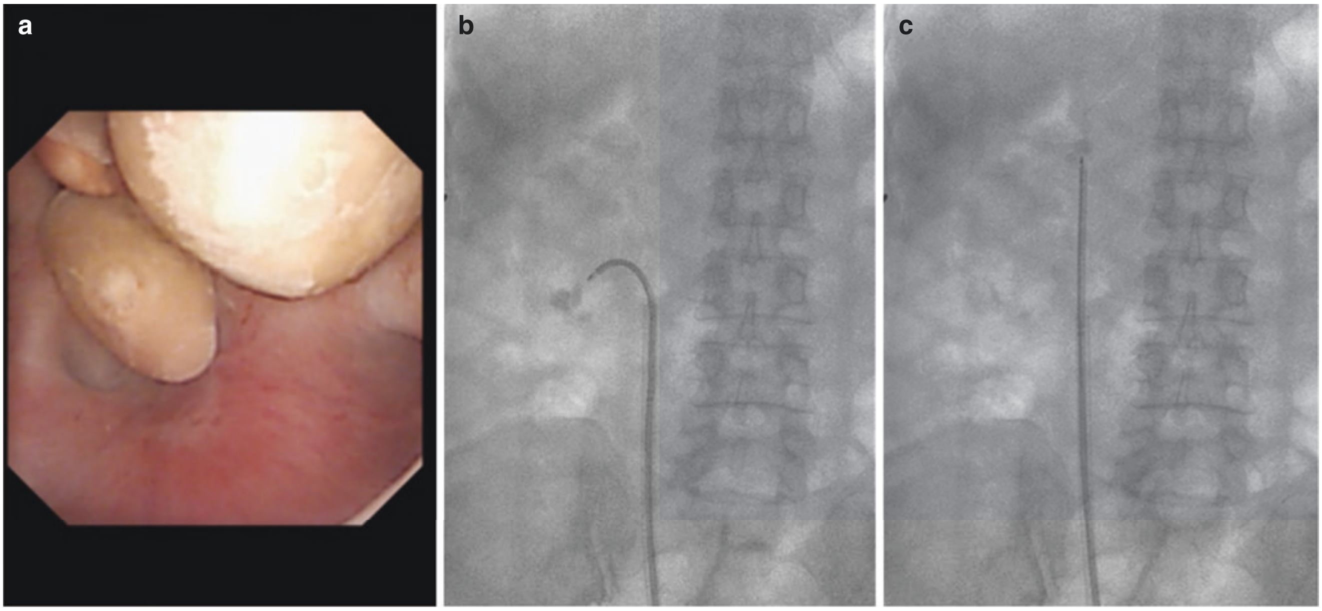


**Fig. 9.5** Transposition of renal stone before breaking. (**a**, **b**) Stones located in lower pole calyx, (**c**) stones moved to upper pole calyx by using stone basket

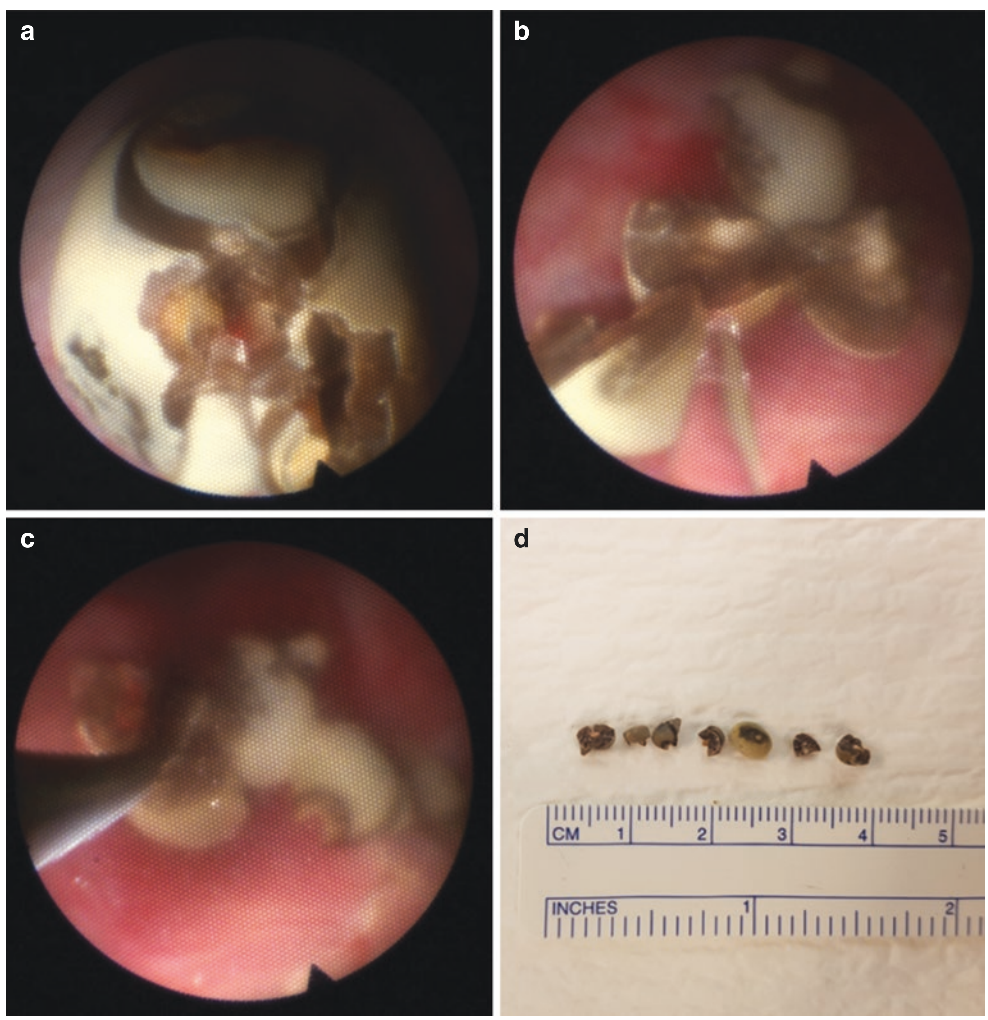


**Fig. 9.6** Fragmentation method of stone breaking. (**a**) Breaking stone with a laser of 0.6 J × 20 Hz, (**b**) Fragmented stone to several pieces without tiny debris, (**c**) removing stone by using a stone basket, (**d**) removed fragments through 14/16 Fr. ureteral access sheath

the stone diameter becomes twice, the number of pieces increase eight times. That means operation time increases exponentially with stone size with fragmentation method. To enhance the time-efficacy during RIRS in large stones, *dusting method* that grinds the stone surface to tiny pieces or powders is popularly used. This method eliminates the necessity of basket use and may reduce the operation time. For this procedure, a laser with lower pulse power (0.2–0.8 J) is necessary to minimize shockwave effects because the shockwave breaks distant parts of calculi and results in unexpected large fragments (Rassweiler et al. 2016). A laser should be initiated with lowest pulse power and increased gradually if necessary. For better breaking efficiency, dusting is performed in high frequency (20–50 Hz) setting. The quality of dusting is affected by stone composition and size. Dusting is easier with softer and smaller stones. Uric acid stones typically tend to be broken to fine dust regardless of laser power (Han and Jeon 2016).

During fragmentation or dusting, many equivocal sizes of stone debris that are neither suitable for basketing nor appropriate for spontaneous passage may be formed. These equivocal sized stones can be managed by *popcorn method*. In the popcorn method, a laser fiber does not contact stone surface. A laser fiber is located in the middle of a calyx or an infundibulum, and it breaks floating stone fragments that are contacted incidentally by the whirlpool phenomenon. When stone fragments are in a medium sized calyx with narrow infundibulum, stones are broken more efficiently by popcorn method. A laser with high pulse power (1.0–2.0 J) and high frequency (40–60 Hz) is used and kept until stones become sandy pieces.

## References


Auge BK, Pietrow PK, Lallas CD, Raj GV, Santa-Cruz RW, Preminger GM. Ureteral access sheath provides protection against elevated renal pressures during routine flexible ureteroscopic stone manipulation. J Endourol. 2004;18(1):33–6. https://doi.org/10.1089/089277904322836631.

Borin JF, Abdelshehid CS, Clayman RV. Comparison of resolution, contrast, and color differentiation among fiberoptic and digital flexible cystoscopes. J Endourol. 2006;20(1):54–8. https://doi.org/10.1089/end.2006.20.54.

Chapman RA, Somani BK, Robertson A, Healy S, Kata SG. Decreasing cost of flexible ureterorenoscopy: single-use laser fiber cost analysis. Urology. 2014;83(5):1003–5. https://doi.org/10.1016/j.urology.2013.12.019.

Emiliani E, Traxer O. Single use and disposable flexible ureteroscopes. Curr Opin Urol. 2017;27(2):176–81. https://doi.org/10.1097/mou.0000000000000371.

Haberman K, Ortiz-Alvarado O, Chotikawanich E, Monga M. A dual-channel flexible ureteroscope: evaluation of deflection, flow, illumination, and optics. J Endourol. 2011;25(9):1411–4. https://doi.org/10.1089/end.2010.0642.

Han DH, Jeon SH. Stone-breaking and retrieval strategy during retrograde intrarenal surgery. Investig Clin Urol. 2016;57(4):229–30. https://doi.org/10.4111/icu.2016.57.4.229.

Marshall VF. Fiber optics in urology. J Urol. 1964;91:110–4.

Paffen ML, Keizer JG, de Winter GV, Arends AJ, Hendrikx AJ. A comparison of the physical properties of four new generation flexible ureteroscopes: (de)flection, flow properties, torsion stiffness, and optical characteristics. J Endourol. 2008;22(10):2227–34. https://doi.org/10.1089/end.2008.0371.

Quayle SS, Ames CD, Lieber D, Yan Y, Landman J. Comparison of optical resolution with digital and standard fiberoptic cystoscopes in an in vitro model. Urology. 2005;66(3):489–93. https://doi.org/10.1016/j.urology.2005.04.009.

Rassweiler J, Rassweiler MC, Klein J. New technology in ureteroscopy and percutaneous nephrolithotomy. Curr Opin Urol. 2016;26(1):95–106. https://doi.org/10.1097/MOU.0000000000000240.

Rehman J, Monga M, Landman J, Lee DI, Felfela T, Conradie MC, Srinivas R, Sundaram CP, Clayman RV. Characterization of intrapelvic pressure during ureteropyeloscopy with ureteral access sheaths. Urology. 2003;61(4):713–8.

Traxer O, Thomas A. Prospective evaluation and classification of ureteral wall injuries resulting from insertion of a ureteral access sheath during retrograde intrarenal surgery. J Urol. 2013;189(2):580–4. https://doi.org/10.1016/j.juro.2012.08.197.

Turk C, Petrik A, Sarica K, Seitz C, Skolarikos A, Straub M, Knoll T. EAU guidelines on interventional treatment for urolithiasis. Eur Urol. 2016;69(3):475–82. https://doi.org/10.1016/j.eururo.2015.07.041.

Usawachintachit M, Isaacson DS, Taguchi K, Tzou DT, Hsi RS, Sherer BA, Stoller ML, Chi T. A prospective case-control study comparing lithovue, a single-use, flexible disposable ureteroscope, with flexible, reusable fiber-optic ureteroscopes. J Endourol. 2017;31(5):468–75. https://doi.org/10.1089/end.2017.0027.

# 10 Radiation Exposure and Its Prevention in Endourology

Takaaki Inoue and Hidefumi Kinoshita

**Abstract**

Currently, radiation exposure for patient and occupationally exposed personnel has been great concern. Doses exceeding the standard limits likely carry a small, short-term health risk. Radiation exposure is linked to loss of hair, erythema, cataracts, and malignancy, including thyroid cancer and leukemia. Patients with upper urinary tract stones suffer radiation exposure from diagnosis and follow up imaging, and treatment for nephrolithiasis. Furthermore, surgeons, assistants, and medical staffs are mostly exposed from radiation during endourologic procedures. As the disease prevalence of urolithiasis has increased, long-term low-dose radiation for them should not be ignored.

**Keywords**

Endourology · Fluoroscopy · Radiation exposure

## 10.1 Introduction

In recent decades, interventional radiology (IR) has been developing, especially in the field of minimally invasive medicine. An advantage of IR is that it decreases the amount of conventional surgeries with invasiveness. IR is available in many medical fields, such as endovascular surgery, orthopedic therapy, and cancer therapy. In the urological field, endoscopic surgery has been established using real-time radiation imaging, especially for treating urolithiasis. The techniques markedly decrease many peri-surgical parameters, such as the operation time, blood loss, post-surgical pain, and hospital stay. Procedures and treatment outcomes have improved by development of new instruments and materials related to each surgery. Furthermore, sophisticated radiological equipment has also contributed to the spread of IR from some specific surgeons to routine medical procedures.

With the spread of IR, knowledge of the safe use of radiation may be less important for concerns of urologists compared with technical improvements. Notably, radiation itself is harmful and adverse events of radiation exposure should be minimized during procedures.

The International *Commission on Radiological Protection* (ICRP) is an international academic organization that developed, maintained, and elaborated the International System of Radiological Protection. The ICRP is used worldwide as the common basis for radiological protection standards, legislation, guidelines, programs, and practice (ICRP 2007). According to the ICRP recommendation, the System of Radiological Protection is anchored in three fundamental principles of justification, protection, and dose limits as follows.

1. *The Principle of Justification*: Any decision that alters the situation of radiation exposure should do more good than harm.
2. *The Principle of Optimization of Protection*: The likelihood of incurring exposure, the number of people exposed, and the magnitude of their individual doses should be kept as low as reasonably achievable, taking into account economic and societal factors.
3. *The Principle of Application of Dose Limits*: The total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limits specified by the Commission.

Preoperative evaluation and endourological procedures for upper urinary tract stones are mostly performed under fluoroscopy. Patients with stones, and surgeons and medical staff involved in management for upper urinary tract stones can have

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radiation exposure. Radiation exposure in the endourological field is largely divided into medical exposure for patients and occupational radiation exposure for surgeons and medical staff. Although the dose limit of medical exposure for patients has not been established, the occupational radiation exposure dose limit was defined as 50 mSV/year by the National Council on Radiation Protection and Measurements (NCRP) (United States Nuclear Regulatory Commission 1991).

Ionizing radiation exposure is considered as a risk factor of cancer. Currently, how radiation exposure at a low dose is related the risk of cancer is unclear. Therefore, the linear, non-threshold (LNT) hypothesis is applied as a basic philosophy to consider the biological effect of radiation exposure. However, some investigators have reported that low levels of chronic occupational exposure to ionizing radiation cause an increase in the frequency of micronuclei in chromosomes, which are a biomarker of chromosomal damage, genome instability, and a risk of cancer (Eken et al. 2010). A current concern regarding occupational radiation exposure is the effect of IR on the lens of the eye. The ICRP recommends not to exceed a mean dose of 20 μSv/year to the eye. Even if the risk of harmful effects of occupational radiation exposure is relatively small, doses exceeding the standard limits may carry a small, short-term health risk. The ICRP has recommended the principle of limiting radiation exposure to "as low as reasonably achievable" (ALARA) (Hellawell et al. 2005; Duran et al. 2013).

Medical radiation protection principles should be applied in patients and medical staff involved in imaging, such as surgeons, nurses, and medical engineers. General methods for optimizing radiation protection are as follows.

1. Time: Radiation time should be minimized in the time for fluoroscopy and the number of X-ray images.
2. Distance: Medical staff should position themselves as far as possible from the X-ray source.
3. Shielding: Medical staff should use an adequate shielding material, such as a lead apron, lead glasses, and lead glass (radiation shielding glass).

Importantly, reducing the patient's exposure of radiation almost always decreases that of the medical staff, but *the reverse is not always true*. To protect the patients and medical staff from as little radiation exposure as possible, physicians need to perform surgery based on these three factors. Improvement in radiation-free techniques for imaging stones is required.

## 10.2 Radiation Protection for Patients

A major source of radiation exposure for patients is caused by direct radiation that is generated in the fluoroscopy field between an X-ray tube and an image intensifier (Fig. 10.1).

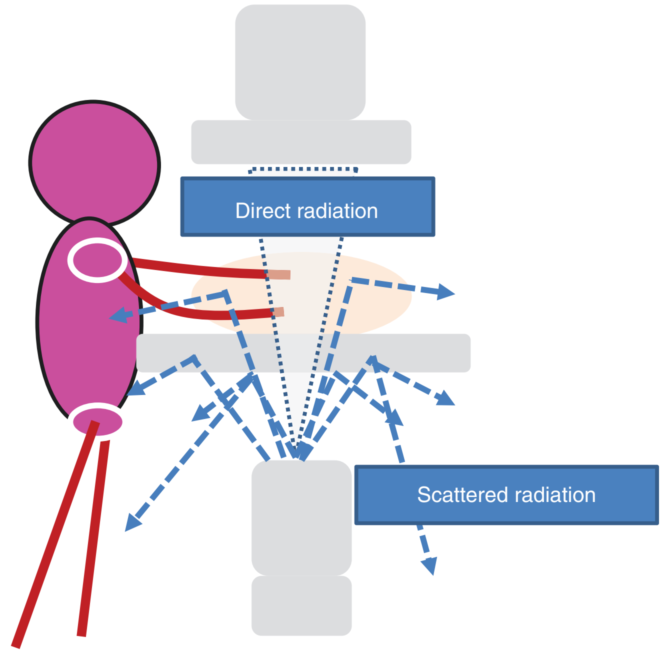


**Fig. 10.1** Direct and scattered radiation in endourological surgery

The dose of medical exposure for patients is not limited for some advantages, including examinations and treatment for their diseases. However, decreasing the radiation exposure as much as possible for patients is important according to the ALARA principle. Patients with upper urinary tract stones suffer radiation exposure from diagnosis and follow-up imaging, and treatment for nephrolithiasis.

Standard imaging in diagnosis for nephrolithiasis is mostly non-contrast computed tomography (NCCT). An effective dose (ED) in current NCCT for the abdomen and pelvis is 4.5–5 mSv (Turk et al. 2015). However, the use of low-dose NCCT (LDCT) offers the advantage of less radiation exposure for patients. A meta-analysis of LDCT studies showed a sensitivity and specificity of 96.6% and 94.9%, respectively, to diagnose urolithiasis, which is comparable with that of NCCT (Niemann et al. 2008). The mean ED for patient in LDCT is 1.40 mSV in males and 1.97 mSV in females. However, when body mass index (BMI) is considered, sensitivity and specificity decrease to 50% and 89%, respectively, in patients with a BMI larger than 30 kg/m$^2$ (Poletti et al. 2007). The American Urological Association (AUA) currently recommends standard NCCT over LDCT to evaluate stones in obese patients with a BMI greater than 30 kg/m$^2$ (Fulgham et al. 2013). Furthermore, current advancements in imaging studies have enabled development of ultra-low-dose iterative reconstruction algorithms, which preserve image quality at low doses, allowing evaluation of urolithiasis. Ultra-low-dose NCCT (ULDCT) delivers an ED of less than 1 mSV, which is a lower ED compared with LDCT (Pooler et al. 2014; Chen et al. 2015).

In follow-up of patients on medical expulsive therapy or after procedures for nephrolithiasis, standard imaging studies are X-ray of the kidney-ureter-bladder (KUB) and ultrasound (US), which are better modalities than NCCT for radiation exposure and cost. The mean ED of the KUB is 0.5–1.0 mSv (Turk et al. 2015; Astroza et al. 2013). However, the patient does not become exposed to radiation when using US.

During procedures for management of nephrolithiasis, almost all patients are exposed to radiation under fluoroscopy. Generally, radiation exposure in percutaneous nephrolithotomy (PCNL) is higher than in ureteroscopy (URS) for nephrolithiasis because of the prolonged fluoroscopic time (FT). A retrospective study showed that the mean FT in PCNL was 7.09 ± 4.8 min and the mean ED of patients undergoing PCNL was 8.66 mSV (Rizvi et al. 2017; Mancini et al. 2010). Various techniques can decrease radiation exposure in PCNL. An air retrograde pyelogram can clarify calyceal anatomy of the puncture site in the prone position. Consequently, the mean adjusted ED during PCNL for an air retrograde pyelogram is 4.45 mSV compared with 7.67 mSV for a contrast retrograde pyelogram. This finding is likely due to the increased density of contrast, leading to automatic adjustment of the C-arm tube and tube voltage Tube voltage is lower when air is in the field (Lipkin et al. 2011). US guidance to assist PCNL reduces radiation exposure compared with fluoroscopic guidance, and is particularly beneficial for treating obese patients with renal stones (Usawachintachit et al. 2016). Furthermore, combined US and ureteroscopic-assisted access for PCNL reduces the mean FT compared with conventional PCNL under fluoroscopic-guided access (Alsyouf et al. 2016).

Generally, radiation exposure of patients with nephrolithiasis during URS is significantly less than that during PCNL. Investigators found a median FT of 46.9 s and a median ED of 1.13 mSV per procedure (Lipkin et al. 2012). Additionally, in an anthropomorphic adult phantom, the mean effective dose rate (EDR, mSV/s) is significantly increased during URS in the obese model (BMI >30 kg/m$^2$) compared with the non-obese model during PCNL (Shin et al. 2015). Appropriate fluoroscopic education and protocols, such as tactile and visual feedback, reduces radiation exposure to the patient (Olgin et al. 2015). The mean FT and entrance skin dose from pre-radiation safety training protocols to post-radiation safety training protocols are −0.5 min and −0.1 mGy (34%), respectively, for ureteroscopy (Canales et al. 2016). In other methods, the fluoroscopy beam should be collimated to the area of interest, the image intensifier should be placed as close to the patient as possible, and a pulsed fluoroscopy mode should be used to minimize radiation exposure during PCNL and URS for nephrolithiasis (Park and Pearle 2006; Yecies et al. 2017). Furthermore, a drape placed over or under the patient may help reduce scatter radiation. However, the main factor for reducing radiation exposure for patients is promotion of the physician's awareness of the risk of radiation exposure and importance of protection from radiation exposure.

## 10.3 Radiation Protection for Surgeons and Medical Staff

A major source of radiation exposure for surgeons and medical staff is scattered radiation that is produced from interaction of the primary radiation beam with the patient's body and the operating table (Fig. 10.1). These staff may rarely be exposed because of direct radiation when their hands are inside the fluoroscopy field between an X-ray tube and an image intensifier. However, medical personnel are mostly exposed because of scattered radiation during procedures. Shielding for surgeons and medical staff is usually performed by using protective clothes for protecting oneself. The standard lead protection protocol requires the use of 0.35-mm lead aprons and thyroid shields for the operating surgeon and 0.25-mm lead aprons for other personnel (Institute of Physics and Engineering in Medicine 2002). However, protection from scattered radiation by protective clothes is incomplete, especially to the arms, eyes, and brain.

In PCNL, radiation exposure doses of surgeons include a mean ED of 12.7 mSV per procedure, which is higher than 11.6 μSV in fURS because of a longer FT and the close distance between the source of radiation and the surgeon (Safak et al. 2009; Hellawell et al. 2005). Some investigators reported that the mean fluoroscopy screening time during PCNL was 4.5–6.04 min (range, 1–12.16 min) (Kumari et al. 2006). Furthermore, the mean radiation exposure to the finger and ocular of the surgeon was actually 0.28 and 0.125 mSV because of non-uniform radiation exposure of scattered radiation (Majidpour 2010; Taylor et al. 2013). Therefore, the operator should also protect the hands and eyes from scattered radiation exposure using groves and glass lined with lead. Most endourologists generally perform needle puncture under fluoroscopy for renal access. Therefore, the US approach is beneficial for protecting surgeons from radiation exposure during PCNL compared with the fluoroscopic approach. Yang et al. reported that using a radiation shield constructed from 0.5-mm lead sheeting is effective for reducing surgeons' radiation exposure (Yang et al. 2002).

In URS, radiation exposure doses of the surgeon in almost cases are less than those in PCNL according to a shorter FT and a longer distance between the source of radiation and the surgeon. Pulsed fluoroscopy was introduced to reduce the radiation dose by limiting the time of exposure to X-rays and the number of exposures per second. The original application of this technology during URS was decreased from 4.7 to 0.62 min (Bagley and Cubler-Goodman 1990). Recent reports have shown that the mean fluoroscopy screening time during URS is 44.1 s (range, 36.5–51.6 s) (Elkoushy et al. 2012). Additionally, Zoller and co-workers reported that a face protection shield was effective in reducing eye lens radiation exposure during URS (Zoller et al. 2016). Furthermore, Inoue and associates reported that using protective lead curtains on both sides of the patient's table, the operating table end, and the image intensifier were useful for reducing radiation exposure for surgeons during URS. They investigated spatial scattered radiation doses in the operating room for managing urolithiasis using an anthropomorphic phantom and the ionization chamber. They measured the scattered radiation dose with protective lead curtains or without them under the patient's table and image intensifier. Consequently, protective lead curtains led to a reduction of 75–80% in the scattered radiation dose compared with without lead curtains (Inoue et al. 2017) (Fig. 10.2a–c).

In modern radiation protection practice, active personal dosimeters are essential operational tools for satisfying the ALARA principle (Bolognese-Milsztajn et al. 2004). Most urologists may have an insufficient perception of radiation protection for themselves. A previous study showed that although 84.4% of urologists who were chronically exposed to ionizing radiation wore lead aprons, only 53.9% wore a thyroid shield and 27.9% wore eye glasses with lead lining. Moreover, only 23.6% of urologists wore a dosimeter (Borges et al. 2015). Awareness of physicians for occupational radiation exposure in the urological field still remains low. Although the risks of harmful effects of occupational radiation exposure may be relatively small, they should not be ignored.

In summary, simple methods for reducing or minimizing occupational radiation and the radiation dose to patients include minimizing the FT and the number of acquired images, and collimating and avoiding high-scatter areas. Additionally, a pulsed fluoroscopic mode should be used, and the distance between the X-ray tube and the patient should be maximized and the distance between patients and the image intensifier should be minimized. Furthermore, US should be used instead of fluoroscopy if possible. Protective shielding should be used and personal dosimeters should be worn to determine the exposure dose (Table 10.1). Effective use of these methods requires appropriate education and training in radiation exposure for all endourologists and medical staff, and availability of appropriate tools and equipment.

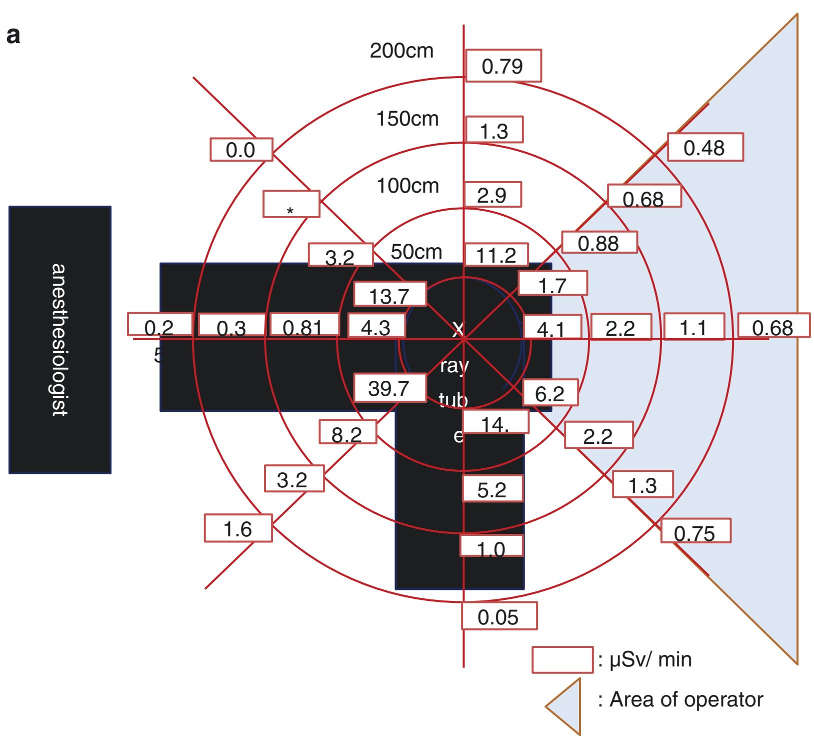


**Fig. 10.2** An anthropomorphic phantom study that measured the scattered radiation dose (**a**) with protective lead curtains, (**b**) without protective lead curtains, and (**c**) with lead protective curtains under the patient's table and image intensifier

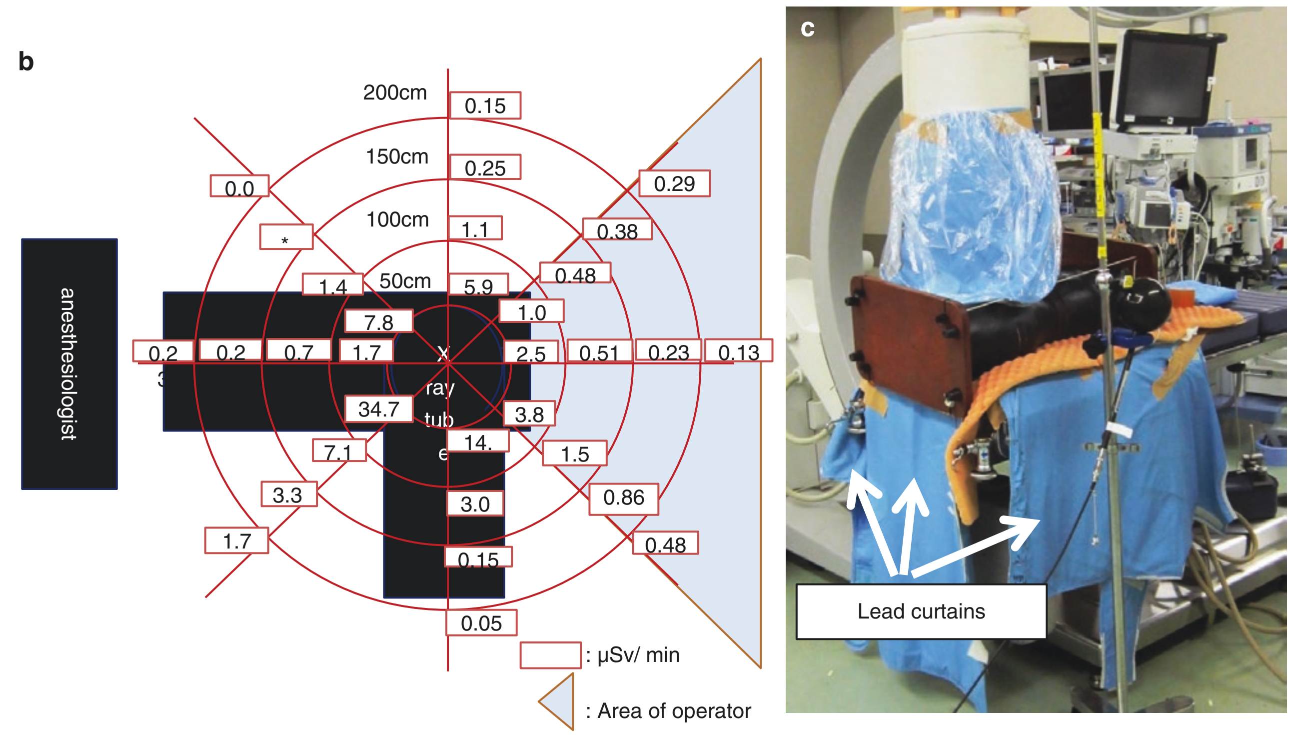


**Fig. 10.2** (continued)

**Table 10.1** Reduction technique of radiation exposure for patients and operator

| Subjects | Methods | | | |
|---|---|---|---|---|
| C-arm, image inteisifier | 1. Maximizing the distance between the X-ray tube and the patient | 2. Minimizing the distance between patients and the image Intensifier | 3. Collimating | 4. Pulsed fluoroscopic mode |
| Operator | 1. Minimizing fluoroscopy time | 2. Protective shielding for operator | 3. Protective shielding for patient table | |
| Instrument | 1. Using ultrasound instead of fluoroscopy | | | |

## References


Alsyouf M, Arenas JL, Smith JC, et al. Direct endoscopic visualization combined with ultrasound guided access during percutaneous nephrolithotomy: a feasibility study and comparison to a conventional cohort. J Urol. 2016;196:227–33.

Astroza GM, Neisius A, Wang AJ, et al. Radiation exposure in the follow-up of patients with urolithiasis comparing digital tomosynthesism non contrast CT, standard KUBm and IVU. J Endourol. 2013;27:1187.

Bagley DH, Cubler-Goodman A. Radiation exposure during ureteroscopy. J Urol. 1990;144:1356–8.

Bolognese-Milsztajn T, Ginjaume M, Luszik-Bhadra M, et al. Active personal dosimeters for individual monitoring and other new development. Radiat Prot Dosim. 2004;112:141–68.

Borges CF, Reggio E, Vicentini FC, et al. How are we protecting ourselves from radiation exposure? A nationwide survey. Int Urol Nephrol. 2015;47:271–4.

Canales BK, Sinclair L, Kang D, et al. Changing default fluoroscopy equipment setting decreases entrance skin dose in patients. J Urol. 2016;195:992–7.

Chen TT, Wang C, Ferrandino MN, et al. Radiation exposure during the evaluation and management of nephrolithiasis. J Urol. 2015;194:878.

Duran A, Hian SK, Miller DL, et al. Recommendations for occupational radiation protection in interventional cardiology. Cathet Cardiovasc Interv. 2013;82:29–42.

Eken A, Aydin A, Erdem O, et al. Cytogenetic analysis of peripheral blood lymphocytes of hospital staff occupationally exposed to low doses of ionizing radiation. Toxicol Ind Health. 2010;26:273–80.

Elkoushy MA, Shahrour W, Andonian S. Pulsed fluoroscopy in ureteroscopy and percutaneous nephrolithotomy. Urology. 2012;79:1230–5.

Fulgham PF, Assimos DG, Pearle MS, et al. Clinical effectiveness protocols for imaging in the management of ureteral calculous disease: AUA technology assessment. J Urol. 2013;189:1203.

Hellawell GO, Mutch SJ, Thevendran G, et al. Radiation exposure and the urologist: what are the risks? J Urol. 2005;174:948–52.

ICRP. The 2007 recommendations of the International Commission on Radiological Protection. ICRP Publication 103 (ICRP-103) [3] 3. Ann ICRP. 37(2–4):2007.

Inoue T, Komemushi A, Matsuda T, et al. Effect of protective lead curtains on scattered radiation exposure to the operator during ureteroscopy for stone disease: a controlled trial. Urology. 2017;109:60–6.

Institute of Physics and Engineering in Medicine. Medical and dental guidance notes: a good practice guide on all aspects of ionising radiation protection in the clinical environment. York: Institute of Physics and Engineering in Medicine; 2002.

Kumari G, Kumar P, Wadhwa P, et al. Radiation exposure to the patient and operating room personnel during percutaneous nephrolithotomy. Int Urol Nephrol. 2006;38:207–10.

Lipkin ME, Mancini JG, Zilberman DE, et al. Reduced radiation exposure with the use of an air retrograde pyelogram during fluoroscopic access for percutaneous nephrolithotomy. J Endourol. 2011;25:563.

Lipkin ME, Wang AJ, Toncheva G, et al. Determination of patient radiation dose during ureteroscopic treatment of urolithiasis using a validated model. J Urol. 2012;187:920.

Majidpour HS. Risk of radiation exposure during PCNL. Urol J. 2010;7:87–9.

Mancini JG, Raymundo EM, Lipkin M, et al. Factors affecting patient radiation exposure during percutaneous nephrolithotomy. J Urol. 2010;184:2373.

Niemann T, Kollmann T, Bongartz G. Diagnostic performance of low-dose CT for the detection of urolithiasis: a meta-analysis. AJR Am J Roentgenol. 2008;191:396.

Olgin G, Smith D, Alsyouf M, et al. Ureteroscopy without fluoroscopy: a feasibility study and comparison with conventional ureteroscopy. J Endourol. 2015;29:625–9.

Park S, Pearle MS. Imaging for percutaneous renal access and management of renal calculi. Urol Clin North Am. 2006;33:353–64.

Poletti PA, Platon A, Rutschmann OT, et al. Low-dose versus standard-dose CT protocol in patients with clinically suspected renal colic. AJR Am J Roentgenol. 2007;188:927.

Pooler BD, Lubner MG, Kim DH, et al. Prospective trial of the detection of urolithiasis on ultralow dose non contrast computerized tomography: direct comparison against routine low dose reference standard. J Urol. 2014;192:1433.

Rizvi SAH, Hussain M, Askari SH, et al. Surgical outcomes of percutaneous nephrolithotomy in 3402 patients and results of stone analysis in 1559 patients. BJU Int. 2017;120(5):702–9.

Safak M, Olgar T, Bor D, et al. Radiation doses of patients and urologists during percutaneous nephrolithotomy. J Radiol Prot. 2009;29:409–15.

Shin RH, Cabrera FJ, Nguyen G, et al. Radiation dosimetry for ureteroscopy patients: a phantom study comparing the standard and obese patient models. J Endourol. 2015;30:57–62.

Taylor ER, Kramer B, Frye TP, et al. Ocular radiation exposure in modern urological practice. J Urol. 2013;190:139–43.

Turk C, Knoll T, Petrik A, et al. Guidelines on urolithiasis. Arnhem, The Netherlands: EAU; 2015. p. 12.

United States Nuclear Regulatory Commission. Occupational dose limits for adults. Part 20-Standards for protection against radiation, Nuclear Regulatory Commission Regulations Title 10, Code of federal Regulation. Washington, DC: United States Nuclear Regulatory Commission; 1991.

Usawachintachit M, Masic S, Chang HC, et al. Ultrasound guidance to assist percutaneous nephrolithotomy reduces radiation exposure in obese patients. Urology. 2016;98:32–8.

Yang RM, Morgan T, Bellman GC. Radiation protection during percutaneous nephrolithomy: a new urologic surgery radiation shield. J Endourol. 2002;16:727–31.

Yecies TS, Fombona A, Semins MJ. Single pulse-per-second setting reduces fluoroscopy time during ureteroscopy. Urology. 2017;103:63–7.

Zoller G, Figel M, Denk J, et al. Eye lens radiation exposure during ureteroscopy with and without a face protection shield: investigations on a phantom model. Urologe A. 2016;55:364–9.

# TURBT: An Old Operation with New Insights

# 11

Bryan Kwun-Chung Cheng and Jeremy Yuen-Chun Teoh

**Abstract**

Transurethral resection of bladder tumour (TURBT) is the gold standard in diagnosing and treating non-muscle-invasive bladder cancer (NMIBC). The first resectoscope has been introduced more than a century ago, and TURBT remains as a cornerstone in the management of bladder cancer. Although it is a minimally-invasive surgery that has gained favour over the years, the recurrence rate of NMIBC is in general unsatisfactory ranging from 15% to 61% at 1 year and 31% to 78% at 5 years. Tremendous efforts have been made to improve the treatment outcomes of NMIBC, and the current treatment algorithm has been shaped over the past decades. This book chapter shall first discuss about the history of TURBT and the current standard of the initial management of NMIBC, followed by newer concepts that have been proposed including enhanced imaging during TURBT and en bloc resection of bladder tumour. We hope to provide our readers the backbone of the TURBT procedure and new insights that might be helpful in optimizing the management of NMIBC.

**Keywords**

Bladder cancer · TURBT · Photodynamic diagnosis Narrow-band imaging · En bloc resection

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## 11.1 History of Transurethral Resection of Bladder Tumour

The dedication, wisdom and creativity of our great predecessors had cultivated the standard of modern transurethral resection of bladder tumour (TURBT). Development of TURBT was nonetheless a reflection of milestones in scientific discoveries and technical advancements. The history of TURBT is indeed a story of modern industrial development and the success of various innovative inventions.

Earliest documented surgeries for removal of bladder tumours were dated back in the sixteenth and seventeenth century. Franco and Couillard removed tumours in open suprapubic approaches in 1561 and 1639 respectively. Removal of bladder tumours blindly through the urethra has also been reported. Early operations were mainly limited in women, in which bladder neck or urethral tumours were grasped and amputated (Herr 2006). Before the invention of endoscopy, diagnosis and treatment of bladder tumours were very limited.

Thanks to the inventors of endoscope, endoluminal visualization of bladder becomes possible. Philipp Bozzini (1773–1809) used candle light as an external light source, and illuminated the bladder through a metal tube. However, the design was criticised to be unpractical. It was further optimized by Antonin Jean Desormeaux (1815–1894). Alcohol lamp was used instead of candle, and concave mirror was used for reflection. His cystoscope was regarded as more usable. The improved vision allowed simple endoscopic operation such as chemical cauterization and extraction of urethral papillomas. Another breakthrough was achieved by a Hungarian urologist, Josef Grunfeld (1840–1912), who equipped a set of simple endoscopic instruments to his urethroscope. He was the first to report removal of a bladder papilloma endoscopically (Herr 2005; European Museum of Urology 2017).

A significant problem which hindered further development of endoscopic diagnosis or treatment was the small field of vision. This problem had been tackled by Maximilian


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Nitze, who revolutionised the design of cystoscope and was widely regarded as the father of modern cystoscope. He had invented multiple refinements to the existing cystoscope. He recognised that in order to improve cystoscopic vision, the light source must be brought inside the bladder. Therefore, a built-in light source was subsequently designed. The bladder interior could always be illuminated in a bright light no matter how the instrument was angled and manipulated. Initially a galvanized platinum wire was adopted as light source, later it was modified into a miniaturized light bulb after Edison's invention of electric light bulb. More importantly, the field of vision was also expanded by using optical microscopy technology (Nezhat n.d.; European Museum of Urology 2017).

Apart from the important contributions in cystoscopy, Nitze was also one of the pioneers in transurethral bladder tumour treatment. He created an operating cystoscope by equipping the cystoscope with a platinum wire loop and galvanocautery. A 150 cases of successful endoscopic treatment of bladder tumours by cutting and coagulating the bladder tumours with wire loop were reported. This result was remarkable and had inspired Edwin Beer, another brilliant inventor and urologist, to modify the surgery and bring endoscopic surgery forward. Beer was the first to utilize high frequency electric current to cauterize bladder tumours, employing similar electrocauterization technique for treatment of skin warts by Oudin (Beer 1983). He used a Nitze cystoscope with two channels, one for the insertion of an insulated copper electrode and another for irrigation. Tumour was fulgurated by applying direct current at the tumour surface. This technique was a very influential discovery, and it is still being used nowadays for effective treatment of small papillary growths (Beer 1983; Herr 2005).

The prototype of modern resectoscope was created and optimized by Maximilian Stern (1843–1946), Theodore Davis (1889–1973) and Joseph McCarthy (1874–1965) (Surgeons TBAoU Virtual Museum Resectoscopes n.d.). The first resectoscope had been introduced by Stern. Its major problem was failure of deep coagulation. It was subsequently refined by Davis, who incorporated both cutting and coagulation current in the instrument. A foot pedal was also invented which allows switching of the electrical current by the surgeon intra-operatively. McCarthy had further improved the design and encased the instrument into non-conducting Bakelite sheath. This resectoscope was also known as the Stern-McCarthy resectoscope. It had swiftly replaced Beer's fulguration and had been popularised among urologists internationally. Subsequent modifications happened but they largely followed the prototype of Stern-McCarthy design. Since then, TURBT with resectoscope has become the cornerstone for endoscopic treatment of bladder cancer (Nezhat n.d.; Surgeons TBAoU Virtual Museum Resectoscopes n.d.).

## 11.2 Standard TURBT

TURBT remains as the standard in the initial management of bladder tumours. In terms of diagnosis, it can ascertain the pathological diagnosis, local staging and tumour grading. Therapeutically, it may cure non-muscle-invasive bladder cancers (NMIBC) (Herr 1987), palliate symptoms for bleeding tumours and play an important role in multi-modal bladder sparing treatment for muscle-invasive bladder cancer (Ploussard et al. 2014). Upon TURBT, we aim to remove all endoscopically visible tumours and sample detrusor muscle for assessment of any muscle invasion. Presence of detrusor muscle in the pathological specimen serves as a surrogate marker for the quality of resection (Mariappan et al. 2010). TURBT is a very common urological procedure, which is in general easy to learn but difficult to master (Herr and Donat 2008). It is indeed important to perform the procedure properly, and it has a strong influence on the tumour recurrence rate (Brausi et al. 2002).

### 11.2.1 Preoperative Preparations

The general condition of the patient should be assessed. Patients with poor mobility should be carefully examined for lower limb contracture. Presence of severe lower limb contracture and hip joints diseases would render lithotomy position difficult.

Comprehensive anaesthetist assessment is essential. Blood tests should be taken to assess the serum haemoglobin, platelet count, serum creatinine, electrolyte and clotting profile. Urine culture should be saved prior to operation. Presence of bacteriuria should be treated to reduce chance of postoperative infections (Badenoch et al. 1990). Upper tract imaging with computer tomography urogram should be considered to detect synchronous upper tract urothelial cancers (UTUC). The incidence of concomitant UTUC is general low at 1.8%, however, the risk increases in patients with multiple or trigonal tumours (Palou et al. 2005).

Locations of bladder tumours should be reviewed. Liaison should be sought with anaesthetists to arrange either general anaesthesia with muscle relaxant or spinal anaesthesia with obturator block for lateral wall tumours to reduce occurrence of obturator jerk. Sudden adductor contraction may potentially lead to inadvertent bladder perforation (Augspurger and Donohue 1980).

### 11.2.2 Operating Procedures

Prophylactic antibiotics should be given upon induction of anaesthesia (Alsaywid and Smith 2013). A dorsal lithotomy position is adopted. Ensure pressure points are well padded and avoid excessive hip flexion or rotation to prevent femoral or peroneal nerve palsy.

Bimanual examination of the pelvis has a vital role in assessing the clinical stage. It should be performed before and after surgery, and the surgeon should assess for any extra-vesicle disease and tumour fixation, which corresponds to T3 and T4 diseases respectively (Rozanskia et al. 2015).

A thorough cystoscopic examination is necessary. Use 30° and 70° lens to examine the urethra, prostate, bladder and ureteric orifice completely. Number, locations, morphology, size of bladder tumours and any involvement of the ureteric orifice should be documented. Either monopolar or bipolar resectoscopes can be used for resection with 1.5% glycine or 0.9% saline as irrigant respectively. Conventionally, the exophytic portion of the bladder tumours are first resected in a piecemeal manner (Babjuk et al. 2017). The resection width and depth have practical implications for tumour staging and treatment. Appreciation of the ideal resection extent requires considerable judgement, experience and skill (Herr and Donat 2008).The underlying bladder wall and the edges of the resection area should also be resected and sent separately to provide information about the vertical and horizontal extent of the tumour (Richterstetter et al. 2012).

Extra caution should be paid when resecting large tumours and tumours which are located at the bladder dome region, as the risks of extraperitoneal and intraperitoneal perforation are higher, and may necessitate laparotomy for bladder repair (Balbay et al. 2005). Overdistention of bladder should be avoided, as it may cause thinning of bladder wall and increase chance of inadvertent perforation (Wein et al. 2012). Some anterior wall or dome tumours may require simultaneous suprapubic compression to position tumours within your range of resection. This requires one hand manipulation of the resectoscope and beginners may find it difficult. In any difficult circumstances, assistance from scrub nurses could always be sought to perform the suprapubic compression.

Occurrence of obturator jerk during resection of lateral wall tumours could result in bladder perforation (Augspurger and Donohue 1980). Meticulous technique and rigorous attention are required to avoid excitation of obturator nerves. As mentioned previously, for bladder tumours which are located at the lateral wall, anaesthetist should be liased for spinal anaesthesia with obturator nerve block or general anaesthesia with muscle relaxant. Resection can be performed at lower energy with an intermittent burst technique to reduce chance of obturator jerk (Wein et al. 2012; Blandy and Reynard 2005). The use of bipolar energy may reduce obturator jerk by localized current, however, one should be aware that obturator jerk may still occur despite use of this energy source (Gupta et al. 2011; Ozer et al. 2015).

Perform biopsy on any suspicious erythematous velvety mucosa which may represent carcinoma in situ (CIS). Routine random biopsy is not recommended as the yield of detecting CIS is low. Consider random biopsy if there is a positive urine cytology but negative cystoscopy, or if endoscopic features of the bladder tumours are suggestive of high risk disease (Wein et al. 2012). Prostatic urethral involvement is an important prognostic factor for disease recurrence and progression (Palou et al. 2012), and urethrectomy may be indicated in patients with muscle-invasive bladder cancer contemplating cystectomy. Urethral biopsy should be taken at the prostatic urethra and the precollicular area in high risk cases such as trigone tumour or bladder neck tumour, multiple tumours or presence of CIS (Mungan et al. 2005).

Hemostasis should be ascertained before concluding the surgery. Distention and decompression of the bladder may reveal any occult bleeders. Complete the operation with a bimanual examination of pelvis. Any persistence of pelvic mass may indicate a T3 or above disease. Urethral catheter should be inserted and adjuvant chemotherapy instillation should be given if complete tumour resection can be achieved endoscopically without any evidence of bladder perforation.

## 11.3 Post-operative Adjuvant Treatment

Single instillation of intravesical chemotherapy in the immediate postoperative period has been shown to eliminate circulating tumour cells and have a chemoresection effect on any residual cancer cells in the previous resection sites (Oosterlinck et al. 1993; Brocks et al. 2005). Numerous agents including epirubicin, pirarubicin, thiotepa, gemcitabine and mitomycin C are all effective as adjuvant treatment (Oosterlinck et al. 1993; Brocks et al. 2005; Pan et al. 1989; Sylvester et al. 2016).

Extensive research has been conducted to study the efficacies of these agents. Several large meta-analyses have proven that TURBT with single instillation of chemotherapy could disease recurrence as compared to TURBT alone (Abern et al. 2013; Sylvester et al. 2016; Perlis et al. 2013). Timing of instillation is also crucial. Ideally, it should be instilled within the first few hours after the operation, as floating tumour cells may reimplant to the bladder wall and could be covered with extracellular matrix afterwards (Pode et al. 1986; Bohle et al. 2002). Immediate instillation after urethral catheterization inside the operating theatre can be considered, however, this has to be balanced with concerns of occupational hazard, logistics of drug administration and drug disposal. Contraindications of intravesical instillation of chemotherapy include allergy, extensive resection, bladder perforation, pregnancy, lactating women and macroscopic residual diseases (AUA policy statements. Intravesical Administration of Therapeutic Medication 2015. Available from: http://www.auanet.org/guidelines/intravesical-administration-of-therapeutic-medication; Wein et al. 2012).

**Table 11.1** EAU risk group stratification

| Risk group stratification | Characteristics |
|---|---|
| Low-risk tumours | Primary, solitary, TaG1 (PUNLMP, LG), <3 cm, no CIS |
| Intermediate-risk tumours | All tumours not defined in the two adjacent categories (between the category of low- and high risk) |
| High-risk tumours | Any of the following:<br>• T1 tumour<br>• G3 (HG) tumour<br>• Carcinoma in situ (CIS)<br>• Multiple, recurrent and large (>3 cm) TaG1/G2/LG tumours (all features must be present) |
| | Subgroup of highest risk tumours: |
| | T1G3/HG associated with concurrent bladder CIS, multiple and/or large T1G3/HG and/or recurrent T1G3/HG, T1G3/HG with CIS in the prostatic urethra, some forms of variant histology of urothelial carcinoma, lymphovascular invasion |

A recently published meta-analysis showed that patients with a European Organisation for Research and Treatment of Cancer (EORTC) recurrence score ≥5 and/or patients with a prior recurrence rate of >1 recurrence per year, single instillation was not effective and should not be used (Sylvester et al. 2016).

Intravesical chemotherapy has also been utilized as a maintenance treatment. The exact treatment regimen, duration of chemotherapy depends on the risk stratification of bladder cancer. European Association of Urology (EAU) risk group is adopted for reference (Table 11.1). For low-risk diseases, only single dose of immediate post-operative instillation of chemotherapy is needed and further instillations are not beneficial (Sylvester et al. 2016). For intermediate-risk cases, maintenance chemotherapy up to 1 year has been shown to improve recurrence-free survival (Tolley et al. 1996) and can be considered. The ideal duration and schedule of chemotherapy, however, remains unknown because of conflicting data (Sylvester et al. 2008). For high-risk cases, maintenance chemotherapy is not preferred and intravesical bacillus Calmette-Guérin (BCG) immunotherapy is recommended (Babjuk et al. 2017).

Several methods have been proposed to improve the efficacy of chemotherapy. The drug concentration can be increased by pharmacokinetic modifications to decrease urine volume and to alkalinize urine. This has been reported to result in a longer time to recurrence, and an improved 5-year recurrence-free survival (Au et al. 2001). Few data are available for using microwave-induced hyperthermia and electromotive drug administration as adjunct (Di Stasi et al. 2006; Arends et al. 2014). Currently these methods have not been popularised and further large scale studies are required to confirm their efficacies.

## 11.4 Role of Second TURBT

Conventionally, TURBT is performed in a piecemeal manner with a top-down approach. Whether the bladder tumor is completely resected is dependent on the operating surgeon's judgement intra-operatively. Unfortunately, this judgement is prone to error and relies greatly on the surgeons' resection technique and past experiences. In a prospective study (Mariappan et al. 2012) comparing between senior surgeons (including consultant and trainees in year 5 or 6) and junior surgeons (trainees below year 5), senior surgeons were more likely to obtain detrusor muscle in the specimen (OR = 4.9, 95% CI 2.3–10.7, $p < 0.001$) and were associated with a lower recurrence rate at the first follow up cystoscopy (OR = 5.3, 95% CI 2.1–12.9, $p < 0.001$). This highlighted the importance of quality control in performing TURBT (Herr and Donat 2008).

Second TURBT following an initial 'complete tumour resection' has been advocated in selected groups of patients with NMIBC. There are several goals in performing second TURBT. First, we aim to resect any residual Ta or T1 disease. In patients with Ta high-grade disease, residual disease could be detected in 37.9–59.5% of them upon second TURBT (Lazica et al. 2014; Gendy et al. 2016); in patients with T1 disease, residual disease could be detected in 25.7–71.3% of them upon second TURBT (Gendy et al. 2016; Hashine et al. 2016; Vasdev et al. 2012; Gontero et al. 2016; Divrik et al. 2010). Second, we aim to detect any under-staged T2 disease. In patients with Ta high-grade disease, upstaging of disease is rare and was only reported in up to 2.7% of them (Lazica et al. 2014; Gendy et al. 2016). However, in patients with T1 disease, upstaging of disease was reported in up to 14.6% of them (Vasdev et al. 2012; Gontero et al. 2016; Hashine et al. 2016; Gendy et al. 2016; Divrik et al. 2010). In particular, for patients with T1 disease without detrusor muscle in the first TURBT, upstaging of disease was much higher than those with detrusor muscle (25% vs. 4.5%) (Gendy et al. 2016). To a certain extent, the presence of detrusor muscle in the specimen reflects whether appropriate depth of resection has been achieved during TURBT and it is important for local staging of the disease. Third, we aim to enhance the efficacy of intravesical BCG. In a retrospective study on 1021 patients with NMIBC receiving intravesical BCG (Sfakianos et al. 2014), patients with a single TURBT had a recurrence rate of 44.3% compared to 9.6% in patients with second TURBT being performed.

Second TURBT has become the cornerstone in the management of NMIBC. In the only randomized controlled trial investigating the role of second TURBT in patients with T1 disease, second TURBT has been shown to improve recurrence-free survival, progression-free survival and disease-specific survival. Second TURBT is indicated in patients with incomplete tumour resection during first TURBT, in patients with T1 disease, and when there is no detrusor muscle in the first TURBT specimen with the exception of Ta low-grade tumours and primary carcinoma-in-situ (Babjuk et al. 2017). When indicated, second TURBT should be performed within 2–6 weeks after first TURBT, as a delay in second TURBT has been shown to be a risk factor of both disease recurrence and progression (Baltaci et al. 2015).

## 11.5 New Developments that May Improve the Treatment Outcomes of TURBT

A number of new developments have been investigated and applied to our clinical practice in the past decade. They include the use of enhanced imaging during TURBT, use of alternative energy sources and en bloc resection of bladder tumour.

### 11.5.1 Enhanced Imaging During TURBT

Undetected bladder tumour upon TURBT may lead to 'early disease recurrence'. In order to facilitate bladder tumour detection, the use of photodynamic diagnosis (PDD) and narrow-band imaging (NBI) have been investigated in high-quality studies previously.

#### 11.5.1.1 Photodynamic Diagnosis

The principle of PDD is based on the preferential accumulation of a photosensitizing compound in neoplastic cells that emits a fluorescence upon blue-violet excitation (Kausch et al. 2010). This can be achieved after intravesical instillation of 5-aminolevulinice acid (ALA) or hexaminolevulinic acid (HAL) for 1 h and using violet light during cystoscopy.

A number of studies have investigated the role of PDD in the management of NMIBC. Concerning the use of ALA during TURBT, meta-analyses have shown that it could significantly reduce residual disease and improve recurrence-free survival when compared to white light alone (Kausch et al. 2010; Mowatt et al. 2011). However, two subsequent randomized controlled trials failed to demonstrate any significant benefit of ALA in recurrence-free survival and progression-free survival (Stenzl et al. 2011; Schumacher et al. 2010). Concerning the use of HAL, a meta-analysis based on raw data from prospective studies showed that HAL could significantly reduce recurrence rate when compared to white light alone (Burger et al. 2013). One subsequent randomized controlled trial on the use of HAL-assisted TURBT showed similar benefit (Mariappan et al. 2015), but another trial showed no significant reduction in disease recurrence (O'Brien et al. 2013). Further trials are needed to investigate the value of PDD, be it ALA or HAL, in particular for important outcomes including progression-free survival and disease-specific survival. One should also be aware of the possible false-positive results due to inflammation, recent TURBT and BCG therapy (Draga et al. 2010; Ray et al. 2010).

#### 11.5.1.2 Narrow-Band Imaging

In NBI, white light is being filtered into two bandwidths of 415 and 540 nm, which can only penetrate urothelium superficially and are strongly absorbed by hemoglobin. This can therefore enhance the contrast between normal urothelium and hypervascular cancer tissue and facilitate detection of subtle urothelial abnormalities.

A meta-analysis showed that NBI cystoscopy could yield a higher diagnostic accuracy than white light cystoscopy (Zheng et al. 2012). More recently, a multi-centre randomized trial comparing between NBI-assisted TURBT versus white light imaging-assisted TURBT has been conducted (Naito et al. 2016). In this randomized trial, 965 patients were included, with 481 patients in the NBI group and 485 patients in the white light group. Overall, no significant differences in the 1-year recurrence rates were detected between the two groups. However, upon the subgroup analysis on low-risk patients, NBI-assisted TURBT was found to significantly improve 1-year recurrence rate from 27.3% to 5.6% ($p = 0.002$). Therefore, NBI can be considered to assist TURBT in patients with presumably low-risk features. Compared to PDD, NBI can be performed more conveniently as no intravesical instillation is necessary before hand.

### 11.5.2 Bipolar TURBT

Conventionally, TURBT is performed using monopolar energy. However, when monopolar energy is applied, the electrical resistance creates a high temperature up to 400 degrees with collateral tissue damage (Singh et al. 2005). This results in a significant charring effect which may hinder further resection of the adjacent tissue. This led to the utility of bipolar energy in performing TURBT. By converting the conductive medium into a plasma field of highly ionized particles, organic molecular bonds can be disrupted readily and resection can be achieved in a more precise manner (Teoh et al. 2016).

There are three well-designed randomized controlled trials evaluating the use of bipolar energy in performing TURBT. When compared to monopolar TURBT, bipolar TURBT has been shown to be associated with higher detrusor sampling rate, fewer incidence of cautery artifacts, shorter catheterization time and shorter hospital stay (Venkatramani et al. 2014; Del Rosso et al. 2013; Teoh et al. 2017). In a recent meta-analysis (Zhao et al. 2016), bipolar TURBT has also been shown to be associated with less blood loss, fewer incidence of obturator nerve reflex and bladder perforation. In addition, bipolar TURBT could result in a lower recurrence rate at 2 years (Zhao et al. 2016). Therefore, the use of bipolar energy can be considered in patients undergoing TURBT.

The use of bipolar system requires additional costs and resources. However, in a propensity score-matched comparative study (Sugihara et al. 2014), taking into account the type of operation being performed, the peri-operative complications and duration of hospital stay, the calculated mean costs were USD 4628 for one bipolar TURBT procedure and USD 4727 for one monopolar TURBT procedure. The cost reduction following bipolar TURBT was 1.1% and it was statistically significant ($p = 0.034$). The authors concluded that the use of bipolar TURBT could reduce cost in treating patients with bladder tumours.

### 11.5.3 En Bloc Resection of Bladder Tumour

Due to the size limitation of the urethra, TURBT is conventionally performed in a piecemeal manner. However, this renders histological assessment of resection margin impossible. Complete tumour resection as judged by the operating surgeon is often inaccurate, and residual disease may lead to 'early disease recurrence'. Moreover, piecemeal resection causes tumour fragmentation. Floating tumour cells may re-implant into the bladder wall causing multiple early tumour recurrences. While the recurrence rates of NMIBC following TURBT were high, ranging from 15% to 61% at 1 year and 31% to 78% at 5 years, the concept of en bloc resection has been proposed in the hope of ensuring complete tumour resection and minimizing chance of tumour re-implantation (Ukai et al. 2000).

A number of energy sources including monopolar electrocautery, bipolar electrocautery, holmium laser, thulium laser and HybridKnife system have been used in performing en bloc resection (Kramer et al. 2015; Islas-Garcia et al. 2016); neither of them has shown superiority over the other in clinical trial settings. Based on the authors' experiences, there are a few potential differences between the energy sources. For example, using bipolar energy allows a more precision incision and may be technically easier than monopolar energy in performing en bloc resection. The occurrence of obturator nerve reflex may be reduced by using bipolar energy, and can be completely eliminated by using holmium or thulium laser. HybridKnife system may allow easier identification of the dissection plane by lifting up the mucosal with saline injection. However, whether such maneuver has any impact on detrusor muscle sampling and its potential implications are unknown. While more studies are needed to define the best energy source for en bloc resection, the availability of resources and the operating surgeons experiences and preferences are probably more important.

As en bloc resection aims to remove the bladder tumour in one piece via the urethra, there is a limitation in the maximal size of bladder tumour that can be handled. Based on the authors' experiences, bladder tumours with maximal dimension of 3 cm can be removed readily, although removal of tumour up to 4.5 cm has been reported (Naselli et al. 2012). On the other hand, as en bloc resection is intended to treat NMIBC, most of them are smaller tumours which should be amenable to this approach. Therefore, despite its limitation, en bloc resection should be a technically feasible option for most patients with bladder tumours.

A meta-analysis showed that en bloc resection was associated with shorter catheterization time and hospital stay, lower incidence of obturator nerve reflex and bladder perforation, and lower recurrence rate at 24 months. However, among the seven studies being included, there was only one single-centre randomized controlled trial, and other studies were either retrospective or prospective non-randomized studies. There was another single-centre randomized controlled trial comparing between thulium laser en bloc resection and TURBT, which failed to demonstrate significant differences in disease recurrence. Large-scale multi-centre randomized controlled trial are needed to investigate whether the theoretical benefits of en bloc resection could translate into clinical significance in terms of disease recurrence, progression and survival outcomes.

## References

Abern MR, Owusu RA, Anderson MR, Rampersaud EN, Inman BA. Perioperative intravesical chemotherapy in non-muscle-invasive bladder cancer: a systematic review and meta-analysis. J Natl Compr Cancer Netw. 2013;11(4):477–84.

Alsaywid BS, Smith GH. Antibiotic prophylaxis for transurethral urological surgeries: systematic review. Urol Ann. 2013;5(2):61–74. https://doi.org/10.4103/0974-7796.109993.

Arends TJ, van der Heijden AG, Witjes JA. Combined chemohyperthermia: 10-year single center experience in 160 patients with nonmuscle invasive bladder cancer. J Urol. 2014;192(3):708–13. https://doi.org/10.1016/j.juro.2014.03.101.

Au JL, Badalament RA, Wientjes MG, Young DC, Warner JA, Venema PL, Pollifrone DL, Harbrecht JD, Chin JL, Lerner SP, Miles BJ, For the International Mitomycin C Consortium. Methods to improve efficacy of intravesical mitomycin C: results of a randomized phase III trial. J Natl Cancer Inst. 2001;93(8):597–604.

AUA policy statements. Intravesical administration of therapeutic medication 2015. Available from: http://www.auanet.org/guidelines/intravesical-administration-of-therapeutic-medication.

Augspurger RR, Donohue RE. Prevention of obturator nerve stimulation during transurethral surgery. J Urol. 1980;123(2):170–2.

Babjuk M, Comperat E, Gontero P, Mostafid AH, Palou Redorta J, Van Rhijn B, Roupret M, Shariat S, Sylvester PW, Zigeuner R. Non-muscle-invasive bladder cancer: European Association of Urology

Guidelines. 2017. Available from: http://uroweb.org/guideline/non-muscle-invasive-bladder-cancer/.

Badenoch DF, Murdoch DA, Tiptaft RC. Microbiological study of bladder tumors, their histology and infective complications. Urology. 1990;35(1):5–8.

Balbay MD, Cimentepe E, Unsal A, Bayrak O, Koc A, Akbulut Z. The actual incidence of bladder perforation following transurethral bladder surgery. J Urol. 2005;174(6):2260–2, discussion 2262–3. https://doi.org/10.1097/01.ju.0000181811.61199.35.

Baltaci S, Bozlu M, Yildirim A, Gokce MI, Tinay I, Aslan G, Can C, Turkeri L, Kuyumcuoglu U, Mungan A. Significance of the interval between first and second transurethral resection on recurrence and progression rates in patients with high-risk non-muscle-invasive bladder cancer treated with maintenance intravesical Bacillus Calmette-Guerin. BJU Int. 2015;116(5):721–6. https://doi.org/10.1111/bju.13102.

Beer E. Landmark article May 28, 1910: Removal of neoplasms of the urinary bladder. By Edwin Beer. JAMA. 1983;250(10):1324–5.

Blandy JP, Reynard JM. Transurethral resection. 5th ed. Abingdon: Taylor & Francis; 2005.

Bohle A, Jurczok A, Ardelt P, Wulf T, Ulmer AJ, Jocham D, Brandau S. Inhibition of bladder carcinoma cell adhesion by oligopeptide combinations in vitro and in vivo. J Urol. 2002;167(1):357–63.

Brausi M, Collette L, Kurth K, van der Meijden AP, Oosterlinck W, Witjes JA, Newling D, Bouffioux C, Sylvester RJ, EORTC Genito-Urinary Tract Cancer Collaborative Group. Variability in the recurrence rate at first follow-up cystoscopy after TUR in stage Ta T1 transitional cell carcinoma of the bladder: a combined analysis of seven EORTC studies. Eur Urol. 2002;41(5):523–31.

Brocks CP, Buttner H, Bohle A. Inhibition of tumor implantation by intravesical gemcitabine in a murine model of superficial bladder cancer. J Urol. 2005;174(3):1115–8. https://doi.org/10.1097/01.ju.0000168657.51551.49.

Burger M, Grossman HB, Droller M, Schmidbauer J, Hermann G, Dragoescu O, Ray E, Fradet Y, Karl A, Burgues JP, Witjes JA, Stenzl A, Jichlinski P, Jocham D. Photodynamic diagnosis of non-muscle-invasive bladder cancer with hexaminolevulinate cystoscopy: a meta-analysis of detection and recurrence based on raw data. Eur Urol. 2013;64(5):846–54. https://doi.org/10.1016/j.eururo.2013.03.059.

Del Rosso A, Pace G, Masciovecchio S, Saldutto P, Galatioto GP, Vicentini C. Plasmakinetic bipolar versus monopolar transurethral resection of non-muscle invasive bladder cancer: a single center randomized controlled trial. Int J Urol. 2013;20(4):399–403. https://doi.org/10.1111/j.1442-2042.2012.03174.x.

Di Stasi SM, Giannantoni A, Giurioli A, Valenti M, Zampa G, Storti L, Attisani F, De Carolis A, Capelli G, Vespasiani G, Stephen RL. Sequential BCG and electromotive mitomycin versus BCG alone for high-risk superficial bladder cancer: a randomised controlled trial. Lancet Oncol. 2006;7(1):43–51. https://doi.org/10.1016/S1470-2045(05)70472-1.

Divrik RT, Sahin AF, Yildirim U, Altok M, Zorlu F. Impact of routine second transurethral resection on the long-term outcome of patients with newly diagnosed pT1 urothelial carcinoma with respect to recurrence, progression rate, and disease-specific survival: a prospective randomised clinical trial. Eur Urol. 2010;58(2):185–90. https://doi.org/10.1016/j.eururo.2010.03.007.

Draga RO, Grimbergen MC, Kok ET, Jonges TN, van Swol CF, Bosch JL. Photodynamic diagnosis (5-aminolevulinic acid) of transitional cell carcinoma after bacillus Calmette-Guerin immunotherapy and mitomycin C intravesical therapy. Eur Urol. 2010;57(4):655–60. https://doi.org/10.1016/j.eururo.2009.09.037.

European Museum of Urology. History of urology: European Association of Urology; 2017. Available from: http://history.uroweb.org/history-of-urology/diagnosis/looking-into-the-body/bozzini-and-the-lichtleiter/.

Gendy R, Delprado W, Brenner P, Brooks A, Coombes G, Cozzi P, Nash P, Patel MI. Repeat transurethral resection for non-muscle-invasive bladder cancer: a contemporary series. BJU Int. 2016;117(Suppl 4):54–9. https://doi.org/10.1111/bju.13265.

Gontero P, Sylvester R, Pisano F, Joniau S, Oderda M, Serretta V, Larre S, Di Stasi S, Van Rhijn B, Witjes AJ, Grotenhuis AJ, Colombo R, Briganti A, Babjuk M, Soukup V, Malmstrom PU, Irani J, Malats N, Baniel J, Mano R, Cai T, Cha EK, Ardelt P, Vakarakis J, Bartoletti R, Dalbagni G, Shariat SF, Xylinas E, Karnes RJ, Palou J. The impact of re-transurethral resection on clinical outcomes in a large multicentre cohort of patients with T1 high-grade/Grade 3 bladder cancer treated with bacille Calmette-Guerin. BJU Int. 2016;118(1):44–52. https://doi.org/10.1111/bju.13354.

Gupta NP, Saini AK, Dogra PN, Seth A, Kumar R. Bipolar energy for transurethral resection of bladder tumours at low-power settings: initial experience. BJU Int. 2011;108(4):553–6. https://doi.org/10.1111/j.1464-410X.2010.09903.x.

Hashine K, Ide T, Nakashima T, Hosokawa T, Ninomiya I, Teramoto N. Results of second transurethral resection for high-grade T1 bladder cancer. Urol Ann. 2016;8(1):10–5. https://doi.org/10.4103/0974-7796.163798.

Herr HW. Conservative management of muscle-infiltrating bladder cancer: prospective experience. J Urol. 1987;138(5):1162–3.

Herr HW. Legacy of Edwin Beer: fulguration of papillary bladder tumors. J Urol. 2005;173(4):1087–9. https://doi.org/10.1097/01.ju.0000152314.60154.d7.

Herr HW. Early history of endoscopic treatment of bladder tumors from Grunfeld's polypenkneipe to the Stern-McCarthy resectoscope. J Endourol. 2006;20(2):85–91. https://doi.org/10.1089/end.2006.20.85.

Herr HW, Donat SM. Quality control in transurethral resection of bladder tumours. BJU Int. 2008;102(9 Pt B):1242–6. https://doi.org/10.1111/j.1464-410X.2008.07966.x.

Islas-Garcia JJ, Campos-Salcedo JG, Lopez-Benjume BI, Torres-Gomez JJ, Aguilar-Colmenero J, Martinez-Alonso IA, Gil-Villa SA. Surgical technique for en bloc transurethral resection of bladder tumour with a Hybrid Knife((R)). Actas Urol Esp. 2016;40(4):263–7. https://doi.org/10.1016/j.acuro.2015.11.001.

Kausch I, Sommerauer M, Montorsi F, Stenzl A, Jacqmin D, Jichlinski P, Jocham D, Ziegler A, Vonthein R. Photodynamic diagnosis in non-muscle-invasive bladder cancer: a systematic review and cumulative analysis of prospective studies. Eur Urol. 2010;57(4):595–606. https://doi.org/10.1016/j.eururo.2009.11.041.

Kramer MW, Rassweiler JJ, Klein J, Martov A, Baykov N, Lusuardi L, Janetschek G, Hurle R, Wolters M, Abbas M, von Klot CA, Leitenberger A, Riedl M, Nagele U, Merseburger AS, Kuczyk MA, Babjuk M, Herrmann TR. En bloc resection of urothelium carcinoma of the bladder (EBRUC): a European multicenter study to compare safety, efficacy, and outcome of laser and electrical en bloc transurethral resection of bladder tumor. World J Urol. 2015;33(12):1937–43. https://doi.org/10.1007/s00345-015-1568-6.

Lazica DA, Roth S, Brandt AS, Bottcher S, Mathers MJ, Ubrig B. Second transurethral resection after Ta high-grade bladder tumor: a 4.5-year period at a single university center. Urol Int. 2014;92(2):131–5. https://doi.org/10.1159/000353089.

Mariappan P, Zachou A, Grigor KM, Edinburgh Uro-Oncology Group. Detrusor muscle in the first, apparently complete transurethral resection of bladder tumour specimen is a surrogate marker of resection quality, predicts risk of early recurrence, and is dependent on operator experience. Eur Urol. 2010;57(5):843–9. https://doi.org/10.1016/j.eururo.2009.05.047.

Mariappan P, Finney SM, Head E, Somani BK, Zachou A, Smith G, Mishriki SF, N'Dow J, Grigor KM, Edinburgh Urological Cancer Group. Good quality white-light transurethral resection of bladder tumours (GQ-WLTURBT) with experienced surgeons performing complete resections and obtaining detrusor muscle reduces early recurrence in new non-muscle-invasive bladder cancer: validation across time and place and recommendation for benchmarking. BJU Int. 2012;109(11):1666–73. https://doi.org/10.1111/j.1464-410X.2011.10571.x.

Mariappan P, Rai B, El-Mokadem I, Anderson CH, Lee H, Stewart S, Donat R. Real-life experience: early recurrence with Hexvix photodynamic diagnosis-assisted transurethral resection of bladder tumour vs good-quality white light TURBT in new non-muscle-invasive bladder cancer. Urology. 2015;86(2):327–31. https://doi.org/10.1016/j.urology.2015.04.015.

Mowatt G, N'Dow J, Vale L, Nabi G, Boachie C, Cook JA, Fraser C, Griffiths TR, Aberdeen Technology Assessment Review Group. Photodynamic diagnosis of bladder cancer compared with white light cystoscopy: systematic review and meta-analysis. Int J Technol Assess Health Care. 2011;27(1):3–10. https://doi.org/10.1017/S0266462310001364.

Mungan MU, Canda AE, Tuzel E, Yorukoglu K, Kirkali Z. Risk factors for mucosal prostatic urethral involvement in superficial transitional cell carcinoma of the bladder. Eur Urol. 2005;48(5):760–3. https://doi.org/10.1016/j.eururo.2005.05.021.

Naito S, Algaba F, Babjuk M, Bryan RT, Sun YH, Valiquette L, de la Rosette J, on behalf of the CROES Narrow Band Imaging Global Study Group. The Clinical Research Office of the Endourological Society (CROES) multicentre randomised trial of narrow band imaging-assisted Transurethral Resection of Bladder Tumour (TURBT) versus conventional white light imaging-assisted TURBT in primary non-muscle-invasive bladder cancer patients: trial protocol and 1-year results. Eur Urol. 2016;70(3):506–15. https://doi.org/10.1016/j.eururo.2016.03.053.

Naselli A, Introini C, Germinale F, Spina B, Puppo P. En bloc transurethral resection of bladder lesions: a trick to retrieve specimens up to 4.5 cm. BJU Int. 2012;109(6):960–3. https://doi.org/10.1111/j.1464-410X.2012.10982.x.

Nezhat C. Nezhat's history of endoscopy. n.d. 2018. http://laparoscopy.blogs.com/endoscopyhistory/chapter_11/.

O'Brien T, Ray E, Chatterton K, Khan MS, Chandra A, Thomas K. Prospective randomized trial of hexylaminolevulinate photodynamic-assisted transurethral resection of bladder tumour (TURBT) plus single-shot intravesical mitomycin C vs conventional white-light TURBT plus mitomycin C in newly presenting non-muscle-invasive bladder cancer. BJU Int. 2013;112(8):1096–104. https://doi.org/10.1111/bju.12355.

Oosterlinck W, Kurth KH, Schroder F, Bultinck J, Hammond B, Sylvester R. A prospective European Organization for Research and Treatment of Cancer Genitourinary Group randomized trial comparing transurethral resection followed by a single intravesical instillation of epirubicin or water in single stage Ta, T1 papillary carcinoma of the bladder. J Urol. 1993;149(4):749–52.

Ozer K, Horsanali MO, Gorgel SN, Ozbek E. Bladder injury secondary to obturator reflex is more common with plasmakinetic transurethral resection than monopolar transurethral resection of bladder cancer. Cent Eur J Urol. 2015;68(3):284–8. https://doi.org/10.5173/ceju.2015.565.

Palou J, Rodriguez-Rubio F, Huguet J, Segarra J, Ribal MJ, Alcaraz A, Villavicencio H. Multivariate analysis of clinical parameters of synchronous primary superficial bladder cancer and upper urinary tract tumor. J Urol. 2005;174(3):859–61; discussion 861. https://doi.org/10.1097/01.ju.0000169424.79702.6d.

Palou J, Sylvester RJ, Faba OR, Parada R, Pena JA, Algaba F, Villavicencio H. Female gender and carcinoma in situ in the prostatic urethra are prognostic factors for recurrence, progression, and disease-specific mortality in T1G3 bladder cancer patients treated with bacillus Calmette-Guerin. Eur Urol. 2012;62(1):118–25. https://doi.org/10.1016/j.eururo.2011.10.029.

Pan JS, Slocum HK, Rustum YM, Greco WR, Gaeta JF, Huben RP. Inhibition of implantation of murine bladder tumor by thiotepa in cauterized bladder. J Urol. 1989;142(6):1589–93.

Perlis N, Zlotta AR, Beyene J, Finelli A, Fleshner NE, Kulkarni GS. Immediate post-transurethral resection of bladder tumor intravesical chemotherapy prevents non-muscle-invasive bladder cancer recurrences: an updated meta-analysis on 2548 patients and quality-of-evidence review. Eur Urol. 2013;64(3):421–30. https://doi.org/10.1016/j.eururo.2013.06.009.

Ploussard G, Daneshmand S, Efstathiou JA, Herr HW, James ND, Rodel CM, Shariat SF, Shipley WU, Sternberg CN, Thalmann GN, Kassouf W. Critical analysis of bladder sparing with trimodal therapy in muscle-invasive bladder cancer: a systematic review. Eur Urol. 2014;66(1):120–37. https://doi.org/10.1016/j.eururo.2014.02.038.

Pode D, Alon Y, Horowitz AT, Vlodavsky I, Biran S. The mechanism of human bladder tumor implantation in an in vitro model. J Urol. 1986;136(2):482–6.

Ray ER, Chatterton K, Khan MS, Chandra A, Thomas K, Dasgupta P, O'Brien TS. Hexylaminolaevulinate fluorescence cystoscopy in patients previously treated with intravesical bacille Calmette-Guerin. BJU Int. 2010;105(6):789–94. https://doi.org/10.1111/j.1464-410X.2009.08839.x.

Richterstetter M, Wullich B, Amann K, Haeberle L, Engehausen DG, Goebell PJ, Krause FS. The value of extended transurethral resection of bladder tumour (TURBT) in the treatment of bladder cancer. BJU Int. 2012;110(2 Pt 2):E76–9. https://doi.org/10.1111/j.1464-410X.2011.10904.x.

Rozanskia AT, Benson C, McCoyb JA, Green CE, Barton Grossmana H, Svatekd RS, Shah JB. Is exam under anesthesia still necessary for the staging of bladder cancer in the era of modern imaging? Bladder Cancer. 2015;1:91–6.

Schumacher MC, Holmang S, Davidsson T, Friedrich B, Pedersen J, Wiklund NP. Transurethral resection of non-muscle-invasive bladder transitional cell cancers with or without 5-aminolevulinic acid under visible and fluorescent light: results of a prospective, randomised, multicentre study. Eur Urol. 2010;57(2):293–9. https://doi.org/10.1016/j.eururo.2009.10.030.

Sfakianos JP, Kim PH, Hakimi AA, Herr HW. The effect of restaging transurethral resection on recurrence and progression rates in patients with nonmuscle invasive bladder cancer treated with intravesical bacillus Calmette-Guerin. J Urol. 2014;191(2):341–5. https://doi.org/10.1016/j.juro.2013.08.022.

Singh H, Desai MR, Shrivastav P, Vani K. Bipolar versus monopolar transurethral resection of prostate: randomized controlled study. J Endourol. 2005;19(3):333–8. https://doi.org/10.1089/end.2005.19.333.

Stenzl A, Penkoff H, Dajc-Sommerer E, Zumbraegel A, Hoeltl L, Scholz M, Riedl C, Bugelnig J, Hobisch A, Burger M, Mikuz G, Pichlmeier U. Detection and clinical outcome of urinary bladder cancer with 5-aminolevulinic acid-induced fluorescence cystoscopy: a multicenter randomized, double-blind, placebo-controlled trial. Cancer. 2011;117(5):938–47. https://doi.org/10.1002/cncr.25523.

Sugihara T, Yasunaga H, Horiguchi H, Matsui H, Nishimatsu H, Nakagawa T, Fushimi K, Kattan MW, Homma Y. Comparison of perioperative outcomes including severe bladder injury between monopolar and bipolar transurethral resection of bladder tumors: a population based comparison. J Urol. 2014;192(5):1355–9. https://doi.org/10.1016/j.juro.2014.05.100.

Surgeons TBAoU Virtual Museum Resectoscopes. The British Association of Urological Surgeons. n.d. 2018. https://www.baus.org.uk/museum/133/sternmccarthy_resectoscope.

Sylvester RJ, Oosterlinck W, Witjes JA. The schedule and duration of intravesical chemotherapy in patients with non-muscle-invasive bladder cancer: a systematic review of the published results of randomized clinical trials. Eur Urol. 2008;53(4):709–19. https://doi.org/10.1016/j.eururo.2008.01.015.

Sylvester RJ, Oosterlinck W, Holmang S, Sydes MR, Birtle A, Gudjonsson S, De Nunzio C, Okamura K, Kaasinen E, Solsona E, Ali-El-Dein B, Tatar CA, Inman BA, N'Dow J, Oddens JR, Babjuk M. Systematic review and individual patient data meta-analysis of randomized trials comparing a single immediate instillation of chemotherapy after transurethral resection with transurethral resection alone in patients with stage pTa-pT1 urothelial carcinoma of the bladder: which patients benefit from the instillation? Eur Urol. 2016;69(2):231–44. https://doi.org/10.1016/j.eururo.2015.05.050.

Teoh JY, Chan ES, Yip SY, Tam HM, Chiu PK, Yee CH, Wong HM, Chan CK, Hou SS, Ng CF. Comparison of detrusor muscle sampling rate in monopolar and bipolar transurethral resection of bladder tumor: a randomized trial. Ann Surg Oncol. 2016; https://doi.org/10.1245/s10434-016-5700-7.

Teoh JY, Chan ES, Yip SY, Tam HM, Chiu PK, Yee CH, Wong HM, Chan CK, Hou SS, Ng CF. Comparison of detrusor muscle sampling rate in monopolar and bipolar transurethral resection of bladder tumor: a randomized trial. Ann Surg Oncol. 2017;24(5):1428–34. https://doi.org/10.1245/s10434-016-5700-7.

Tolley DA, Parmar MK, Grigor KM, Lallemand G, Benyon LL, Fellows J, Freedman LS, Grigor KM, Hall RR, Hargreave TB, Munson K, Newling DW, Richards B, Robinson MR, Rose MB, Smith PH, Williams JL, Whelan P. The effect of intravesical mitomycin C on recurrence of newly diagnosed superficial bladder cancer: a further report with 7 years of follow up. J Urol. 1996;155(4):1233–8.

Ukai R, Kawashita E, Ikeda H. A new technique for transurethral resection of superficial bladder tumor in 1 piece. J Urol. 2000;163(3):878–9.

Vasdev N, Dominguez-Escrig J, Paez E, Johnson MI, Durkan GC, Thorpe AC. The impact of early re-resection in patients with pT1 high-grade non-muscle invasive bladder cancer. Ecancermedicalscience. 2012;6:269. https://doi.org/10.3332/ecancer.2012.269.

Venkatramani V, Panda A, Manojkumar R, Kekre NS. Monopolar versus bipolar transurethral resection of bladder tumors: a single center, parallel arm, randomized, controlled trial. J Urol. 2014;191(6):1703–7. https://doi.org/10.1016/j.juro.2013.12.004.

Wein AJ, Kavoussi LR, Novick AC, Partin AW, Peters CA. Campbell-Walsh urology. 10th ed. Amsterdam: Elsevier; 2012.

Zhao C, Tang K, Yang H, Xia D, Chen Z. Bipolar versus monopolar transurethral resection of nonmuscle-invasive bladder cancer: a meta-analysis. J Endourol. 2016;30(1):5–12. https://doi.org/10.1089/end.2015.0410.

Zheng C, Lv Y, Zhong Q, Wang R, Jiang Q. Narrow band imaging diagnosis of bladder cancer: systematic review and meta-analysis. BJU Int. 2012;110(11 Pt B):E680–7. https://doi.org/10.1111/j.1464-410X.2012.11500.x.

# Robot-Assisted Radical Cystectomy: Surgical Technique

12

Cheng-kuang Yang

**Abstract**

Radical cystectomy is the standard treatment of muscle-invasive bladder cancer. The feasibility and safety of robotic radical cystectomy have been proven and is gaining popularity in recent years. The surgical techniques are getting more standardized. In this article, we will share the surgical techniques of robotic radical cystectomy in stepwise manner with illustrations in our center.

**Keywords**

Robotic · Assisted radical cystectomy · Bladder cancer Urothelial carcinoma

## 12.1 Introduction

In 2015, bladder cancer is the tenth most common cancer in Taiwanese male. Bladder cancer tends to be male predominant (Siegel et al. 2016; Chavan et al. 2014), in a male-to-female predominance ratio of 2.55:1. Urothelial carcinoma (UC) is the most common type of bladder cancer, accounting for 94.3%. The mortality rate of bladder cancer is relatively low in 2015, 3.15 per 100,000 in male and 1.34 in female.

The diagnosis and treatment for bladder cancer also mainly follows NCCN (Spiess et al. 2017) and EAU guidelines (Alfred Witjes et al. 2017). Transurethral resection of bladder tumor is routinely performed for initial diagnosis, staging and treatment. Radical cystectomy is indicated for patients with muscle-invasive bladder cancers, as well as persistent Tis, T1 and Ta high-grade disease with failure to intravesical therapy. Open procedure remains the gold standard. Laparoscopic and robotic approaches are performed in the selected institutions.

## 12.2 Surgical Procedures and Techniques

### 12.2.1 Step 1: Positioning and Port Placement

Patient is placed in supine position at the beginning and standard six port technique is common used for the procedure. Camera port is placed 4–5 cm above the umbilicus using Hasson method. Pneumoperitonium is created with a pressure around 15 mmHg. Then patient is placed to Trendelenburg head down position, until the cul de sac exposures. 12 mm assistant port is placed at 2 cm above and medial to the right anterior superior iliac spine. Two robotic ports are placed 8–10 cm away from camera. The third robotic ports were placed through the 12 mm or 15 mm port, also at 2 cm above and medial to the left anterior superior iliac spine. Another assistant port is placed at either side of upper abdomen (Fig. 12.1). All robotic and assistant ports are placed under vision.

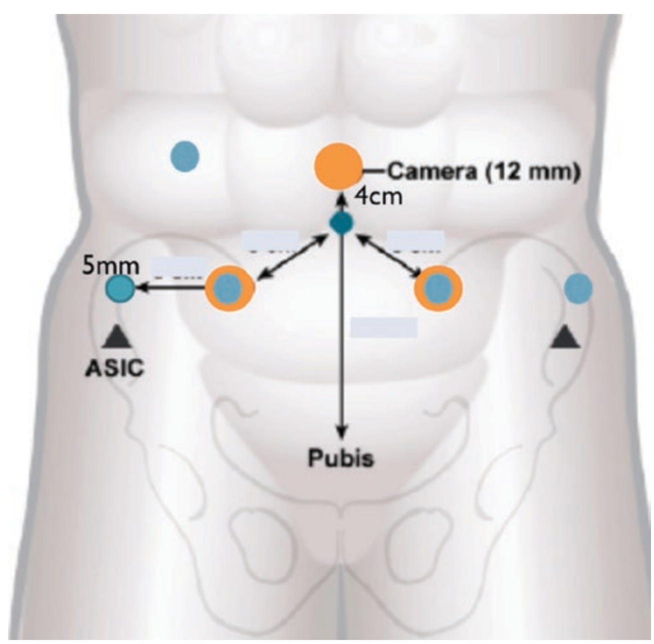


**Fig. 12.1** Port site location

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**Fig. 12.2** Dissection posterior to seminal vesicles

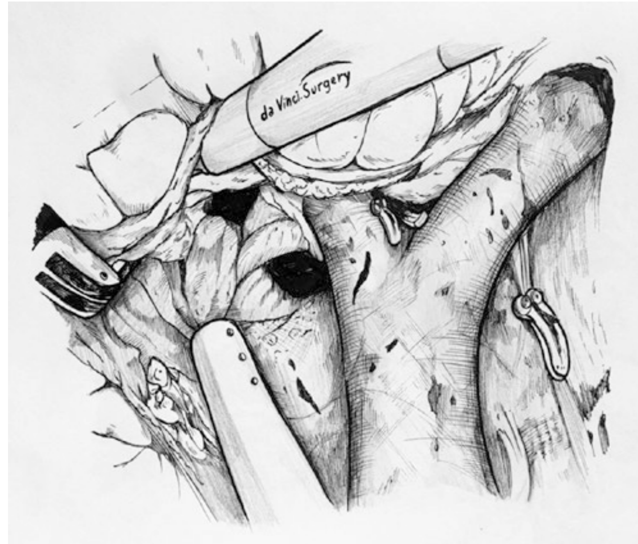


**Fig. 12.3** Exposure of aortic bifurcations

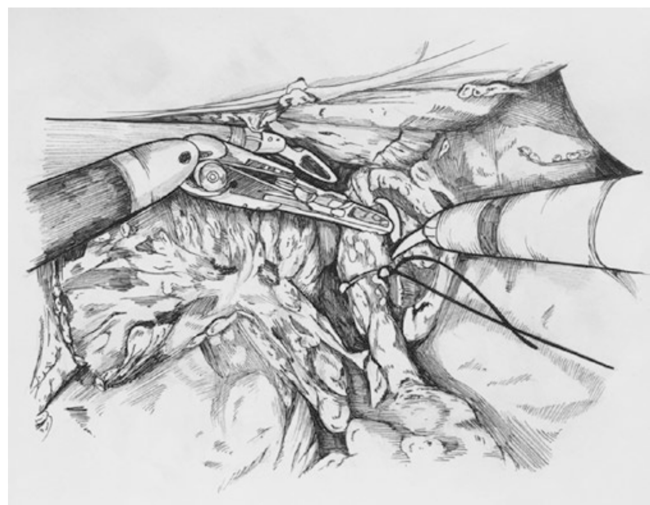

**Fig. 12.4** Division of right ureter

### 12.2.2 Step 2: Posterior Dissection

Identify the anterior rectal space and incise the peritoneum close to the seminal vesicle in male or, uterine base in female cystectomy between the mesorectum. Meticulously dissection along the plane behind the seminal vesicle/uterine base is performed until Denonvilliar's fascia is exposure. After incising the Denonvilliar's fascia, dissection is carried on along the plane between prostate/uterine base posteriorly and to the prostate and uterine pedicles laterally (Fig. 12.2). Special attendtion is given to the prerectal fat tissue and erectile nerve while dissection.

### 12.2.3 Step 3: Pelvic Lymph Node Dissection and Lateral Dissection

Incise the peritoneum over the aortic bifurcation and open the peritoneum lateral to right ureter (Fig. 12.3). Dissect the ureter down to the ureterovesical junction with the periureteral soft tissue intact. Distal ureter is divided after clipping with Hemolok (Fig. 12.4). Retract the ureter cranially and expose the aortic bifurcation and inferior vena cava. Identify the inferior mesenteric artery first, then dissect the lymphatic tissue along the aorta to the presarcral region meticulously. Dissect the lymphatic tissue from medial (common iliac artery) to the lateral (external iliac artery) and develop the space of Retzius. Urachus and umbilical ligament are kept intact to ensure the bladder attached anteriorly not to influence operating field. Dissect the external iliac lymphatic tissue from common iliac region to the pelvic side wall. Genitofemoral nerve, psoas muscle and obturator nerve can be identified in this moment (Fig. 12.5). Lymphatic tissue at the obturator region can be cleared from lateral to medial up to proximal obturator nerve region. Internal iliac lymph nodes, which are located lateral to the obturator nerve its vessels, can be excised with meticulous hemostasis (Fig. 12.6).

Endopelvic fascia is incised. Prostate/cervix is dissected free from levator ani muscle fascia and surrounding tissues. Lifting the seminal vesicle tip or uterine base with third robotic arm facilitates apical dissection. Bladder pedicles are controlled with endoscopic staplers or Hemolok clips carefully (Fig. 12.7). Vessel sealer is not recommended due to

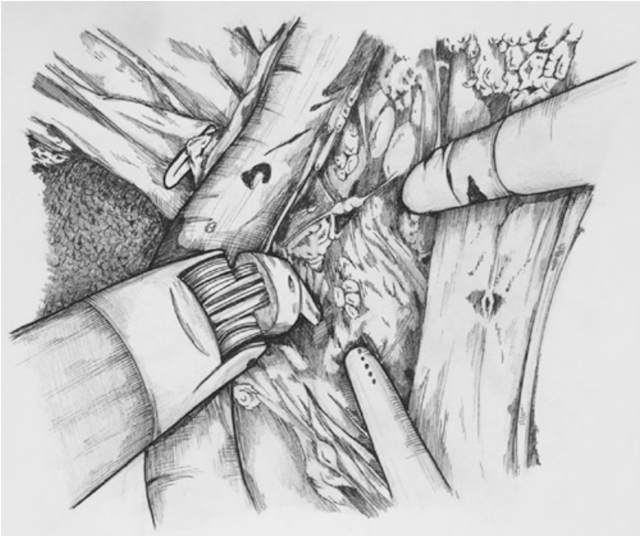

Fig. 12.5 Lymph node dissection at angle of Marcille

Fig. 12.6 Obturator fossa

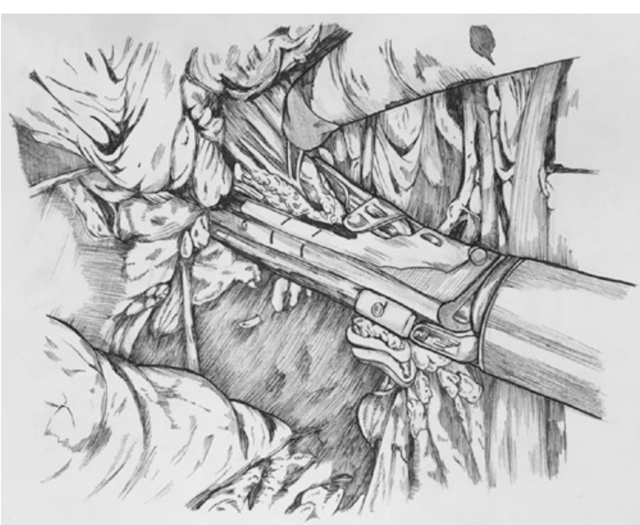

Fig. 12.7 Transection of lateral pedicle by using endoscopic staplers

potential thermal injury to hypogastric nerve and inadequate control for vascular pedicles. Similar procedures are performed on the left side lymph node dissection and following pedicle control.

### 12.2.4 Step 4: Completion of Cystectomy

Take down the bladder along the areolar space after dividing the urachus and umbilical ligaments. Preserve the neurovascular bundles from the prostate capsule. The deep dorsal venous complex (DVC) is divided with cold scissors followed by suturing of DVC stump. Maximal sparing of the periurethral tissues is crucial for orthotropic neobaldder reconstruction for continence concern. Suturing or clipping of proximal urethral stump is performed in order to avoid urine spillage from bladder. For female cystectomy with ileal conduit diversion, total urethrectomy is performed. If orthotropic neobladder is scheduled for female cystectomy, urethra stump is preserved 0.5 cm distal to bladder neck. After completion of cystectomy, specimen is placed into retrieval bag. The left ureter is brought behind the sigmoid mesentery to the right side for subsequent ureteroenteric anastomosis (Fig. 12.8).

## 12.3 Discussion

Although open procedure is the gold standard of radical cystectomy, laparoscopic or robot-assisted approaches have gained increasing attention worldwide due to the benefits from minimal invasive nature, including less blood loss, shorter recovery and better cosmesis. However, the reconstruction of

Fig. 12.8 Left ureter is brought to right side behind sigmoid colon

urinary tract, either orthotopic bladder substitution or ileal conduit, is still a challenging part in the laparoscopic or robot-assisted radical cystectomy. Intracorporeal urinary diversion is time-consuming and may be associated with increased ureteric or bowel complications. We prefer extracorporeal reconstruction via a 4-cm transverse extension incision of the right robot port or laparoscopic trocar. This approach shares the same advantage of minimal invasive properties and prevent from the disadvantages and complications from total intracorporeal reconstruction.

## References

Alfred Witjes J, Lebret T, Compérat EM, et al. Updated 2016 EAU guidelines on muscle-invasive and metastatic bladder cancer. Eur Urol. 2017;71(3):462–75.

Chavan S, Bray F, Lortet-Tieulent J, Goodman M, Jemal A. International variations in bladder cancer incidence and mortality. Eur Urol. 2014;66:59–73.

Siegel RL, Miller KD, Jemal A. Cancer statistics, 2016. CA Cancer J Clin. 2016;66:7–30.

Spiess PE, Agarqal N, Bangs R, et al. Bladder cancer, version 5.2017, NCCN clinical practice guidelines in oncology. J Natl Compr Cancer Netw. 2017 Oct;15(10):1240–67.

# Robot-Assisted Radical Cystectomy: Technical Tips for Totally Intracorporeal Urinary Diversion

13

Seok Ho Kang and Ji Sung Shim

**Abstract**

Robot-assisted radical cystectomy (RARC) has emerged as an equivalent approach to open radical cystectomy (RC) with potentially equivalent oncological outcomes. Whether urinary diversion (UD) during RARC is best completed extracorporeally or intracorporeally remains a debatable topic among clinicians. The UD procedure could constitute a more significant factor associated with postoperative morbidity and complications than the actual cystectomy itself. Following the introduction of minimally invasive techniques used to perform a cystectomy, extracorporeal urinary diversion (ECUD) is widely accepted as a more efficient and safe method, and most RARC procedures in the United States are performed through an ECUD.

Most case reports describing RARC indicate the use of ECUD owing to perceived difficulties with intracorporeal bowel reconstruction (ICUD) and concerns about time efficiency compared to open surgery. However, a total ICUD approach could be considered a possible alternative to maximize the advantages of minimally invasive surgery. It is known that ICUD minimizes evaporative fluid loss, decreases estimated blood loss, reduces the risk of fluid imbalance, and pain, and rapidly restores bowel function. Despite there are potential perioperative benefits, ICUD has been criticized due to doubts regarding the ability to perform this procedure routinely during surgery and its benefits to patients without further increasing the rate of complications.

We adduce a step-wise description of our RARC technique with bilateral PLND and UD that adheres to the established dimensions and configuration of the Studer neobladder.

**Keywords**

Bladder cancer · Radical cystectomy · Robotic surgical procedures · Urinary diversion

## 13.1 Preface

Approximately 20–30% of patients examined in clinical practice present with muscle-invasive bladder cancer (MIBC) at the time of initial diagnosis (Herr 2009). Radical cystectomy (RC) with bilateral pelvic lymph node dissection (PLND) is the treatment of choice for clinically localized MIBC and is also performed for the management of patients with aggressive non-muscle-invasive bladder cancer (NMIBC) (Shariat et al. 2006).

Robot-assisted radical cystectomy (RARC) has emerged as an equivalent approach to open RC with potentially equivalent oncological outcomes. Moreover, it has been suggested that RARC is associated with improved perioperative morbidity, better recovery, and allows earlier initiation of adjuvant systemic therapies. Although early oncological outcomes appear to be favorable, longer-term follow-up studies are limited (Khan et al. 2013; Xylinas et al. 2013).

Whether urinary diversion (UD) during RARC is best completed extracorporeally or intracorporeally remains a debatable topic among clinicians. Most case reports describing RARC indicate the use of extracorporeal urinary diversion (ECUD) owing to the complexity of the intracorporeal urinary diversion (ICUD) procedure. However, a total ICUD approach could be considered a possible alternative to maximize the advantages of minimally invasive surgery (Pyun et al. 2016).

It is known that ICUD minimizes evaporative fluid loss, decreases estimated blood loss, reduces the risk of fluid imbalance, and pain, and rapidly restores bowel function (Pyun et al. 2016; Jonsson et al. 2011). Despite potential perioperative benefits, ICUD has been criticized due to doubts regarding the ability to perform this procedure routinely during surgery and its benefits to patients without further increasing the rate of complications.

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We present a step-wise description of our RARC technique with bilateral PLND and UD that adheres to the established dimensions and configuration of the Studer neobladder. We have particularly focused on the technical aspect of ICUD instead of the overall procedure.

## 13.2 Background for Considering Intracorporeal Urinary Diversion

### 13.2.1 Current Status of Intracorporeal Urinary Diversion

The UD procedure could constitute a more significant factor associated with postoperative morbidity and complications than the actual cystectomy itself (Liedberg 2010). Following the introduction of minimally invasive techniques used to perform a cystectomy, ECUD is widely accepted as a more efficient and safe method (Menon et al. 2004; Smith et al. 2012), and most RARC procedures in the United States are performed through an ECUD. Recent multicenter surveys reveal that only approximately 3% of cystectomies are performed via an ICUD (Smith et al. 2012). Despite the several theoretical benefits associated with reduced bowel manipulation, a relatively longer operation time and the need to use the incision site to extract the specimen are factors that favor the use of an ECUD. Additionally, surgeon fatigue must be considered a relevant issue because a mean operation time of 6 or 7 h has been reported in previous studies (Bochner et al. 2015; Raza et al. 2015).

### 13.2.2 Theoretical Benefits of Intracorporeal Urinary Diversion

1. Patients undergoing RC are often elderly patients with various associated comorbidities, which act as risk factors associated with a higher incidence of complications. There is a substantial body of evidence suggesting that compared to open surgery, RARC is useful in elderly and other vulnerable patients because it reduces surgical stress (Knox et al. 2013; Richards et al. 2012).

   This reduction in stress response that is characteristic of minimal access surgery (MAS) is also noted with ICUD and benefits both surgeons and patients. It minimizes the time of exposure of the abdominal viscera to ambient air, reduces blood loss, shortens postoperative recovery, and eventually accelerates recovery to normal life (Ost et al. 2005).
2. Open surgery is known to be associated with a significant suppression of the immune system (Grande et al. 2002). However, MAS is known to preserve immune function and maintain a good immune response and is useful for patient recovery. This action is primarily due to a local intraperitoneal immune response through a carbon dioxide pneumoperitoneum and a mechanical compression effect (Carter and Whelan 2001).
3. Gastrointestinal complications related to cystectomy are significant issues that often lead to longer hospitalization. In experimental models using white rats, the time of exposure of the peritoneum to the ambient air was directly proportional to intestinal inflammation and oxidative stress response. This leads to intestinal paralysis or intestinal obstruction, and it has been observed that the delay in restoration of bowel function is proportional to the time of exposure to the ambient air (Tan et al. 2014). The duration of peritoneal exposure was observed to be associated with systemic or intestinal inflammation and a subsequent increase in serum levels of malondialdehyde, superoxide dismutase, glutathione peroxidase, and the total antioxidant capacity (Lee et al. 2003; Sammour et al. 2010). A previous study comparing open bowel surgery with laparoscopy and laparotomy, has shown that cytokines including interleukin-1 and 6, and tumor necrosis factor alpha as well as systemic immunosuppression were lesser in the minimally invasive group. Additionally, degradation of muscle protein, lipolysis, glycolysis and fatigue were also decreased in the minimal access surgery/laparotomy and laparoscopy group (Sammour et al. 2010).

### 13.2.3 Proven Benefits of Intracorporeal Urinary Diversion

The International Robotic Cystectomy Consortium (IRCC) performed a large-scale study and reported a comparative analysis between ICUD and ECUD. Overall, ICUD showed favorable results in terms of lower complications—gastrointestinal complications which are the most common were significantly lesser with use of ICUD (10% vs. 23%, respectively, $P < 0.001$). This supports the theory that minimizing the loss of moisture from the intestine and preventing secondary intestinal damage and edema from manipulation, or mobilization of the abdominal viscera reduces complications (Ahmed et al. 2014).

Another advantage of ICUD is the relatively smaller incision required for the procedure (Shim et al. 2017). Usually, ECUD requires use of an Alexis wound retractor and an incision that is ≥7 cm because the ECUD procedure requires handling of the bowel to create a ureteral anastomosis. In comparison the ICUD incision is smaller and is used only to extract the specimen, which therefore causes fewer complications like wound dehiscence and provides a cosmetic advantage (Pyun et al. 2016). Prolonged hospitalization following RC is most commonly related to wound-related complications. ICUD offers a distinct advantage in this regard with a smaller incision and thereby facilitates early recovery of the patient (Mmeje et al. 2013; Zehnder and Gill 2011) (Fig. 13.1).

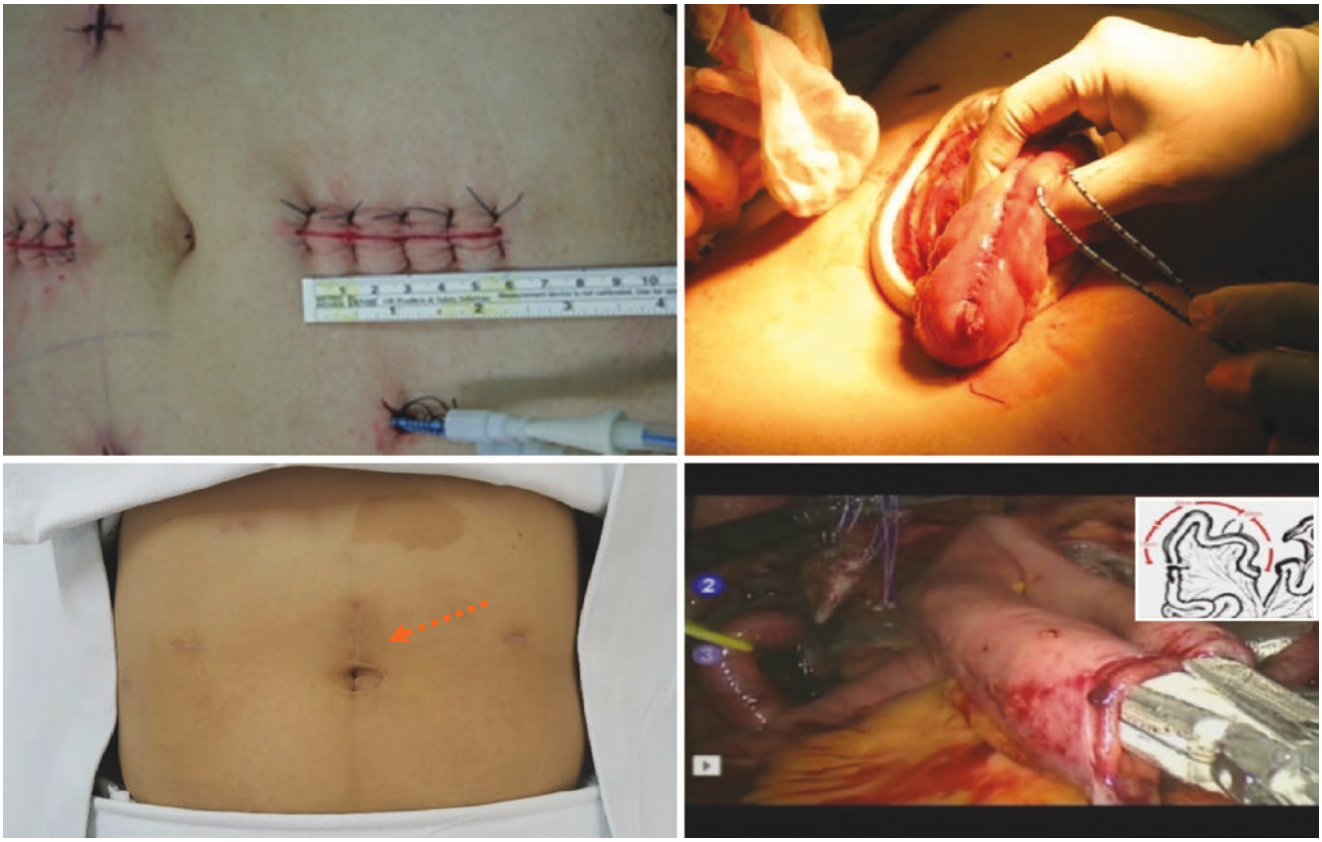

**Fig. 13.1** Comparison of wound size [extracorporeal urinary diversion (ECUD), postoperative image vs. intracorporeal urinary diversion (ICUD) 3 months later]

## 13.3 Detailed Technical Tips for a Robot-Assisted Radical Cystectomy with Intracorporeal Urinary Diversion

### 13.3.1 Preparation for Surgery

Usually, patients are admitted to the hospital approximately 1–3 days prior to the operation. Following an explanation about the risks, benefits, and alternatives of surgery, written informed consent is obtained. Patients receive education throughout the perioperative period regarding catheter management, pelvic floor exercises, and a proper voiding technique. We collect 24-h urine samples to calculate the glomerular filtration rate. We consult ophthalmology due to long time fixed position and perform urethrography in patients who are planned for neobladder formation. Bowel preparation is begun a day before surgery. Intake of water is permitted until mid day, and patients are maintained on a strict NPO status beginning mid night. On the day of surgery, bowel prep with betadine enema is applied once more and anti medication applied also.

#### 13.3.1.1 Postoperative Care

Mean postoperative hospitalization is approximately 10–14 days. We have recently adopted an Early Recovery after Surgery (ERAS) protocol that allows early postoperative discharge (Daneshmand et al. 2014). This protocol includes avoiding bowel preparation and nasogastric tubes, decreasing narcotic pain management (including epidural narcotics), instituting early feeding, and using a μ-opioid antagonist (morphine being the prototype) that blocks the effects of narcotics on the bowel. A nasogastric tube inserted during surgery is promptly removed after surgery. Sips of water are allowed the day after surgery. Advancement of solid food is based on the patient's symptoms and abdominal X-ray findings. The single-J catheter is removed approximately 5–7 days after RC. If there is no leakage observed, the Foley catheter is removed approximately 7–9 days after surgery, followed by removal of the drain. The protocol by which routine cystograms of the neobladder are obtained varies among centers.

### 13.3.2 Access and Port Placement

Patients are placed in the low lithotomy position with both arms adducted, tucked and padded. After sequential compression stockings are applied, patients are placed in the steep Trendelenburg position, and a Foley catheter is inserted under sterile precautions. A six-port (including the camera

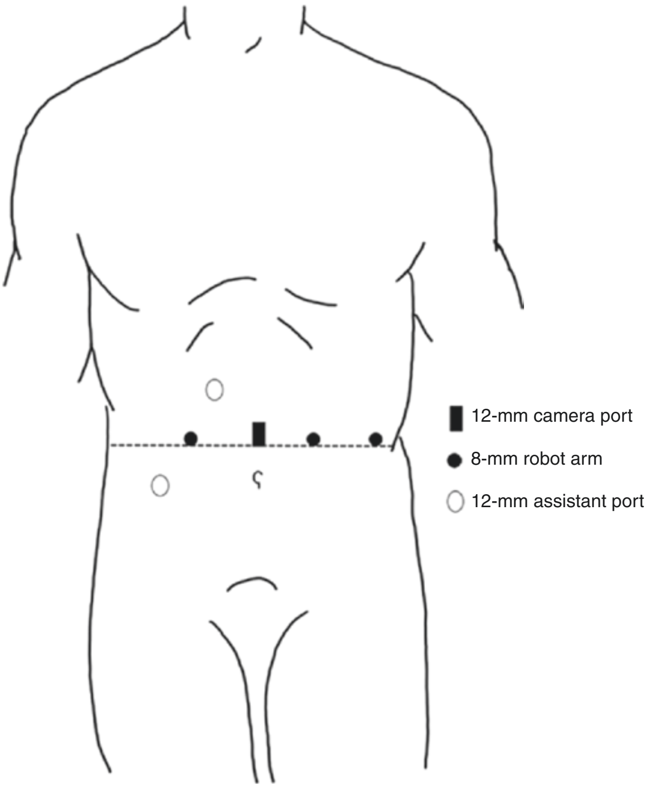


**Fig. 13.2** Port placement for robot-assisted radical cystectomy (RARC) and urinary diversion (UD)

port) transperitoneal technique is employed. Detailed port positions are depicted in Fig. 13.2.

### 13.3.3 Bilateral Pelvic Lymph Node Dissection

To date, there is no consensus among surgeons regarding whether RC or PLND should be performed first. At our hospital, we perform bilateral PLND prior to RC because this technique provides greater space and a wider operative field to perform the extended PLND (ePLND) which we perform after the RC. However, there are several reasons to adopt this sequence: (1) With the urachus suspended in its original anatomical position, the obliterated umbilical artery provides a useful guide to approach the internal iliac territory (Chan et al. 2015). (2) This dissection exposes the vascular pedicles clearly and allows the surgeon to perform a meticulous cystectomy. Notably, this is a very important oncological component of the procedure and the most technical and time-intensive segment of the operation.

At our hospital, we usually perform a ePLND during the operation. A Korean retrospective multicenter study including our center, demonstrated the mean lymph node yield of an ePLND was 24.0 ± 11.9 (Shim et al. 2017). The boundaries of ePLND are: Cranially, above the level of aortic bifurcation; laterally, the genitofemoral nerve; caudally, the femoral ring/circumflex iliac vein; and dorsally, the deep obturator and levator ani muscles, the sacrotuberous ligament, and the sacral bone. We carefully perform PLND including dissection in the triangle of Marcille. Individual packets are retrieved using a EndoPouch or a piece of surgical glove to avoid tumor spillage (Fig. 13.3).

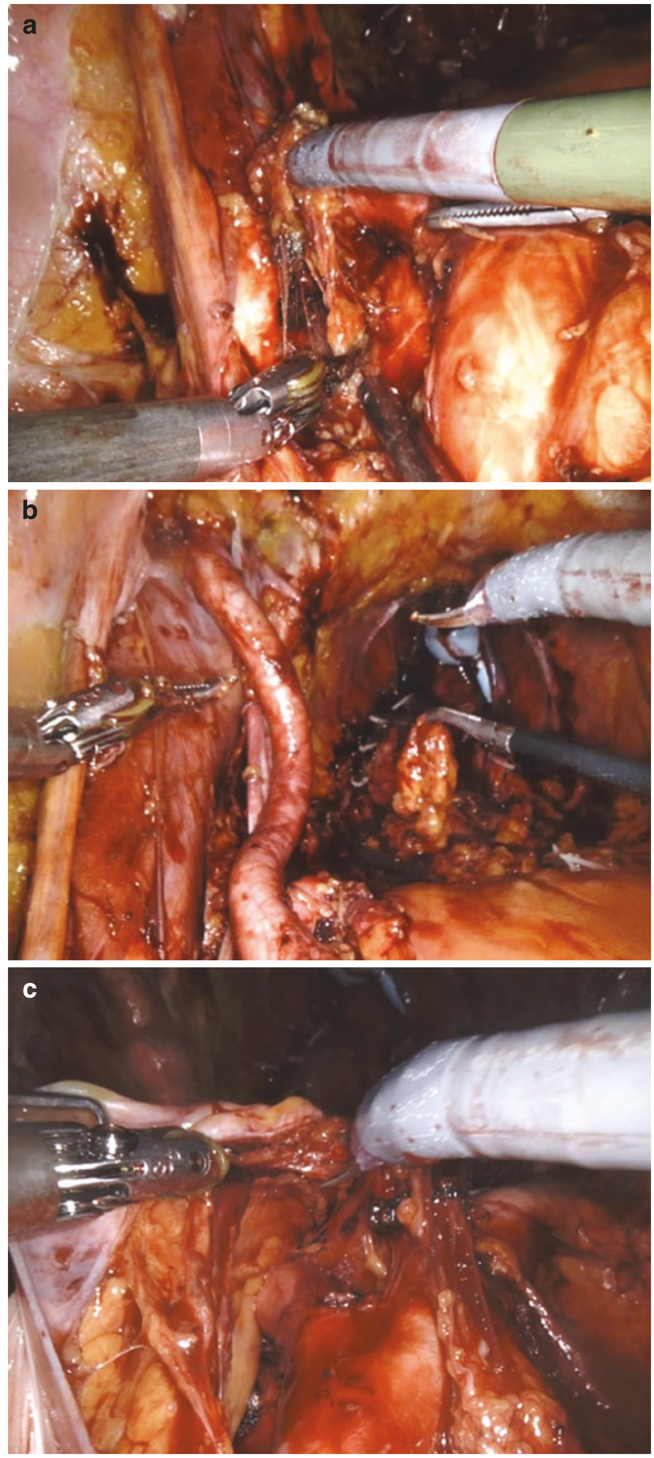


**Fig. 13.3** (**a**) Pelvic lymph node dissection (PLND) at the triangle of Marcille. (**b**) Picture after completion of the PLND on the left side. (**c**) PLND on aortic bifurcation

### 13.3.4 Radical Cystectomy

RC is easy to perform following successful completion of PLND. The principle and surgical technique is similar to an open surgery. Usually, the left ureter is under a greater amount of tension due to the overlying sigmoid colon and rectum. Lateral attachments of the sigmoid colon are divided to visualize the white line of Toldt. The sigmoid and descending colon are elevated and retracted medially to enter the retroperitoneum. Further medialization of the sigmoid colon helps to reach the left ureter. A clip and suture are applied together for easy manipulation and the ureter is replaced beneath the colon.

In RC, the initial posterior dissection is important in the early step of RARC (Canda et al. 2012). To ensure that patients do not experience post-procedural erectile dysfunction, a nerve-sparing procedure can be achieved using a retrograde early release (Fig. 13.4). Following lateral dissection, bilateral ligation of bladder vessels is performed using Hem-o-lok, metal clips, or endo GIA stapler. A robotic LigaSure can dissect all vessels other than the major arteries supplying the bladder, which reduces the operation time.

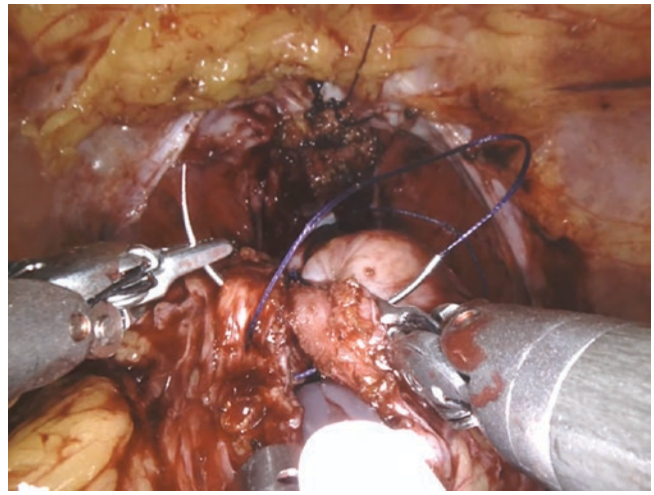

**Fig. 13.5** Suture for urethral opening by using V-Loc™ 4–0

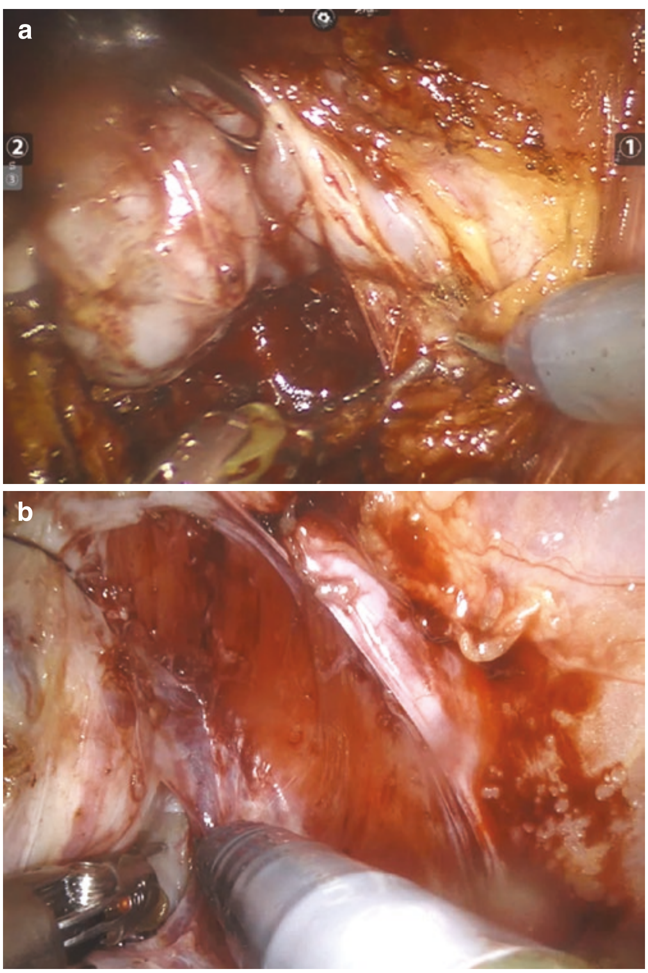


**Fig. 13.4** (**a**) Dissection at the posterior aspect of the prostate. (**b**) A nerve-sparing procedure is performed through the anterior aspect

An important precaution to consider during these procedures is preventing any local spillage of tumor and leakage of urine even after removing the specimen and transferring it into the EndoPouch. Additionally, we perform a suture around the urethral opening to prevent urinary leakage (Fig. 13.5).

### 13.3.5 Isolation of Ileum and Restoration of Bowel Continuity

The robot is undocked, and the patient is flattened out of the steep Trendelenburg position to proceed with the neobladder reconstruction procedure (Fig. 13.6). This facilitates easy handling of the bowel to bring the neobladder down to the urethra decreasing task gravity. A flexible ruler is used to approximate the antimesenteric ileal borders, which are tagged with a suture. Indocyanine green dye (quantity calculated based on the patient's weight) is injected to identify mesenteric vasculature. After identifying the vasculature, two sequential firings of Endo-GIA are performed and continuity of the open ends of the ileum is established using a single transverse firing of the Endo-GIA stapler, ensuring that both sides of the anastomosis are included (Fig. 13.7).

### 13.3.6 Application of Various Techniques for Neobladder Configuration

In addition to the most commonly used Studer procedure, various surgical methods are used in hospitals globally. A spheroidal configuration comprises of varieties such as the Studer orthotopic neobladder, the Hautmann ileal neobladder with a W-configured spherical reservoir, and the Padua

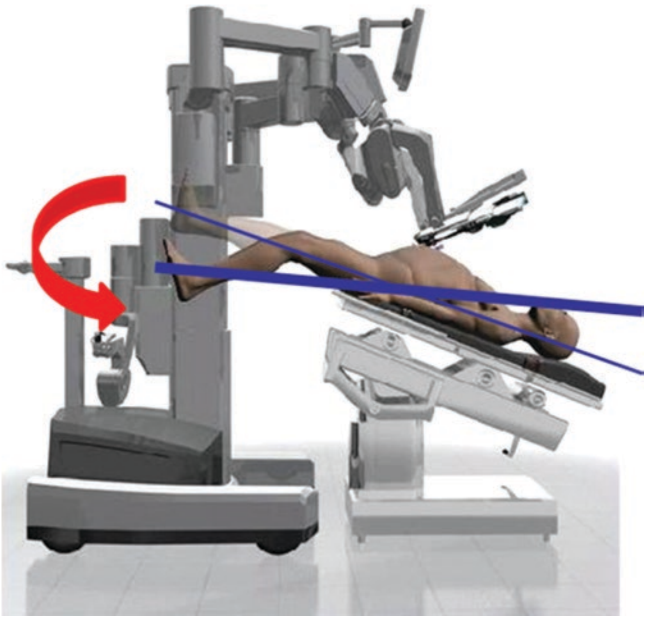

Fig. 13.6 The robot is undocked and the patient is flattened out of the steep Trendelenburg position

ileal neobladder to minimize the surface area and maximize the storage volume while reducing the pressure (Goh et al. 2012; Hussein et al. 2017; Simone et al. 2018; Studer and Turner 1995). There exist several variations in the length of the ileal segment used for each organ, methods of bowel detubularization, pouch construction, gross shape, and ureteroileal anastomosis. If only the principle of Laplace (making low-pressure, high-capacity globular reservoir) is well adhered to, these various procedures and their development represent the potential of ICUD itself.

### 13.3.7 Bilateral Stents with Ureteroileal Anastomosis

Each ureter is spatulated and a standard bilateral end-to-side ureteroileal anastomosis is performed using interrupted 4–0 polyglycolic acid sutures on a cutting needle. The incidence of ureteroileal stricture is identical to that observed with creation of an ileal conduit diversion and is influenced by the type of anastomosis performed. The direct end-to-side

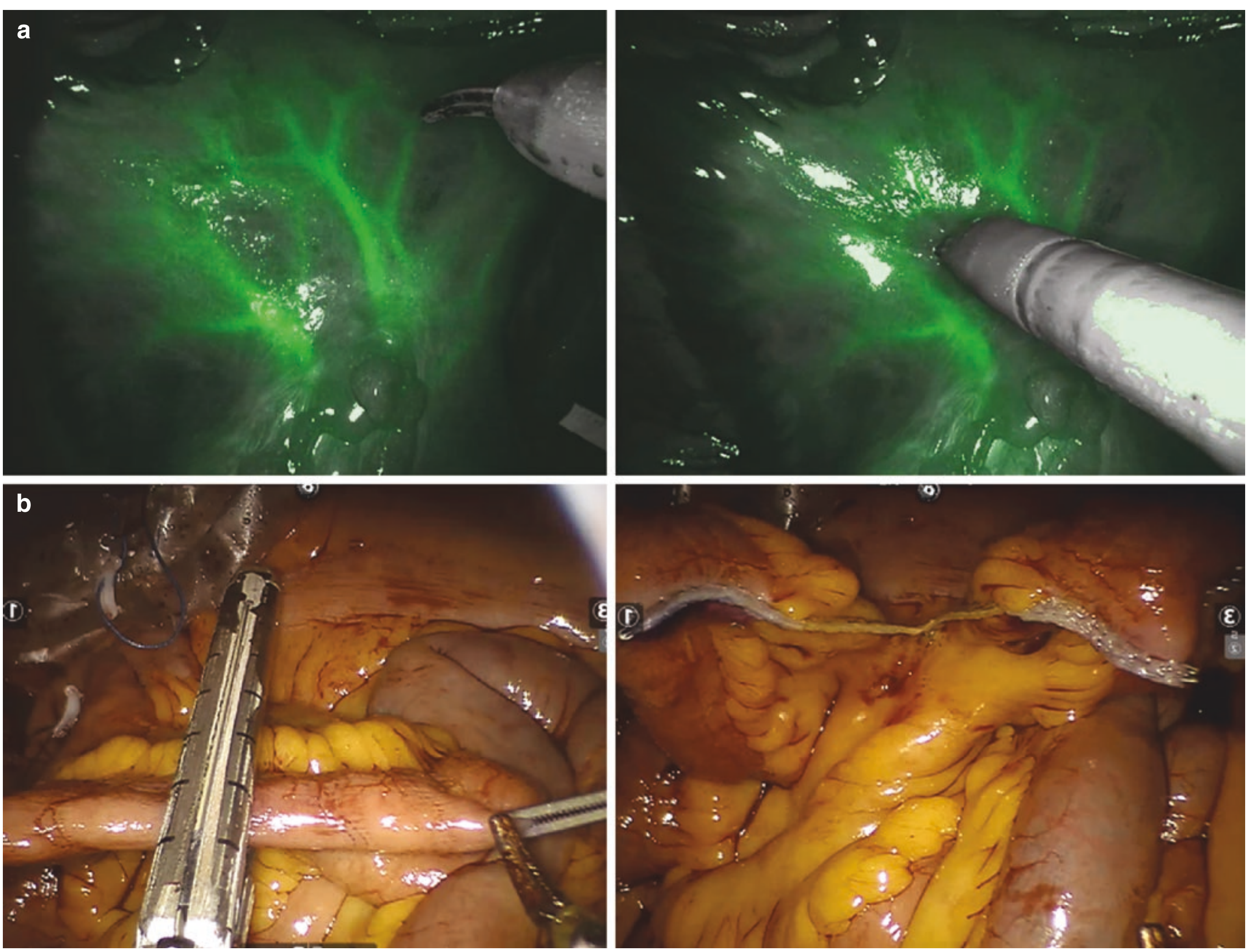


**Fig. 13.7** (**a**) Identification of the vascular supply to the mesentery. (**b**) Application of the Endo-GIA stapler to the ileum

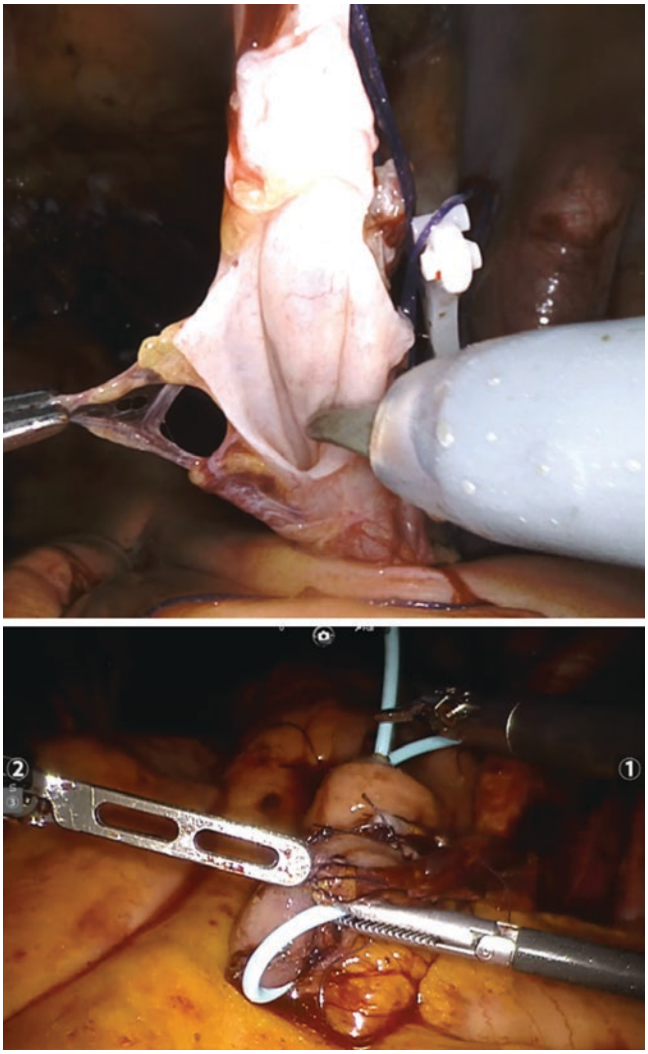

**Fig. 13.8** Wide spatulation of ureter, single-J stent insertion

Leadbetter or the combined Wallace anastomoses using interrupted fine absorbable sutures have been shown to be associated with the lowest risk of stricture formation (approximately 3–6%) (Hautmann et al. 2011). Next, a single-J stent is passed up to the kidney after one side of the surface is secured with a running suture. The end of the stent is gently pulled out through a midline incision made in the abdomen just above the pubic symphysis avoiding injury to the epigastric vessels. An advantage of using the single-J stent is that it does not need to be irrigated through a Foley catheter (Fig. 13.8).

## 13.4 Discussion Regarding the Learning Curve

Because RARC is a complicated and time-consuming technique, the learning curve associated with the procedure remains a controversial issue. When ICUD was newly introduced approximately 10 years ago, most published data indicated that the total operation time lasted between 9 and 10 h before overcoming the learning curve (Collins and Wiklund 2014). However, it is difficult to compare the present time with that a decade ago. In 2004, Wiklund and Gill reported the efficacy of an ICUD, and their findings have been supported by related evidence from other studies (Collins et al. 2014a). Moreover, although RARC by itself is associated with a long learning curve, its learning curve is shorter when compared to pure laparoscopic surgery (Haber et al. 2007; Richards et al. 2011). The IRCC suggest that surgeons with adequate experience in performing robotic-assisted prostatectomies are better equipped to overcome the learning curve associated with RARC (Hayn et al. 2010a, b). It is also known that working under the guidance of an experienced senior mentor surgeon in the same hospital could help to overcome the learning curve (Collins and Wiklund 2014; Collins et al. 2013, 2014b). At our hospital we determined the learning curve in terms of perioperative and oncological outcomes of RARC in patients diagnosed with bladder cancer by observing/studying single surgeon. With respect to the ICUD approach, we observed that a desired proficiency level was achieved after 30 cases, and there were significant improvements in LN yields as surgeons gained greater experience as described in other studies without affecting the oncological outcomes (Pyun et al. 2016; Ahmed et al. 2014; Hayn et al. 2010b; Kang et al. 2012).

## 13.5 Conclusion

As discussed above, ICUD is associated with reasonably realistic, safe and excellent mid- to long-term surgical and oncological outcomes. Leading hospitals have been involved globally in presenting evolutions of the technique. A stage-wise standardization of this relatively complicated technique and achieving time efficiency can help to popularize this procedure.

Here we would like to propose factors that could help in developing the ICUD technique:

1. The widespread improvements/innovations in the entire field of robotic-assisted surgery and not just Urology has helped to standardize each step of RARC.
2. Technological advances leading to availability of novel surgical instruments like the barbed suture, which has been commercialized for years, or the development of absorbable stapler for neobladder construction has facilitated intracorporeal procedures.
3. Provided the established principles of orthotopic pouch configuration are followed surgeons can apply various surgical methods for neobladder reconstruction. Several papers and videos are available to help practitioners with these techniques.

## References


Ahmed K, Khan SA, Hayn MH, et al. Analysis of intracorporeal compared with extracorporeal urinary diversion after robot-assisted radical cystectomy: results from the International Robotic Cystectomy Consortium. Eur Urol. 2014;65(2):340–7.

Bochner BH, Dalbagni G, Sjoberg DD, et al. Comparing open radical cystectomy and robot-assisted laparoscopic radical cystectomy: a randomized clinical trial. Eur Urol. 2015;67(6):1042–50.

Canda AE, Atmaca AF, Altinova S, Akbulut Z, Balbay MD. Robot-assisted nerve-sparing radical cystectomy with bilateral extended pelvic lymph node dissection (PLND) and intracorporeal urinary diversion for bladder cancer: initial experience in 27 cases. BJU Int. 2012;110(3):434–44.

Carter JJ, Whelan RL. The immunologic consequences of laparoscopy in oncology. Surg Oncol Clin N Am. 2001;10(3):655–77. Epub 2001/11/01. eng

Chan KG, Guru K, Wiklund P, et al. Robot-assisted radical cystectomy and urinary diversion: technical recommendations from the Pasadena Consensus Panel. Eur Urol. 2015;67(3):423–31.

Collins JW, Sooriakumaran P, Sanchez-Salas R, et al. Robot-assisted radical cystectomy with intracorporeal neobladder diversion: the Karolinska experience. Indian J Urol. 2014a;30(3):307–13. Epub 2014/08/07. eng

Collins JW, Tyritzis S, Nyberg T, et al. Robot-assisted radical cystectomy (RARC) with intracorporeal neobladder—what is the effect of the learning curve on outcomes? BJU Int. 2014b;113(1):100–7.

Collins JW, Wiklund NP. Totally intracorporeal robot-assisted radical cystectomy: optimizing total outcomes. BJU Int. 2014;114(3):326–33.

Collins JW, Wiklund PN, Desai MM, Goh AC, Gill IS. Total intracorporeal robotic cystectomy: are we there yet? Curr Opin Urol. 2013;23(2):135–40.

Daneshmand S, Ahmadi H, Schuckman AK, et al. Enhanced recovery protocol after radical cystectomy for bladder cancer. J Urol. 2014;192(1):50–6.

Goh AC, Gill IS, Lee DJ, et al. Robotic intracorporeal orthotopic ileal neobladder: replicating open surgical principles. Eur Urol. 2012;62(5):891–901.

Grande M, Tucci GF, Adorisio O, et al. Systemic acute-phase response after laparoscopic and open cholecystectomy. Surg Endosc. 2002;16(2):313–6. Epub 2002/04/23. eng

Haber GP, Campbell SC, Colombo JR Jr, et al. Perioperative outcomes with laparoscopic radical cystectomy: "pure laparoscopic" and "open-assisted laparoscopic" approaches. Urology. 2007;70(5):910–5. Epub 2007/12/11. eng

Hautmann RE, de Petriconi RC, Volkmer BG. 25 years of experience with 1,000 neobladders: long-term complications. J Urol. 2011;185(6):2207–12.

Hayn MH, Hellenthal NJ, Hussain A, et al. Does previous robot-assisted radical prostatectomy experience affect outcomes at robot-assisted radical cystectomy? Results from the International Robotic Cystectomy Consortium. Urology. 2010a;76(5):1111–6.

Hayn MH, Hussain A, Mansour AM, et al. The learning curve of robot-assisted radical cystectomy: results from the International Robotic Cystectomy Consortium. Eur Urol. 2010b;58(2):197–202.

Herr HW. Neoadjuvant chemotherapy: a new treatment paradigm for muscle-invasive bladder cancer. Eur Urol. 2009;55(2):303–5.

Hussein AA, Ahmed YE, Kozlowski JD, et al. Robot-assisted approach to 'W'-configuration urinary diversion: a step-by-step technique. BJU Int. 2017;120(1):152–7.

Jonsson MN, Adding LC, Hosseini A, et al. Robot-assisted radical cystectomy with intracorporeal urinary diversion in patients with transitional cell carcinoma of the bladder. Eur Urol. 2011;60(5):1066–73. Epub 2011/08/20. eng

Kang SG, Ko YH, Jang HA, et al. Initial experience of robot-assisted radical cystectomy with total intracorporeal urinary diversion: comparison with extracorporeal method. J Laparoendosc Adv Surg Tech. 2012;22(5):456–62.

Khan MS, Elhage O, Challacombe B, et al. Long-term outcomes of robot-assisted radical cystectomy for bladder cancer. Eur Urol. 2013;64(2):219–24.

Knox ML, El-Galley R, Busby JE. Robotic versus open radical cystectomy: identification of patients who benefit from the robotic approach. J Endourol. 2013;27(1):40–4. Epub 2012/07/14. eng

Lee SW, Feingold DL, Carter JJ, et al. Peritoneal macrophage and blood monocyte functions after open and laparoscopic-assisted cecectomy in rats. Surg Endosc. 2003;17(12):1996–2002.

Liedberg F. Early complications and morbidity of radical cystectomy. Eur Urol Suppl. 2010;9(1):25–30.

Menon M, Hemal AK, Tewari A, et al. Robot-assisted radical cystectomy and urinary diversion in female patients: technique with preservation of the uterus and vagina. J Am Coll Surg. 2004;198(3):386–93. Epub 2004/03/03. eng

Mmeje CO, Martin AD, Nunez-Nateras R, Parker AS, Thiel DD, Castle EP. Cost analysis of open radical cystectomy versus robot-assisted radical cystectomy. Curr Urol Rep. 2013;14(1):26–31. Epub 2012/11/28. eng

Ost MC, Tan BJ, Lee BR. Urological laparoscopy: basic physiological considerations and immunological consequences. J Urol. 2005;174(4 Pt 1):1183–8. Epub 2005/09/08. eng

Pyun JH, Kim HK, Cho S, et al. Robot-assisted radical cystectomy with total intracorporeal urinary diversion: comparative analysis with extracorporeal urinary diversion. J Laparoendosc Adv Surg Tech A. 2016;26(5):349–55.

Raza SJ, Wilson T, Peabody JO, et al. Long-term oncologic outcomes following robot-assisted radical cystectomy: results from the International Robotic Cystectomy Consortium. Eur Urol. 2015;68(4):721–8.

Richards KA, Kader AK, Otto R, Pettus JA, Smith JJ 3rd, Hemal AK. Is robot-assisted radical cystectomy justified in the elderly? A comparison of robotic versus open radical cystectomy for bladder cancer in elderly >/=75 years old. J Endourol. 2012;26(10):1301–6. Epub 2012/05/16. eng

Richards KA, Kader K, Pettus JA, Smith JJ, Hemal AK. Does initial learning curve compromise outcomes for robot-assisted radical cystectomy? A critical evaluation of the first 60 cases while establishing a robotics program. J Endourol. 2011;25(9):1553–8. Epub 2011/08/13. eng

Sammour T, Kahokehr A, Chan S, Booth RJ, Hill AG. The humoral response after laparoscopic versus open colorectal surgery: a meta-analysis. J Surg Res. 2010;164(1):28–37.

Shariat SF, Karakiewicz PI, Palapattu GS, et al. Outcomes of radical cystectomy for transitional cell carcinoma of the bladder: a contemporary series from the Bladder Cancer Research Consortium. J Urol. 2006;176(6):2414–22.

Shim JS, Kwon TG, Rha KH, et al. Oncologic outcomes and predictive factors for recurrence following robot-assisted radical cystectomy for urothelial carcinoma: multicenter study from Korea. J Korean Med Sci. 2017;32(10):1662–8.

Simone G, Papalia R, Misuraca L, et al. Robotic intracorporeal padua ileal bladder: surgical technique, perioperative, oncologic and functional outcomes. Eur Urol. 2018;73(6):934–40.

Smith AB, Raynor M, Amling CL, et al. Multi-institutional analysis of robotic radical cystectomy for bladder cancer: perioperative outcomes and complications in 227 patients. J Laparoendosc Adv Surg Tech A. 2012;22(1):17–21. Epub 2011/12/07. eng

Studer UE, Turner WH. The ileal orthotopic bladder. Urology. 1995;45(2):185–9.

Tan S, Yu W, Lin Z, et al. Peritoneal air exposure elicits an intestinal inflammation resulting in postoperative ileus. Mediat Inflamm. 2014;2014:924296. Epub 2014/08/21. eng

Xylinas E, Green DA, Otto B, et al. Robotic-assisted radical cystectomy with extracorporeal urinary diversion for urothelial carcinoma of the bladder: analysis of complications and oncologic outcomes in 175 patients with a median follow-up of 3 years. Urology. 2013;82(6):1323–9.

Zehnder P, Gill IS. Cost-effectiveness of open versus laparoscopic versus robotic-assisted laparoscopic cystectomy and urinary diversion. Curr Opin Urol. 2011;21(5):415–9. Epub 2011/08/05. eng

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# Robot-Assisted Radical Prostatectomy: The Evolution of Technique

14

Seock Hwan Choi and Tae Gyun Kwon

**Abstract**

Radical prostatectomy (RP) is a gold standard treatment of localized prostate cancer. Since the introduction of da Vinci robot, robot-assisted radical prostatectomy (RARP) has been replacing open and laparoscopic RP rapidly. RARP surgical techniques have been evolved by many surgeons and it is still ongoing. These surgical techniques are focused on improving functional outcomes after the surgery. The functional outcomes including preservation of continence and erectile function is vital to the patients especially who are young and sexually active. As a result, the evolution of techniques regarding continence and erectile function are improving the quality of life of prostate cancer survivor.

**Keywords**

Robot · Radical prostatectomy · Technique

## 14.1 Introduction

Radical prostatectomy (RP) has been accepted as a gold standard for the treatment of localized prostate cancer. Since the first RP was performed by Young in 1903 (Young 1905), open RP have been greatly advanced after pioneering work done by Walsh and Donker (1982). Although many modifications have been made to this original technique, the important principle of local cancer control with keeping erectile and urinary function has been always kept (Orvieto and Patel 2009). In 2000, the da Vinci robot was approved by Food and Drug Administration (FDA) in United States of America (USA). In same year the first robot-assisted radical prostatectomy (RARP) was carried out in France (Abbou et al. 2000). Over the past 10 years, the RARP has grown increasingly popular and became mainstream of treating localized prostate cancer. Despite its earning fame, there is few comparative studies reporting long-term superiority of RARP over the conventional radical retropubic prostatectomy (RRP) (Laviana et al. 2015). So, there have been continuous efforts to improve oncological and functional outcomes of RARP in many institutes. In this chapter, we will discuss evolution of various RARP surgical techniques.

## 14.2 Understanding of Comprehensive Prostate Anatomy with Robotic Surgery

To improve patient's QoL, understanding of comprehensive anatomy of prostate and pelvis is mandatory. With the introduction of robotic surgical system which provides magnified surgical field and 3-demensional vision, surgeons could understand the pelvis and prostate anatomy better than previous open surgery era. These enhanced vision and dexterity of robotic system helped the surgeons to achieve more advanced surgical techniques and better oncological and functional outcomes (Ficarra et al. 2012).

## 14.3 Evolution of Continence Preservation Technique

At the dawn of RARP, it was a standard procedure to complete control of dorsal vein complex (DVC), opening of endopelvic fascia and dissecting the bladder neck anteriorly.

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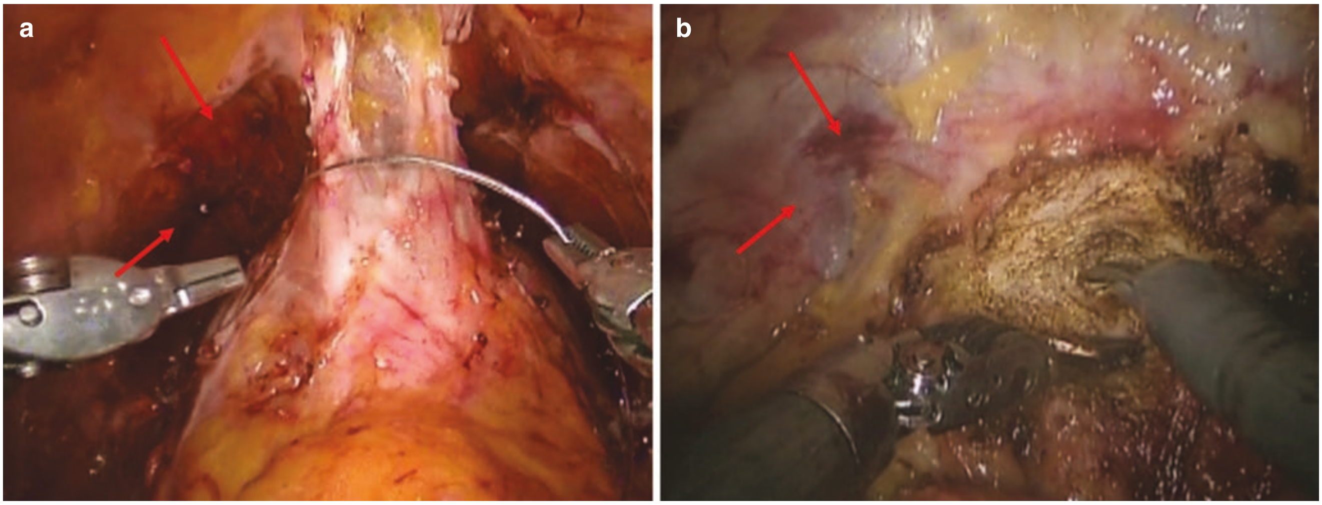


**Fig. 14.1** Endopelvic fascia preservation. (**a**) Conventional endopelvic fascia opening technique. (**b**) Lateral endopelvic fascia preservation technique

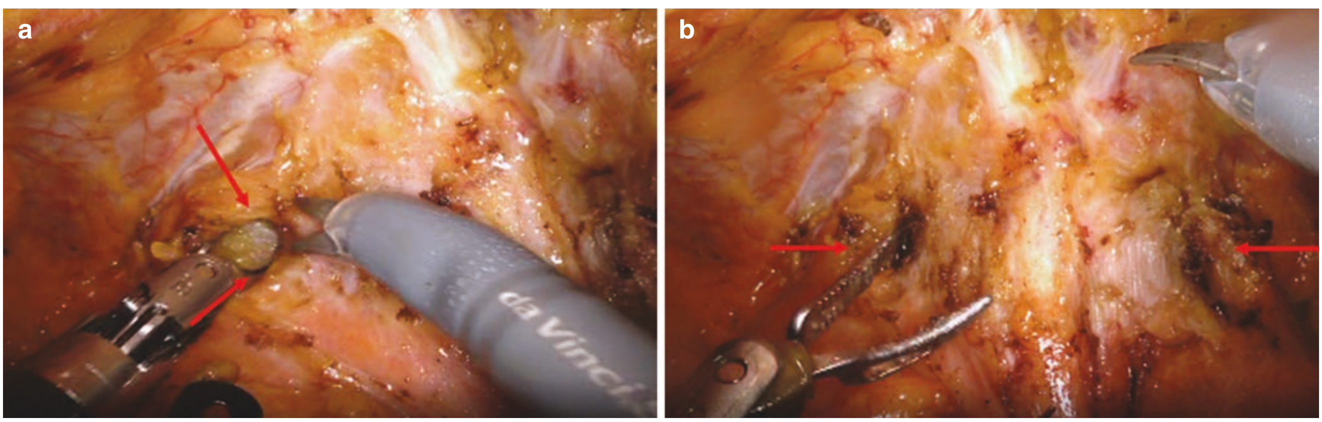


**Fig. 14.2** Bladder neck preservation technique. Modified ultradissection

To achieve DVC control, lateral side of endopelvic fascia was incised and bluntly dissected until DVC was exposed laterally. During this procedure, levator ani muscle could be injured and which led to urinary incontinence. Most of the surgeons were adopting this surgical method but continence rate was low as about 80% at 1 year postoperatively (Yanagida et al. 2014; Kwon et al. 2014). To improve the continence rate, many urologists attempted various surgical techniques including endopelvic fascia preservation, bladder neck saving and anterior, posterior repair. Endopelvic fascia preservation technique has been tried by many surgeons and this one change greatly improved post-operative continence at 12 months after surgery (Fig. 14.1) (Kwon et al. 2014). Moreover, bilateral bladder neck dissection, called ultradissection, originally described by Curto and Gaston in 2008 (Agarwal et al. 2011; Curto et al. 2006; Cusumano et al. 2008). Rha introduced modified ultradissection in 2010 (Jeong et al. 2010). The procedure is performed as following steps. The detrusor muscle fibers are identified from lateral side of bladder neck and dissection is continued to posteriorly until the posterior side of urethrovesical junction is met. When the dissection is completed, detrusor muscle and bladder neck is well distinguished. Then bladder neck is safely cut and preserved (Fig. 14.2). From the data of systematic review and meta-analysis, bladder neck preservation technique enhances the time to continence after RP (Ma et al. 2016). Recently, a few surgeons are trying Retzius-sparing RARP to minimize the short-term incontinence rate and results are quite promising (Lim et al. 2014; Asimakopoulos et al. 2015). More and more surgeons are using these techniques all together at the same time and now the continence rate is almost up to 90–95% at 1 year postoperatively. We believe that incontinence is not a big issue in RARP these days.

## 14.4 Evolution of Nerve Sparing Technique

Early 80s, impotent was inevitable consequence of RP. Thus, RP was not popular even if it was considered to be effective to control localized prostate cancer (Walsh 1998). The current concept of nerve-sparing technique was first described by Patrick Walsh (Walsh and Donker 1982; Walsh 1998). He found out that preservation of the periprostatic parasympathetic nerve fibers important for erectile function (Walsh 1998). Preservation of postero-lateral neurovascular bundle (NVB) enables preserving potency up to 60–70% at 1 year postoperatively (Walsh et al. 2000). To improve these results, many surgeons tried various forms of techniques including veil technique, intrafascial approach, complete periprostatic preservation and Retzius-sparing methods.

Traditionally nerve was thought to be confined to the NVB, but recent anatomic studies revealed that some nerves are spread on the entire lateral area of prostatic fascia (Kiyoshima et al. 2004; Costello et al. 2004). In 2005 Menon described that histology and magnification of the da Vinci robot shows prostatic fascia is a multi-fascial layer of fibrovascular tissue which covers the anterolateral portion of the prostate (Kaul et al. 2005). They called the dissected prostatic fascia the "veil of Aphrodite". This "veil of Aphrodite" technique yielded better recovery of erectile function at 12 months postoperatively compared to conventional bilateral nerve sparing procedure (Menon et al. 2005). Stolzenburg described their intrafascial technique in 2006. The important points of intrafascial technique is that the endopelvic fascia is not incised and the DVC is not ligated at the beginning of the procedure. Posteriorly, Denonvilliers fascia is not incised, instead bluntly dissected from the prostate (Stolzenburg et al. 2006). Puboprostatic ligament, endopelvic fascia, periprostatic fascia and neurovascular bundles can be preserved with Stolzenburg intrafascial technique. In 2010, periprostatic anatomy preservation technique in RARP was introduced (Asimakopoulos et al. 2010). The key point of this technique starts with developing a plane between the detrusor apron and the prostate anteriorly and DVC and the prostate is carefully dissected, leaving the plexus intact (Asimakopoulos et al. 2010). Moreover Galfano described first Retzius-sparing RARP in 2010 (Galfano et al. 2010). With this technique, complete intrafascial dissection of the prostate can be achieved without opening the Retzius space, reducing surgical trauma and providing good functional and oncologic outcomes (Asimakopoulos et al. 2015). In Asia, Rha's group first described the Retzius-sparing RARP in 2014 (Fig. 14.3). In their report, Retzius-sparing RARP, although technically more demanding, was feasible and could led to the faster recovery of early continence (Lim et al. 2014).

## 14.5 Evolution of Urethrovesical Anastomosis

Urethrovesical anastomosis was one of the most difficult part of the procedure during RP. With the introduction of robot system, the anastomosis itself is not a big issue. It can be done by either interrupted or continuous suture technique. Conventionally urethrovesical anastomosis was performed with double-armed monocryl suture in a running fashion in robotic procedure (Jeong et al. 2016). Polyglyconate-barbed suture was approved for soft tissue approximation by FDA in 2010 (Kaul et al. 2010). The barbed suture has brought significant anastomosis time decrease by 26% compared with classic monofilament suture but without any complication increasing (Jeong et al. 2016). Double-layered urethrovesical anastomosis which reconstructs posterior part of the rhabdosphincter was first described by Rocco and it is also known as "Rocco stitch". It is easy and feasible technique and has been demonstrated that reconstruction of the poste-

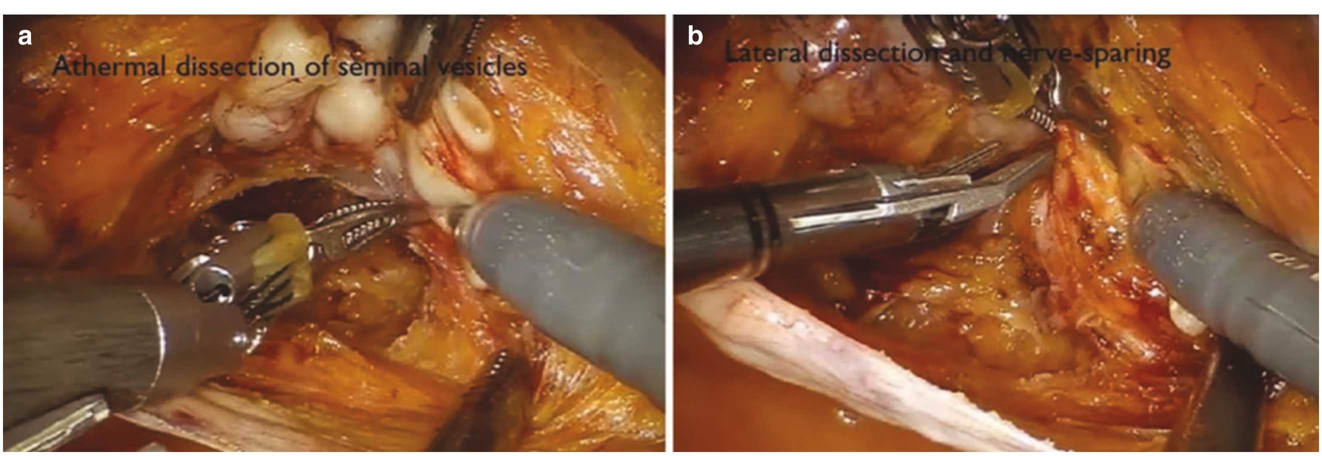


**Fig. 14.3** Retzius-sparing robot-assisted radical prostatectomy

rior aspects of the rhabdosphincter allows a rapid recovery of continence after RRP (Rocco et al. 2007; Menon et al. 2008). But long-term follow up of double-layered technique did not show any difference from single-layered anastomosis in continence rate (Sammon et al. 2010). With recent techniques, long-term functional urinary outcomes were excellent for patients undergoing RP with either single- or double-layer urethrovesical anastomosis. The proven advantage of double-layered technique is less likely to have a leak from anastomosis site and it helped to have short duration of catheter indwelling (Sammon et al. 2010).

## 14.6 Conclusions

Minimally invasive techniques including robotic surgery have been expanding its boundaries in urologic field. As history shows, evolution of surgical techniques has been ongoing and robotic surgery especially RARP techniques are developing rapidly. The evolution of techniques regarding continence and erectile function are improving the QoL of prostate cancer survivor. The ultimate goal of RARP is perfect oncologic control and zero functional loss. Undoubtedly, with the evolution of surgical techniques, we are heading to the that goal.

**Acknowledgment** To Dr. Kwon and Dr. Rha for permitting to publish surgical pictures of their own.

## References

Abbou CC, Hoznek A, Salomon L, Lobontiu A, Saint F, Cicco A, et al. Remote laparoscopic radical prostatectomy carried out with a robot. Report of a case. Prog Urol. 2000;10(4):520–3.

Agarwal PK, Sammon J, Bhandari A, Dabaja A, Diaz M, Dusik-Fenton S, et al. Safety profile of robot-assisted radical prostatectomy: a standardized report of complications in 3317 patients. Eur Urol. 2011;59(5):684–98.

Asimakopoulos AD, Annino F, D'Orazio A, Pereira CF, Mugnier C, Hoepffner JL, et al. Complete periprostatic anatomy preservation during robot-assisted laparoscopic radical prostatectomy (RALP): the new pubovesical complex-sparing technique. Eur Urol. 2010;58(3):407–17.

Asimakopoulos AD, Miano R, Galfano A, Bocciardi AM, Vespasiani G, Spera E, et al. Retzius-sparing robot-assisted laparoscopic radical prostatectomy: critical appraisal of the anatomic landmarks for a complete intrafascial approach. Clin Anat. 2015;28(7):896–902.

Costello AJ, Brooks M, Cole OJ. Anatomical studies of the neurovascular bundle and cavernosal nerves. BJU Int. 2004;94(7):1071–6.

Curto F, Benijts J, Pansadoro A, Barmoshe S, Hoepffner JL, Mugnier C, et al. Nerve sparing laparoscopic radical prostatectomy: our technique. Eur Urol. 2006;49(2):344–52.

Cusumano S, Annino F, Selas ER, Hanna S, Piechaud T, Gaston R. Feasibility, technique, and principles of tension- and energy-free laparoscopic radical prostatectomy with lateral intrafascial dissection of the neurovascular bundles with the use of a high-definition optical device. J Endourol. 2008;22(9):1981–7.

Ficarra V, Novara G, Rosen RC, Artibani W, Carroll PR, Costello A, et al. Systematic review and meta-analysis of studies reporting urinary continence recovery after robot-assisted radical prostatectomy. Eur Urol. 2012;62(3):405–17.

Galfano A, Ascione A, Grimaldi S, Petralia G, Strada E, Bocciardi AM. A new anatomic approach for robot-assisted laparoscopic prostatectomy: a feasibility study for completely intrafascial surgery. Eur Urol. 2010;58(3):457–61.

Jeong W, Araki M, Park SY, Lee YH, Kumon H, Hong SJ, et al. Robot-assisted laparoscopic radical prostatectomy in the Asian population: modified port configuration and ultradissection. Int J Urol. 2010;17(3):297–300.

Jeong W, Kumar R, Menon M. Past, present and future of urological robotic surgery. Invest Clin Urol. 2016;57(2):75–83.

Kaul S, Bhandari A, Hemal A, Savera A, Shrivastava A, Menon M. Robotic radical prostatectomy with preservation of the prostatic fascia: a feasibility study. Urology. 2005;66(6):1261–5.

Kaul S, Sammon J, Bhandari A, Peabody J, Rogers CG, Menon M. A novel method of urethrovesical anastomosis during robot-assisted radical prostatectomy using a unidirectional barbed wound closure device: feasibility study and early outcomes in 51 patients. J Endourol. 2010;24(11):1789–93.

Kiyoshima K, Yokomizo A, Yoshida T, Tomita K, Yonemasu H, Nakamura M, et al. Anatomical features of periprostatic tissue and its surroundings: a histological analysis of 79 radical retropubic prostatectomy specimens. Jpn J Clin Oncol. 2004;34(8):463–8.

Kwon SY, Lee JN, Kim HT, Kim TH, Kim BW, Choi GS, et al. Endopelvic fascia preservation during robot-assisted laparoscopic radical prostatectomy: does it affect urinary incontinence? Scand J Urol. 2014;48(6):506–12.

Laviana AA, Williams SB, King ED, Chuang RJ, Hu JC. Robot assisted radical prostatectomy: the new standard? Eur Urol. 2015;67(1):47–53.

Lim SK, Kim KH, Shin TY, Han WK, Chung BH, Hong SJ, et al. Retzius-sparing robot-assisted laparoscopic radical prostatectomy: combining the best of retropubic and perineal approaches. BJU Int. 2014;114(2):236–44.

Ma X, Tang K, Yang C, Wu G, Xu N, Wang M, et al. Bladder neck preservation improves time to continence after radical prostatectomy: a systematic review and meta-analysis. Oncotarget. 2016;7(41):67463–75.

Menon M, Kaul S, Bhandari A, Shrivastava A, Tewari A, Hemal A. Potency following robotic radical prostatectomy: a questionnaire based analysis of outcomes after conventional nerve sparing and prostatic fascia sparing techniques. J Urol. 2005;174(6):2291–6. discussion 6

Menon M, Muhletaler F, Campos M, Peabody JO. Assessment of early continence after reconstruction of the periprostatic tissues in patients undergoing computer assisted (robotic) prostatectomy: results of a 2 group parallel randomized controlled trial. J Urol. 2008;180(3):1018–23.

Orvieto MA, Patel VR. Evolution of robot-assisted radical prostatectomy. Scand J Surg. 2009;98(2):76–88.

Rocco B, Gregori A, Stener S, Santoro L, Bozzola A, Galli S, et al. Posterior reconstruction of the rhabdosphincter allows a rapid recovery of continence after transperitoneal videolaparoscopic radical prostatectomy. Eur Urol. 2007;51(4):996–1003.

Sammon JD, Muhletaler F, Peabody JO, Diaz-Insua M, Satyanaryana R, Menon M. Long-term functional urinary outcomes comparing single- vs double-layer urethrovesical anastomosis: two-year follow-up of a two-group parallel randomized controlled trial. Urology. 2010;76(5):1102–7.

Stolzenburg JU, Rabenalt R, Tannapfel A, Liatsikos EN. Intrafascial nerve-sparing endoscopic extraperitoneal radical prostatectomy. Urology. 2006;67(1):17–21.

Walsh PC. Anatomic radical prostatectomy: evolution of the surgical technique. J Urol. 1998;160(6 Pt 2):2418–24.

Walsh PC, Donker PJ. Impotence following radical prostatectomy: insight into etiology and prevention. J Urol. 1982;128(3):492–7.

Walsh PC, Marschke P, Ricker D, Burnett AL. Patient-reported urinary continence and sexual function after anatomic radical prostatectomy. Urology. 2000;55(1):58–61.

Yanagida T, Koguchi T, Hata J, Yabe M, Sato Y, Akaihata H, et al. Current techniques to improve outcomes for early return of urinary continence following robot-assisted radical prostatectomy. Fukushima J Med Sci. 2014;60(1):1–13.

Young HH. VIII. Conservative perineal prostatectomy: the results of two years' experience and report of seventy-five cases. Ann Surg. 1905;41(4):549–57.

# Retzius-Sparing Robot-Assisted Laparoscopic Radical Prostatectomy

15

K. D. Chang, C. K. Oh, and K. H. Rha

**Abstracts**

The Bocciardi approach for RALP passes through the Douglas space, following a completely intrafascial plane without any dissection of the anterior compartment, which contains neurovascular bundles, Aphrodite's veil, endopelvic fascia, the Santorini plexus, pubourethral ligaments, and all of the structures throught to play a role in maintenance of continence and potency. In the era of Robot assisted laparoscopic prostatectomy (RALP) including various techniques of anterior suspension and posterior reconstruction. Most of these techniques aim to restore the normal anatomy so that functional outcomes can be optimized. Nearly all published techniques to date have involved dropping the bladder and entering the Retzius space at some point during RALP. Galfano et al. reported they performed a novel Retzius-sparing RALP in three out of five patients in 2010. Since introducing this technique, we have applied this technique on prostatectomy more than 800 cases. Our Retzius-sparing RALP technique is similar to that described by Galfano et al. but there are some modified technique compare to Galfano's.

**Keywords**

Prostatectomy · Robotic · Retzius-sparing

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## 15.1 Introduction

In the era of open surgery, two approaches to radical prostatectomy (RP) have adopted: the retropubic and the perineal approaches. As we entered the age of minimally invasive surgery, the techniques of the retropubic approach were replicated. Robot-assisted laparoscopic prostatectomy (RALP) was first performed in 2000 by Binder et al. in Frankfurt, Germany (Binder and Kramer 2001) and by Abbou et al. in Creteil, France (Abbou et al. 2000). Since then, RALP has been disseminated widely, with continuous improvements in technique, such as Rocco stitch positioning (Patel et al. 2009), improvements in sutures (Williams et al. 2010), use of suprapubic catheters (Menon et al. 2009), initial access to the seminal vesicles through the Douglas space (Montsouris technique) (Menon et al. 2009), and direct access to the Retzius space (the Vatticuti Institute prostatectomy) (Menon et al. 2003). Many doctors have tried to improve early continence rates after RALP using many of these techniques, including various techniques of anterior suspension and posterior reconstruction (Hurtes et al. 2012; Rocco et al. 2007). Most of these techniques aim to restore the normal anatomy so that functional outcomes can be optimsed. Nearly all published techniques to date have involved dropping the bladder and entering the Retzius space at some point during RALP. Galfano et al. (2010) reported their initial success in performing a novel Retzius-sparing RALP in three out of five patient in 2010. More recently, this Milan group has also reported excellent oncological and functional outcomes in 200 patients who underwent Retzius-sparing RALP (Galfano et al. 2013). Retzius-sparing RALP was developed by the idea of how to avoid all related structures by passing through a posterior plane; this previously had been explored only through the transcoccygeal route and the Montsouris laparoscopic approach (ie, the pouch of Douglas). In this chaper, we will introduce the Retzius-sparing prostatectomy technique and result of it.



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## 15.2 Surgical Technique

Our Retzius-sparing RALP technique is similar to that described by Galfano et al. (2010). Modifications used in our techniques are as described below.

### 15.2.1 Trocar Placement

Trocar placement in our Retzus-sparing RALP technique is largely similar to our conventional RALP technique (Jeong et al. 2010). The Endowrist scissor is inserted into the rightmost port and the Endowrist atraumatic grasper (both Intuitive Surgical, Sunnyvale, CA, USA) into the more medial right-sided port.

### 15.2.2 Mobilization of the Colon and Posterior Peritoneal Incision

The patient is placed in a steep Trndelenburg position, and the sigmoid colon is freed from its adherences to the lateral abdominal wall. The bowels are then mobilized cranially to expose the rectovesical space. A horizontal incision is made over the peritoneum in the rectovesical space slightly above the level of the vas deferens. The vas deferens is mobilized and clipped bilaterally. We used 0° lens during these procedures (Figs. 15.1 and 15.2).

### 15.2.3 Athermal Dissection of Seminal Vesicles

The plane between the seminal vesicles and the surrounding tissue is developed and any vessels identified are secured with 5-mm metal clips before ligation, care to avoid coagulation and traction is take posterolateral to the seminal vesicles because of the close proximity to the neurovascular bundle (NVB). In low-risk cancers, the tips of the seminal vesicles may be left in place to minimize NVB injuries. Both seminal vesicles and vas deferens are then pulled upwards with the grasper (Fig. 15.3).

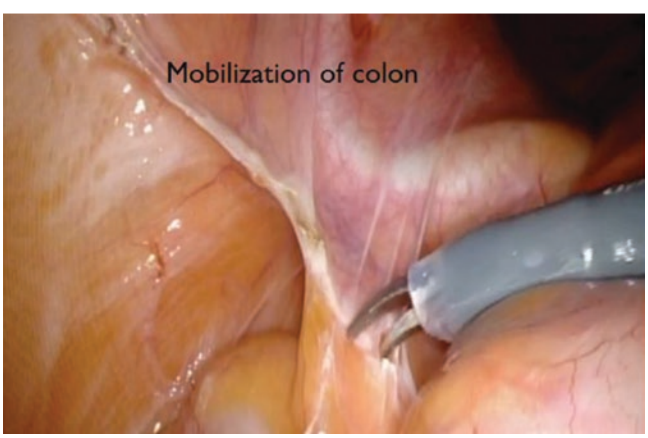


**Fig. 15.1** Mobilization of the colon

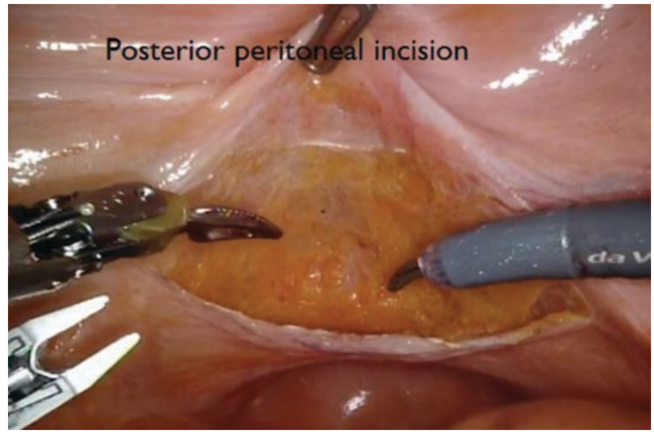


**Fig. 15.2** Posterior peritoneal incision

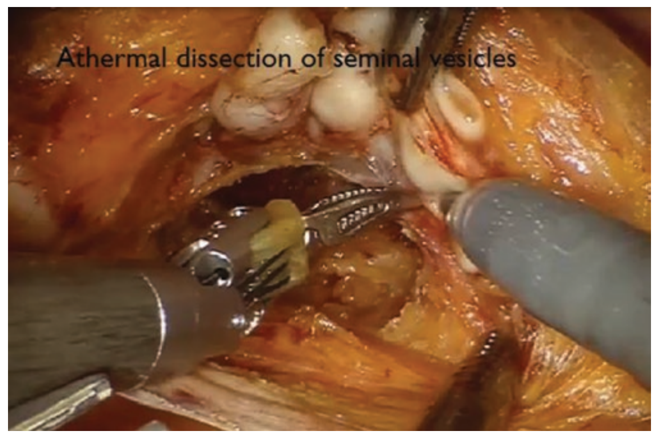


**Fig. 15.3** Athermal dissection of seminal vesicles

### 15.2.4 Posterior Dissection

The avascular plane between Denonvilliers' fascia and the posterior prostatic fascia is developed with the aid of the suction by the assistant. We carried out a dissection as far in depth as possible to reach the prostate–urethral junction, keeping close to the prostate at all times to minimize rectal injuries. The NVB is thus freed from the posterior aspect of the prostate (Fig. 15.4).

### 15.2.5 Lateral Dissection and Nerve-Sparing

Lateral dissection of the lateral prostatic pedicles commences by displacing the vas deferens and seminal vesicles gently downwards and contralateral to the side of dissec-

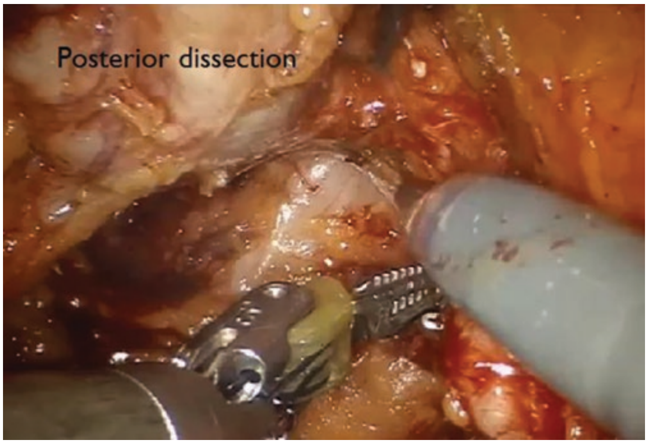


**Fig. 15.4** Posterior dissection

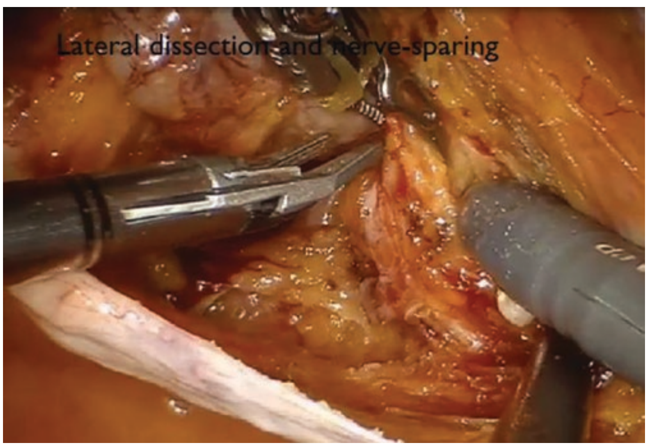


**Fig. 15.5** Lateral dissection and nerve-sparing

tion. Starting posterolaterally, dissection of the prostate is performed circumferentially towards the antero-lateral aspect of the prostate and from the bladder neck distally towards the apex of the prostate. Lateral margins of dissection (intrafascial/interfascial /extrafascial) are dependent on risk of cancer. Respecting the various possible reported anatomy of the NVB, a combination of sharp and blunt dissection is performed, following the curve of the prostate. We clipped and divided any vessels encountered along the way. Following the principles of tension and energy-free dissection, lateral traction of the NVB and use of coagulation are minimized. Instead, the NVB is peeled from the prostate capsule with the scissors moving longitudinally in a posteromedial and anteromedial direction as far as possible. The dissection continues distally until the lateral aspect of the urethral and the dorsal venous complex (DVC) is visible. The procedure is then repeated on the opposite side. At this stage, the posterior and lateral aspects of the prostate are freed (Fig. 15.5).

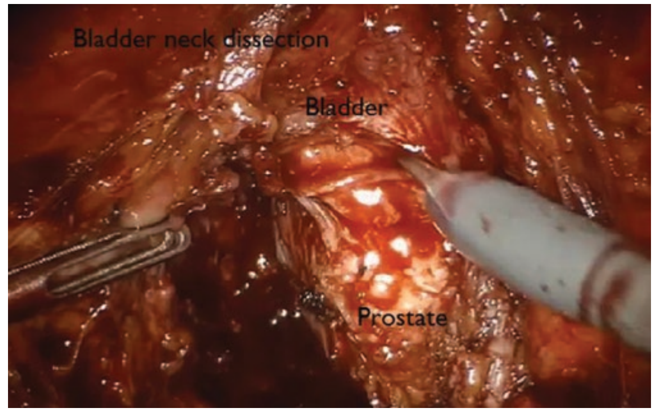


**Fig. 15.6** Bladder neck dissection

### 15.2.6 Bladder Neck Dissection

There are three important ways that prostate vesical junction can be more easily identified by: (1) a notch between the bladder and the prostate; (2) Careful dissection and removal of the peri-vesicle fat around the bladder neck until the detrusor muscles are seen; (3) traction of the prostate downwards to tent the bladder neck. With sharp dissection, the detrusor muscles at the bladder neck are cut and the bladder entered posteriorly. The anterior bladder mucosa is visualized and dissected to form the anterior lip of the bladder neck. The prostate capsule cannot be identified anteriorly where the anterior fibromuscular stroma, including the detrusor apron, is found. At the apex and the base, the prostate stroma blends with the muscle fibers of the urinary sphincter and detrusor muscles, respectively; thus, to avoid a positive anterior surgical margin, the anterior bladder neck is retracted anteriorly, and the plane dissection is directed slightly anteriorly towards the anterior abdominal wall but still sparing the detrusor apron and pubovesical complex. Because of this maneuver, in some cases, instead of reaching the avascular plane between the DVC and the urethra, the DVC may be opened. Circum-apical dissection of the urethra is performed and the urethra is then dissected a few mm distal to the prostatic notch after the catheter is withdrawn (Fig. 15.6).

### 15.2.7 Vesico-Urethral Anastomosis

The scissors and Maryland bipolar forceps should be changed with needle drivers for anastomosis. We use two 25-cm 3/0 Synthetic absorbable monofilament sutures knotted at the tails to form a double arm. Starting with the right-sided suture, anastomosis is performed by suturing the anterior bladder neck to the anterior urethra margin at the 12 o'clock position. With a running suture technique, anastomosis is continued anteriorly on the right side until the 3 o'clock position. The procedure is then repeated on the left side from the 11 o'clock to the 9o'clock position. At this juncture, the catheter is inserted into the bladder and anastomosis of the posterior bladder neck and urethra is resumed bilaterally until both sutures meet close to the 6 o'clock position. A new 16-F silicone catheter is now inserted and its balloon inflated with 10 mL water. Both ends of the sutures are tied together and a water-tight closure is confirmed with 150 mL saline (Fig. 15.7).

### 15.2.8 Packing and Closures of Peritoneal Incision

We packed the retroperitoneal space with absorbable hemostats and tissue glue and anti-adhesives. We routinely close the peritoneal incision, starting in the middle with two 22-cm 3/0 vicryl sutures, tie d at their tails with clips. The closure is secured at both ends with Lapra-Ty (Ethicon, Somerville, NJ, USA) (Fig. 15.8).

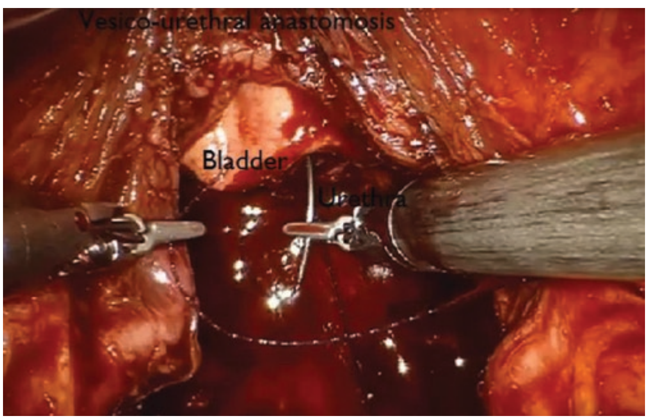


**Fig. 15.7** Vesico-urethral anastomosis

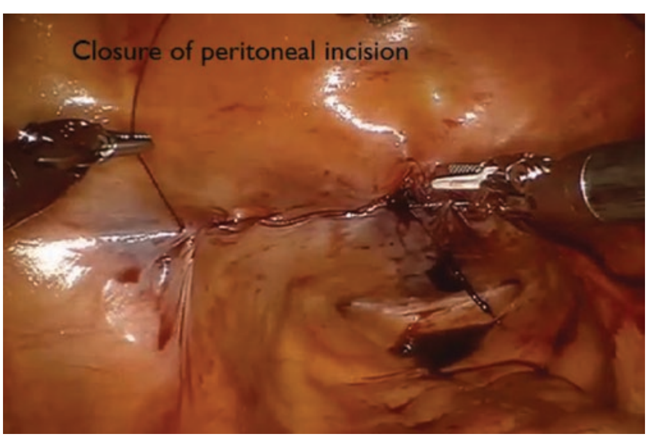


**Fig. 15.8** Closures of peritoneal incision

### 15.2.9 Pelvic Lymph Node Dissection

We made a longitudinal incision (1-2 cm) for standard pelvic lymph node dissection (PLND) towards the apex of the triangle formed by the medial umbilical ligament and the vas deferens. The base of the triangle is formed by the anterior abdominal wall. PLND of the external iliac, obturator and infra-obturator areas are then performed and repeated on the opposite side. Extended PLND (ePLND) commenced with extension of the peritoneal incision into a U-shaped one, as describe d by Galfano et al. (2010). The boundaries of ePLND include the intrapelvic area (internaliliac, obturator and external iliac), common iliac and up to ureteric crossing. Incisions made for PLND are not closed and a drain is inserted routinely to re duce the risk of lymphocele formation.

## 15.3 Results

We reported initial experience of Retzius-sparing RALP compared with conventional RALP (Lim et al. 2014). Table 15.1 is about results of 300 cases of Retzius-sparing RALP with conventional RALP. A comparison of the results

**Table 15.1** Comparison of peri-operative, oncologic and continence outcomes

| | Anterior-RARP (n = 300) | Posterior(RS)-RARP (n = 300) | P-value |
|---|---|---|---|
| Mean age ± SD, year | 64.88 ± 7.38 | 65.61 ± 7.88 | 0.179 |
| Mean BMI ± SD, km/m$^2$ | 24.25 ± 2.84 | 24.23 ± 2.74 | 0.95 |
| Mean PSA ± SD, ng/dl | 14.7 ± 46.29 | 13.2 ± 14.08 | 0.537 |
| Mean Prostate volume ± SD, gm | 34.88 ± 17.06 | 32.71 ± 14.79 | 0.072 |
| Mean Console time ± SD (minute) | 121.6 ± 87.3 | 101.3 ± 39.4 | 0.005 |
| Estimated blood loss±SD (cc) | 308.5 ± 223 | 249.8 ± 190 | 0.002 |
| Complication n, (%) | 15 (5) | 12 (4) | 0.522 |
| (Clavien-Dindo classification over II) | | | |
| 1 year BCR free survival rate (%) | 83.6 | 81.9 | 0.215 |
| Overall positive surgical margin (%) | 79 (26.3) | 72 (24) | 0.164 |
| Continence rate (1 month) (%) | 165 (55) | 255 (85) | 0.005 |
| Continence rate (6 months) (%) | 222 (74) | 273 (91) | 0.015 |
| Continence rate (12 months) (%) | 245 (81.7) | 285 (95) | 0.029 |

*BCR* biochemical recurrence

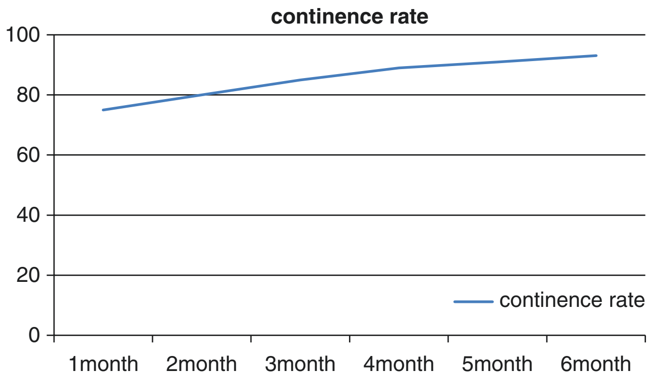


**Fig. 15.9** Continence rate of Retzius-sparing RALP

between the conventional RALP and Retzius-sparing RALP groups is shown in Table 15.1 which is analyzed using propensity matching. There were no significant differences of overall complication rate (Clavien-Dindo ≥2), positive surgical margin rate, and 1 year biochemical recurrence free survival rate between two groups. There were significant differences of continence rates between two groups (Table 15.1). Figure 15.9 shows Continence rate of Retzius-sparing RALP at 6 months was 93.1%.

## 15.4 Discussions

The perineal RP allows more accurate dissection of the urethra and preserves the Retzius space and DVC, but it can damage the pelvic floor muscle tissue and result in deterioration. On the other hand, the Retrofit RP retains the pelvic fascia and pelvic muscles but has to enter the Retzius space. Then there will be more surgical trauma to the front of the bladder. In the current Retzius-sparing RALP technology we have combined the best of both approaches. By performing 'perineum regression RP', Retzius space and pelvic floor anatomy are preserved, minimizing surgical trauma, enabling more delicate reconstruction and maintaining anatomical steady state. The RP disrupts normal anatomy and loses its normal function. Recently, a number of techniques have been developed to restore anatomically normal structures. This approach has been developed due to greater respect for the anatomical considerations and structures involved in the mechanism of adverse effects. First, this approach can perform a full-fascia intramuscular prostatectomy. In fact, this technique preserves the complete anatomic integrity of the veil of Aphrodite, including neurovascular masses. Some studies report the presence of nerves on the higher side of the veil and pelvic fascia of Aphrodite (Stolzenburg et al. 2007). Second, the pubourethral ligament and the ultimate accessory podendal artery can be completely avoided. There are several reports of preservation preservation and efficacy (Potdevin et al. 2009). Third, using this method can reduce blood loss while the doctor avoids Santorini plexus. During the Santorini dissection, it is common to find small arteries whose role is currently unknown. We assume that these factors can improve the early rate with this technique. Anterior fixation of the bladder wall to the abdominal wall was an important suspensory mechanism to prevent pelvic floor escape, urethral and movement disorders, and maintain the angle of the vesicoprostatic junction. This important structure is preserved by this technology.

This approach has some aspects that can perform this technique in the early days. Workspaces are very limited compared to traditional methods. In addition, the ureter will proceed laterally in the posterior bladder wall and should be considered when dissecting this structure. Finally, viewing angles are not very desirable and are especially needed when performing anastomosis. This is because the resected cystoscope retreats to the 0° surgical lens and becomes invisible. It is helpful to change to a 30° lens at this stage.

This technique is not easy to perform in the early days. However, beyond the learning curve of this technology, Retzius-sparing RALP can be a good choice among the various technologies.

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## References

Abbou CC, Hoznek A, Salomon L, Lobontiu A, Saint F, Cicco A, Antiphon P, Chopin D. Remote laparoscopic radical prostatectomy carried out with a robot. Report of a case. Prog Urol. 2000;10(4):520–3.

Binder J, Kramer W. Robotically-assisted laparoscopic radical prostatectomy. BJU Int. 2001;87(4):408–10.

Galfano A, Ascione A, Grimaldi S, Petralia G, Strada E, Bocciardi AM. A new anatomic approach for robot-assisted laparoscopic prostatectomy: a feasibility study for completely intrafascial surgery. Eur Urol. 2010;58(3):457–61. https://doi.org/10.1016/j.eururo.2010.06.008.

Galfano A, Di Trapani D, Sozzi F, Strada E, Petralia G, Bramerio M, Ascione A, Gambacorta M, Bocciardi AM. Beyond the learning curve of the Retzius-sparing approach for robot-assisted laparoscopic radical prostatectomy: oncologic and functional results of the first 200 patients with >/= 1 year of follow-up. Eur Urol. 2013;64(6):974–80. https://doi.org/10.1016/j.eururo.2013.06.046.

Hurtes X, Roupret M, Vaessen C, Pereira H, Faivre d'Arcier B, Cormier L, Bruyere F. Anterior suspension combined with posterior reconstruction during robot-assisted laparoscopic prostatectomy improves early return of urinary continence: a prospective randomized multicentre trial. BJU Int. 2012;110(6):875–83. https://doi.org/10.1111/j.1464-410X.2011.10849.x.

Jeong W, Araki M, Park SY, Lee YH, Kumon H, Hong SJ, Rha KH. Robot-assisted laparoscopic radical prostatectomy in the Asian population: modified port configuration and ultradissection. Int J Urol. 2010;17(3):297–300. https://doi.org/10.1111/j.1442-2042.2010.02480.x.

Lim SK, Kim KH, Shin TY, Han WK, Chung BH, Hong SJ, Choi YD, Rha KH. Retzius-sparing robot-assisted laparoscopic radical prostatectomy: combining the best of retropubic and perineal approaches. BJU Int. 2014;114(2):236–44. https://doi.org/10.1111/bju.12705.

Menon M, Shrivastava A, Bhandari M, Satyanarayana R, Siva S, Agarwal PK. Vattikuti Institute prostatectomy: technical modifications in 2009. Eur Urol. 2009;56(1):89–96. https://doi.org/10.1016/j.eururo.2009.04.032.

Menon M, Tewari A, Peabody J, Team VIP. Vattikuti Institute prostatectomy: technique. J Urol. 2003;169(6):2289–92. https://doi.org/10.1097/01.ju.0000067464.53313.dd.

Patel VR, Coelho RF, Palmer KJ, Rocco B. Periurethral suspension stitch during robot-assisted laparoscopic radical prostatectomy: description of the technique and continence outcomes. Eur Urol. 2009;56(3):472–8. https://doi.org/10.1016/j.eururo.2009.06.007.

Potdevin L, Ercolani M, Jeong J, Kim IY. Functional and oncologic outcomes comparing interfascial and intrafascial nerve sparing in robot-assisted laparoscopic radical prostatectomies. J Endourol. 2009;23(9):1479–84. https://doi.org/10.1089/end.2009.0369.

Rocco B, Gregori A, Stener S, Santoro L, Bozzola A, Galli S, Knez R, Scieri F, Scaburri A, Gaboardi F. Posterior reconstruction of the rhabdosphincter allows a rapid recovery of continence after transperitoneal videolaparoscopic radical prostatectomy. Eur Urol. 2007;51(4):996–1003. https://doi.org/10.1016/j.eururo.2006.10.014.

Stolzenburg JU, Schwalenberg T, Horn LC, Neuhaus J, Constantinides C, Liatsikos EN. Anatomical landmarks of radical prostatecomy. Eur Urol. 2007;51(3):629–39. https://doi.org/10.1016/j.eururo.2006.11.012.

Williams SB, Alemozaffar M, Lei Y, Hevelone N, Lipsitz SR, Plaster BA, Hu JC. Randomized controlled trial of barbed polyglyconate versus polyglactin suture for robot-assisted laparoscopic prostatectomy anastomosis: technique and outcomes. Eur Urol. 2010;58(6):875–81. https://doi.org/10.1016/j.eururo.2010.07.021.

# 16 Robot Assisted Partial Nephrectomy: Technique and Outcomes

Nobuyuki Hinata and Masato Fujisawa

**Abstract**

It is well established that partial nephrectomy is the recommended surgical management for localized T1a renal masses. Partial nephrectomy is also favored over radical nephrectomy in patients with T1b tumors when technically feasible. The robotic platform could directly contribute to the increasing usage of PN for the management of renal masses. Meta-analyses have shown that robot-assisted partial nephrectomy provides better peri-operative outcomes than laparoscopic and open partial nephrectomy. It is foreseeable that usage of robot-assisted partial nephrectomy will continue to increase and may become the standard option for the management of small renal masses. In this chapter, surgical procedures of robot-assisted partial nephrectomy, advantages of robot-assisted surgery in nephron-sparing surgery, balancing functional and oncological outcomes during robot-assisted partial nephrectomy, anatomical aspects regarding partial nephrectomy, learning curve for robot-assisted partial nephrectomy, indications of nephron-sparing surgery and nephron-sparing surgery for high complexity tumors has been described.

**Keywords**

Partial nephrectomy · Robot-assisted surgery · Nephron-sparing surgery · Minimally-invasive surgery · Kidney cancer

The progress of surgical techniques to treat localized renal cell carcinoma has been developed with the following two aims. One is to reduce postoperative functional loss while securing oncological outcomes. The other is to minimize procedure invasiveness. The former has led to the development and evolution of nephron-sparing surgery. The latter has been developed for application to minimally-invasive surgery, particularly robot-assisted surgery. The rapid spread of robot-assisted surgery, which enables minute operation under a magnified view, has led to the reexamination of the surgical anatomy of the kidney, which as a result has led to the progress and refinement of nephron-sparing surgery. This positive synergy has accelerated the evolution of robot-assisted surgery. In this chapter, an outline of the present technique, outcomes and prospects of robot-assisted partial nephrectomy (RAPN), now a mainstream type of nephron-sparing surgery, will be stated.

## 16.1 Robot-Assisted Partial Nephrectomy (RAPN)

Robot-assisted surgery has made it possible to perform precise surgery with three-dimensional stereoscopic vision, high-magnified light field, forceps with multiple joints and multi-movement. It has spread rapidly in radical prostatectomy for localized prostate cancer in urology as a procedure that can overcome both inconvenience of the forceps under conventional laparoscopy and high invasiveness of open surgery.

Initially reported in 2004 by Gettman et al. (2004), RAPN has been performed more and more frequently in partial nephrectomy, which requires the precise excision of a tumor and a minute suture of the urinary tract and the renal parenchyma. This is because robotic technology enables surgeons to achieve minimized invasiveness, oncological curativity, and functional preservation (Sivarajan et al. 2015; Patel 2008).

## 16.2 Surgical Procedures

### 16.2.1 Indications of RAPN

Proper patient selection is important for the success of RAPN, especially during the learning curve. Challenging cases such as complex hilar tumors or endophytic tumors can

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be addressed robotically (Dulabon et al. 2011; Rogers et al. 2008a, b). However, these cases require surgical experience and technical proficiency. Thus they should not be attempted by inexperienced surgeons. The amount and the stiffness of perirenal fat is an important factor of surgical difficulty. It will drastically increase the difficulty of retraction and hilar dissection.

### 16.2.2 Preoperative Management

It is critical to obtain a thorough patient history and to pay special attention to prior abdominal and retroperitoneal surgery, as well as to preexisting kidney disease and other comorbidities such as hypertension or diabetes mellitus. In general, patients who are on anticoagulation medication will require clearance to have their anticoagulants temporarily suspended in the perioperative period.

Proper informed consent is important. Patients must be counseled to the consequent risks of RAPN, including the risk for hemorrhage requiring transfusion, postoperative urine leakage, and incomplete resection of the tumor. Moreover, the patient must be counseled in terms of the possibility of conversion to radical nephrectomy, or to an open procedure.

It is recommended to perform a contrast-enhanced computed tomography (CT) scan whenever possible to identify the hilar anatomy because dissection of the hilar anatomy can be very difficult. This will allow the surgeon to make preparations for multiple arteries and veins, as well as for anatomic aberrancy.

### 16.2.3 Patient Positioning

The patient is placed in a flank position, in a manner nearly identical to that of a laparoscopic or open procedure, except that excessive flexion of the table is usually necessary only with retroperitoneal approach. Furthermore, the arms should be positioned as far cephalad as safely possible, to minimize collision with the robotic arms. Placement of an axillary roll is necessary, and the patient should be secured to the table in a manner that will allow the table to be rolled if necessary. It is necessary to place sequential compression devices should be placed to provide prophylaxis against deep venous thrombosis.

### 16.2.4 Surgical Approaches

In terms of camera and trocar configuration, there are two approaches to be used by most robotic surgeons. The first and most commonly used is a transperitoneal approach. This approach replicates a standard transperitoneal laparoscopic approach, providing position sense and anatomical landmarks familiar to most surgeons. The other approach is a retroperitoneal approach (Patel and Porter 2013). This approach provides a nearer view of the kidney. Both approaches have been described, and can provide enough visualization and instrument mobility (Hughes-Hallett et al. 2013). We mainly use transperitoneal approach; however, retroperitoneal approach might be more suitable for posteriorly located hilar tumors.

The fourth arm can be used to allow the surgeon to control the surgical field (Rogers et al. 2009). However, a novice surgeon should be cautioned that, unlike robot-assisted radical prostatectomy, using the fourth arm during RAPN is often more technically delicate, because of conflict of the instruments and robotic arms in a relatively smaller working space. Therefore, we regard the four-arm approach as an advanced technique.

### 16.2.5 Trocar Placement

When the transperitoneal approach is used, using open or closed techniques the camera port is placed first, usually at the level of the lower pole of the kidney and 5–6 cm lateral to the midline. The caudal port is placed 9 cm lateral and 4 cm caudal to the camera port. The cephalad port is placed 9 cm cranial to the camera port. For right-sided tumors, an accessory port for a liver retractor is often required (Fig. 16.1).

When the retroperitoneal approach is used, camera port is placed on the posterior axillary line and at the middle of the 12th rib and the iliac crest. Then position of the dorsal port is decided, which is placed at 8 cm posterior and 2 cm cephalad to the camera port. The ventral port is placed at 8 cm ventral to the camera port (Fig. 16.2).

### 16.2.6 Instrument Selection

The robot is docked on the perpendicular line of the isosceles triangle of the three ports. The right hand is usually equipped with robotic scissors, which are connected to monopolar electrocautery. The left hand is outfitted with Fenestrated bipolar forceps. The assistant usually provides retraction with a laparoscopic suction device. Other instruments available for the assistant include a Hem-o-lok clip applier (Tele ex, Research Triangle Park, NC USA), a LapraTy clip applier (Ethicon, Cincinnati, OH USA), a laparoscopic ultrasound probe, and a laparoscopic bulldog clip applier and remover.

The renorrhaphy sutures should be prepared on the clean table, as well as sutures for collecting system repair. Because the required sutures can be time consuming to prepare, they should

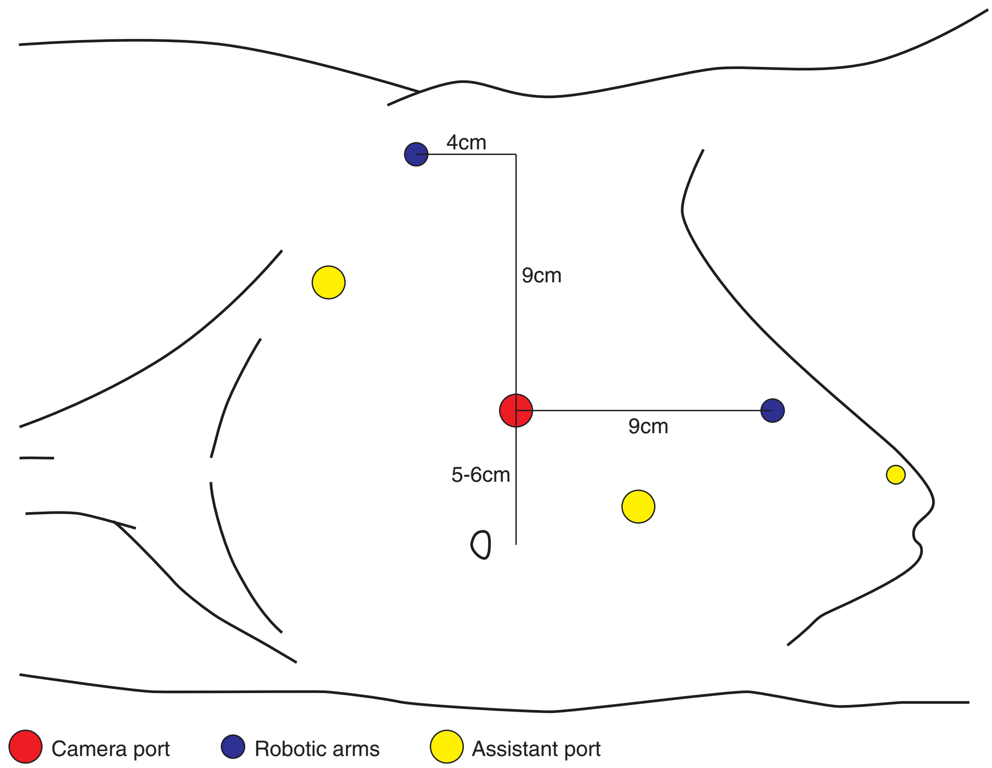


**Fig. 16.1** Camera, robotic and assistant port placement for transperitoneal approach

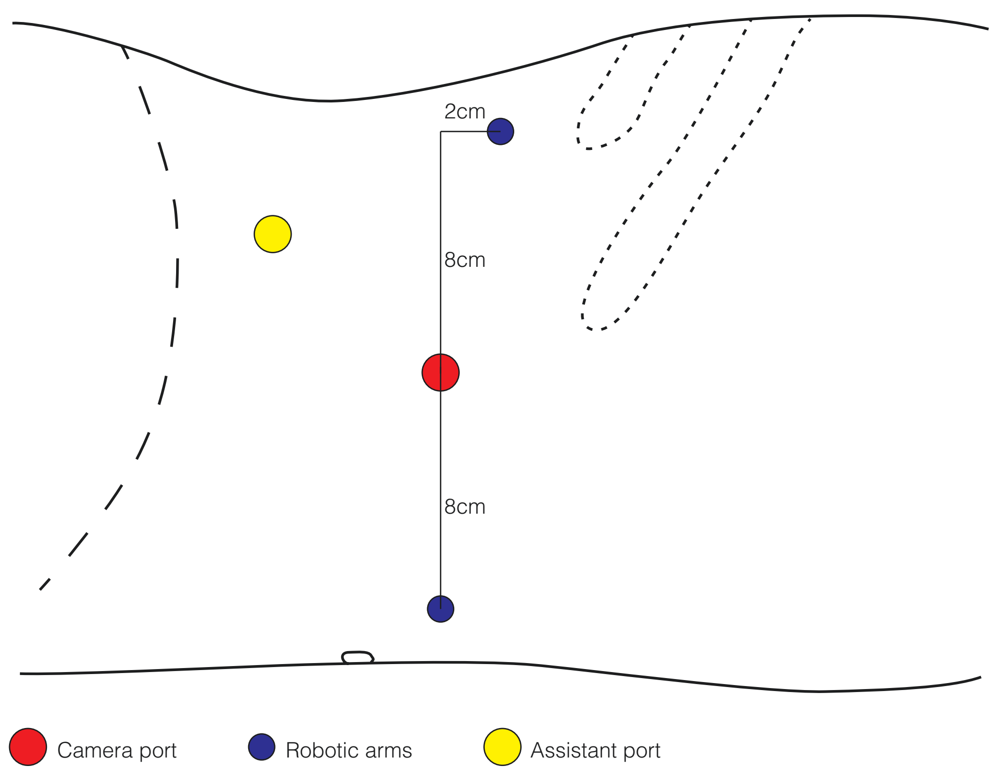


**Fig. 16.2** Camera, robotic and assistant port placement for retroperitoneal approach

be prepared beforehand. We use 3-0 glycomer barbed sutures (15 cm) as the collecting system sutures. For the renorrhaphy, we use 2-0 glycomer barbed sutures (30 cm). Upon completion, a knot is tied, followed by a LapraTy clip, then a Hem-o-lok clip. Two to three sets of these sutures should be prepared. Furthermore, TachoSil® and fibrin glue must be immediately available to achieve acceptable hemostasis and closure.

### 16.2.7 Initial Dissection

The bowel is reflected medially along the white line of Toldt to expose the retroperitoneum. For right-sided tumors, the duodenum should also be carefully mobilized to gain access to the renal hilum. Care must be taken during this maneuver, because the vena cava lies directly inferior to the duodenum, and is therefore apt to iatrogenic injury. Next, the lower pole of the kidney is identified, and just off the lower pole, the ureter and gonadal vein should be identified. It is preferred to leave the gonadal vein intact if possible, and therefore the vein should be dropped medially whenever possible. Care must be taken to avoid excessive skeletonizing of the ureter, so as not to compromise the blood supply. Dissection should be carried out cephalad to reveal the main renal vessels. Surgeons may be able to detect the venous impulse that is the hallmark of the renal vein (Rogers et al. 2008b). The three-dimensional reconstruction model of dynamic computed tomography is useful for identifying renal arteries and veins. They could be projected to the monitor of surgeon console via TilePro™ function (Fig. 16.3).

Laparoscopic or robotic bulldog clamps are generally used. The artery and vein should be identified separately, and the posterior hilar fat will need to be cleared to ensure that the bulldog clamps are able to fully close. In some instances, it is possible to isolate a segmental arterial branch that provides the entire blood supply to the tumor. Selective clamping of this artery may lead to less ischemic insult, because the unaffected portions of the kidney remain perfused. However, while potentially effective, it is reported that selective arterial clamping does not improve outcomes in RAPN (Paulucci et al. 2017).

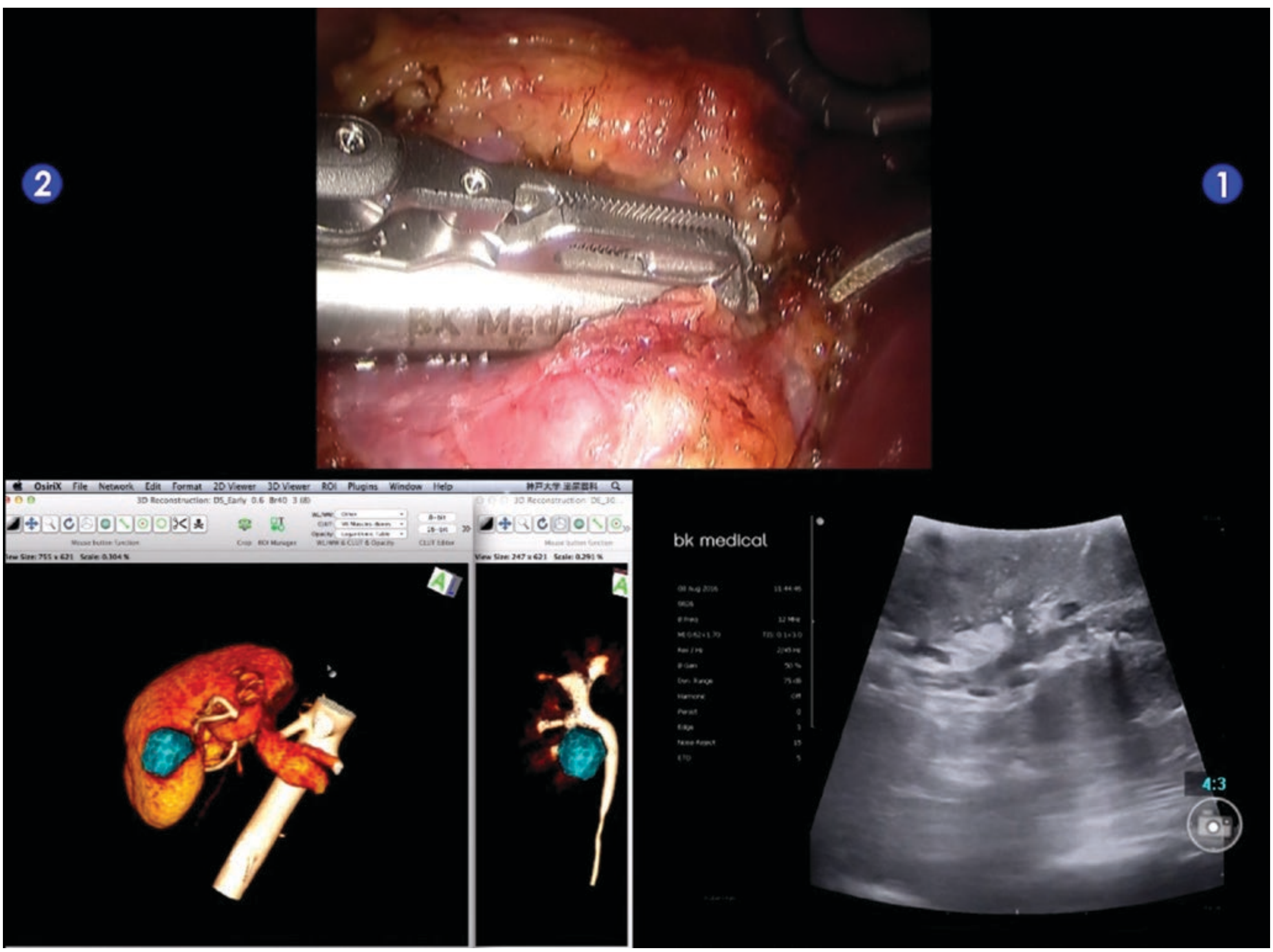


**Fig. 16.3** The three-dimensional reconstruction model of dynamic computed tomography and the intraoperative ultrasound

### 16.2.8 Preparation for Excision

The perirenal fat is dissected off from the renal capsule to expose normal capsular tissue around the tumor. This maneuver will provide the best visualization possible during later reconstruction and enables tension-free renorrhaphy. It is better to leave the fat overlying the tumor intact; however, it may be inadvertently released from the surface of the tumor as the fat is being mobilized. If this occurs, the fat should be collected and placed with the specimen.

Intraoperative ultrasound is performed to assess the extent of the tumor and to delineate the margins of dissection, which is marked by scoring the capsule. Just prior to commencing tumor excision, the renal artery is carefully occluded with a laparoscopic or a robotic bulldog clamp. Clamping of the renal vein is rarely necessary under the pneumoperitoneal pressure.

### 16.2.9 Tumor Excision

The tumor is sharply excised using the robotic scissors, with sparing use of cautery. The Fenestrated bipolar forceps may be used to gently spread the tissues and expose the underlying parenchyma for dissection. Care must be taken in following the expected curvature of the tumor. Both techniques, namely, standard partial nephrectomy and tumor enucleation, could be available. However, standard partial nephrectomy vs. tumor enucleation remains a controversial topic of debate (Gupta et al. 2015). Should the tumor be entered, the last steps must be retraced, and the tumor should be recaptured.

Dissection is carried out from near to far, using the attachment of the far side as a hinge that will allow for comparatively simple retraction as excision is performed. Any entry into the collecting system or into large venous channels should be noted. The tumor should be placed out of the field nearby for later extraction once excision is complete.

### 16.2.10 Renal Reconstruction

The cortex could be cauterized for hemostasis; however, cautery should not be applied to the medulla. During this step, the robotic scissors are replaced with a needle driver. However, the Fenestrated bipolar forceps should remain in the left hand to avoid inadvertent injury to the renal capsule during renorrhaphy. If there has been entry into the collecting system or into a large venous sinus, these areas should be oversewn using the 3-0 barbed suture in a running fashion.

Sliding-clip technique is a well-described method for renorrhaphy (Benway et al. 2009a). However, use of a running suture using a 2-0 barbed suture could be the alternative method. Use of barbed sutures simplifies the renorrhaphy technique during RAPN and improves efficiency, allowing for decreased warm ischemia times (Sammon et al. 2011). The prepared sutures should be placed at 1-cm intervals along the length of the defect. After accomplishing the second throw, the assistant places a Hem-o-lok clip on the loose end. This clip need not be situated in direct apposition to the capsule, as it will be slide into position under tension by the surgeon. Nevertheless, the assistant should pay attention to ensure that the suture is placed as close to the middle of the clip as possible, as this will allow the clip to be slid along the suture with greater ease.

The Hem-o-lok clip is then slid into position by straddling the suture. The Fenestrated bipolar forceps are used to maintain tension on the loose end of the suture in a direction perpendicular to the capsule, in order to minimize the risk of tearing through the capsule. Appropriate tension has been placed when the capsule dimples slightly. Once all renorrhaphy sutures have been placed, they may be retightened by the surgeon to accurately calibrate the tension upon repair.

After the bulldog clamps are removed from the renal hilum the repair should be examined for hemostasis. If slight bleeding is encountered, a period of observation is required, as reperfusion of the kidney will lead to an increase in volume that may further apply tension to the repair and can thus tamponade the bleeding. If bleeding could persist, the clips can be further tightened, or additional sutures can be placed.

### 16.2.11 Extraction and Closure

Once hemostasis has been verified, the specimen is placed in a retrieval bag and the robot is undocked. The specimen is extracted through the incision. A drain may be left in place if it is deemed necessary. The fascia of the extraction site should be repaired, though repair of the remaining sites is generally not necessary. The skin incisions are closed after irrigation.

### 16.2.12 Postoperative Care and Management of Perioperative Complications

Appropriate analgesia should be provided. Serum chemistries and hematocrit must be monitored in the immediate postoperative period and on a daily basis. Most of the patients can tolerate a diet by postoperative day 1.

Immediate postoperative complications may include deep venous thrombosis, myocardial infarction, acute renal insufficiency or failure, unrecognized bowel injury, and renal hemorrhage. Hemorrhage is generally self-limited, and may respond to observation and possible transfusion of blood products. However, on rare occasions, significant bleeding may prompt further intervention, such as selective arterial embolization. Patients who develop renal insufficiency may require nephrology evaluation, and on rare occasions may require dialysis. If ischemic time does not exceed 30 min, it is probable that renal insufficiency will be self-limited (Simmons et al. 2008).

Unrecognized bowel injury is a serious complication that is often associated with an atypical presentation in the minimally invasive setting. Unlike open procedures, patients generally do not develop the classic signs of peritonitis, leukocytosis, and ileus. On the contrary, they will often develop tenderness limited to the port site closest to the injury, leukopenia, and diarrhea (Bishoff et al. 1999). If bowel injury is suspected, immediate evaluation with abdominal imaging is required.

Intermediate-term complications include urine leak and development of a pseudoaneurysm. Urine leaks often have a delayed presentation, and are heralded by excessive drainage from a port site, flank pain, and fever. Abdominal imaging will confirm the diagnosis. Treatment requires the placement of a ureteral stent and percutaneous drainage of the urinoma; repair is rarely required (Meeks et al. 2008). Pseudoaneurysm is a rare complication that can occur at any time, and often presents as painless gross hematuria. Computed tomography angiography confirms the diagnosis, and treatment often consists of selective embolization (Albani and Novick 2003).

### 16.2.13 Long-Term Follow-Up

Long-term follow-up consists of laboratory evaluation and periodic imaging, including complete blood count, basic metabolic panel, hepatic function panel, abdominal CT and chest X-ray.

## 16.3 Advantages of Robot-Assisted Surgery in Nephron-Sparing Surgery

### 16.3.1 In Comparison with Open Partial Nephrectomy (OPN)

RAPN has been reported to be superior to OPN in the following respects: reduction of postoperative pain, shorter hospitalization duration, the prompt recovery to daily living activities, and cosmetic condition of the wound. These advantages are similar to what conventional laparoscopic partial nephrectomy (LPN) has for OPN (Porpiglia et al. 2008). However, some problems of LPN have been pointed out, such as having a prolonged learning curve due to difficulties in maneuvering forceps, thus making partial nephrectomy difficult. A comparison between LPN and RAPN is stated in the following section.

### 16.3.2 In Comparison with Conventional Laparoscopic Partial Nephrectomy (LPN)

The major advantage of robotic-assistance in partial nephrectomy is the delicate movement of the forceps—in other words, its skillfulness—which makes it possible to perform complicated maneuvers such as resecting renal tumors, reconstructing the urinary tract, and suturing renal parenchyma during limited warm ischemia time.

A meta-analysis of the retrospective study that compared LPN with RAPN was reported. Out of 26 retrospective studies, they compared 2618 cases of RAPN with 2238 cases of LPN by systematic review and meta-analysis. Though there were more difficult cases in RAPN group (a tumor diameter was 0.17 cm greater and R.E.N.A.L. nephrometry score was 0.59 points more), the result was as follows; warm ischemia time was 4.3 min shorter, the risk of positive surgical margin was 47% lower, the risk of surgical approach change was 64% lower, and perioperative complications greater than Clavien grade 3 was 29% lower. Summary of the cohort studies are shown in Tables 16.1 and 16.2. Furthermore, they also compared the low volume center with the high volume center (more than 24 cases a year) in the subgroup analysis, and reported that the time saving effect of both surgery and hospitalization period was more remarkable in the low volume center (Leow et al. 2016). They inferred that this might be attributed to the shorter learning curve for robot-assisted surgery.

However, at present there exists no data that indicate the superiority of RAPN based on the results of a prospective randomized controlled trial (RCT) with a high evidence level, so the results of RCT are expected. In contrast, there is no denying that it is difficult to conduct a comparative study under the situation where an obviously novel technique has already spread widely, or that it might be impossible to conduct a prospective RCT now that RARP has become popular and many leading institutions have already been equipped with robotic systems, and consequently many of the skilled surgeons of LPN have already shifted to RAPN.

**Table 16.1** Cohort studies comparing RAPN and LPN

| Authors | Year | Journal | Country | Case numbers | | Mean tumor diameters (cm) | | Shorter warm ischemia time |
|---|---|---|---|---|---|---|---|---|
| | | | | RAPN | LPN | RAPN | LPN | |
| Wang et al. | 2015 | BJU Int | China | 81 | 135 | 3.8 | 3.6 | RAPN |
| Kim et al. | 2015 | World J Urol | Korea | 195 | 195 | 2.4 | 2.3 | RAPN |
| Ricciardulli et al. | 2015 | Arch Ital Urol Androl | China | 58 | 258 | 3.1 | 3.2 | RAPN |
| Carneiro et al. | 2015 | World J Urol | France | 44 | 152 | 3.5 | 3.2 | RAPN |
| Li et al. | 2015 | J Chin Med Assoc | Taiwan | 47 | 55 | 3.9 | 3.6 | RAPN |
| Wu et al. | 2014 | BJU Int | China | 146 | 91 | 3.6 | 3.3 | RAPN |
| Faria et al. | 2014 | World J Urol | USA | 137 | 146 | 3.4 | 3.4 | RAPN |
| Zargar et al. | 2014 | BJU Int | USA | 1185 | 646 | 2.3 | 2.0 | RAPN |
| Jang et al. | 2014 | Korean J Urol | Korea | 89 | 38 | 3.0 | 2.5 | RAPN |
| Leow et al. | 2014 | BJU Int | Singapore | 52 | 51 | 2.7 | 2.6 | RAPN |
| Masson-Lecomte et al. | 2013 | BJU Int | France | 220 | 45 | 3.1 | 3.0 | RAPN |
| Williams et al. | 2013 | World J Urol | USA | 27 | 59 | 2.5 | 3.1 | RAPN |
| Ellison et al. | 2012 | J Urol | USA | 108 | 108 | 2.9 | 2.7 | LPN |
| Long et al. | 2012 | Eur Urol | USA | 199 | 182 | 3.8 | 4.0 | RAPN |
| Lucas et al. | 2012 | JSLS | USA | 27 | 15 | 2.4 | 2.2 | RAPN |
| Lee et al. | 2012 | Can J Urol | USA | 30 | 39 | 3.2 | 3.1 | LPN |
| Seo et al. | 2011 | Korean J Urol | Korea | 13 | 14 | 2.7 | 2.0 | RAPN |
| Cho et al. | 2011 | Hong Kong Med J | Hong Kong | 10 | 10 | 2.7 | 2.8 | RAPN |
| Lavery et al. | 2011 | JSLS | USA | 20 | 18 | 2.5 | 2.3 | RAPN |
| DeLong et al. | 2010 | Can J Urol | USA | 13 | 15 | 2.6 | 2.8 | RAPN |
| Kural et al. | 2009 | J Endourol | Turkey | 11 | 20 | 3.2 | 3.2 | RAPN |
| Jeong et al. | 2009 | J Endourol | Korea | 31 | 26 | 3.4 | 2.4 | LPN |
| Deane et al. | 2008 | J Endourol | USA | 11 | 12 | 3.1 | 2.3 | RAPN |

**Table 16.2** Comparison of surgical efficacy in cohort studies

| Study | Number of patients | | Mean WIT (min) | | Mean operative time (min) | | Mean EBL (ml) | | Mean LOS (days) | | PSM (n) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RPN (n = 1134) | LPN (n = 978) | RPN | LPN | RPN | LPN | RPN | LPN | RPN | LPN | RPN | LPN |
| Alemozaffar et al. (2013) | 25 | 25 | – | – | 232 | 224 | 178 | 154 | 2.5 | 2.7 | – | – |
| Masson-Lecomte et al. (2013) | 220 | 45 | 20.4 | 24.3 | 168 | 200 | 245 | 268 | 5.5 | 6.8 | 18 | 2 |
| Williams et al. (2013) | 27 | 59 | 18.5 | 28 | – | – | – | – | – | – | – | – |
| Ellison et al. (2012) | 108 | 108 | 26.8 | 28.2 | 215 | 162 | 368 | 400 | 2.7 | 2.2 | 6 | 6 |
| Hyams et al. (2012) | 20 | 20 | – | – | 231 | 259 | | | 2.3 | 2.8 | – | – |
| Long et al. (2012) | 199 | 182 | 22.4 | 23.2 | 197 | 241 | 280 | 325 | 3.5 | 3.8 | 2 | 2 |
| Lucas et al. (2012) | 27 | 15 | 25 | 29.5 | 190 | 195 | 100 | 100 | 2 | 3 | 1 | 0 |
| Lavery et al. (2011) | 20 | 18 | 22.7 | 24.7 | 189 | 180 | 93 | 140 | 2.6 | 2.9 | 0 | 0 |
| Pierorazio et al. (2011) | 48 | 102 | – | – | – | – | – | – | – | – | 2 | 1 |
| Seo et al. (2011) | 13 | 14 | 35.3 | 36.4 | 153 | 118 | 284 | 264 | 6.2 | 5.3 | 0 | 0 |
| Boger et al. (2010) | 13 | 46 | – | – | 168 | 171 | 100 | 100 | 2 | 2 | – | – |
| Choi et al. (2010) | 13 | 31 | 35.5 | 32.4 | 296 | 286 | 289 | 205 | – | – | – | – |
| Haber et al. (2010) | 75 | 75 | 18.2 | 20.3 | 200 | 197 | 323 | 222 | 4.2 | 4.1 | 0 | 0 |
| Benway et al. (2009b) | 129 | 118 | 19.7 | 28.4 | 189 | 174 | 155 | 196 | 2.4 | 2.7 | – | – |
| Jeong et al. (2009) | 31 | 26 | 20.9 | 17.2 | 170 | 139 | 198 | 208 | 5.2 | 5.3 | – | – |
| Kural et al. (2009) | 11 | 20 | – | – | 185 | 226 | 286 | 388 | 3.9 | 4.3 | 5 | 1 |
| Wang and Bhayani (2009) | 40 | 62 | 19 | 25 | 140 | 156 | 136 | 173 | 2.5 | 2.9 | 1 | 1 |
| Aron et al. (2008) | 12 | 12 | 23 | 22 | 242 | 256 | 329 | 300 | 4.7 | 4.4 | 1 | – |

*WIT* warm ischemia time, *EBL* estimated blood loss, *LOS* length of stay, *PSM* positive surgical margin

## 16.4 Balancing Functional Outcomes and Oncological Safety

It is reported that multiple factors such as preoperative renal function, comorbidities, age, sex, tumor volume, preserved volume or ischemic time affect renal function after partial nephrectomy (Lane et al. 2008). Technical principles to minimize renal function decrease are to maximize renal remnant volume and to minimize ischemia (Simmons et al. 2012). The oncological safety of the simple enucleation method (peeling off a tumor along the capsule) to maximize renal parenchymal volume preservation has been reported (Minervini et al. 2011). However, some reports questioned whether enucleative partial nephrectomy can achieve cancer control; thus, this conclusion has yet to appear (Gupta et al. 2015). We do not adopt enucleation, but adopt standard partial nephrectomy with a margin of approximately 5 mm for fear of positive surgical margins. To minimize ischemia, there have been various techniques reported, such as cold ischemia, selective clamping, early unclamping, or clampless technique. However, the best way for ischemia during partial nephrectomy has also yet to be discovered.

## 16.5 Anatomical Aspects Regarding Partial Nephrectomy

Knowledge of a surgical anatomy is mandatory for technical improvement of RAPN. Although there are still few reports on surgical anatomy for nephron-sparing surgery that adapt to robotic surgery, there have been anatomical findings in regard to nephron-sparing surgery in recent years. Some findings are as follows. Though in approximately 75% cases there is one renal artery on either side, some kidneys have more than one renal artery. In those cases, plural renal arteries are observed more frequently in the right side. A renal artery is located in the ventral side of a renal vein in 30% of cases. A renal artery is divided into four smaller arteries; apical, upper, middle and lower artery, each of which carries 75% of the bloodstream overall (Rogers et al. 2009). The histologic examination indicating the correlation between a tumor capsule and normal parenchyma of the kidney also continues to be reported, so further study is expected.

## 16.6 Learning Curve

Various approaches are applied to partial nephrectomy depending on the anatomical position of the tumor, the patient's body type, and trans- or retroperitoneal approaches, so it is difficult to evaluate the learning curves of partial nephrectomy. It is reported that the learning curve of LPN reaches more than 200 cases (Porpiglia et al. 2008), while that for RAPN is approximately 25 cases (Pierorazio et al. 2011). In addition, as surgical robots have spread to most major institution, this situation will make it difficult for even skilled LPN surgeons to conduct further operations in LPN in the near future, and as a result it will also be difficult to train young LPN operators. Assessment studies of learning curve using the scores stated below and the development of an effective training system are expected in the future.

## 16.7 Indications of Nephron-Sparing Surgery and Nephron-Sparing Surgery for High Complexity Tumors

At present, partial nephrectomy is the standard treatment for clinical T1a tumor in various guidelines. As for clinical T1b tumor, partial nephrectomy is recommended rather than radical nephrectomy when it is technically feasible. As for tumors larger than clinical T2, radical nephrectomy is considered to be the standard treatment. In recent years, nephron-sparing surgery has been proven to be effective for technically difficult localized renal cell carcinoma (Mir et al. 2017). Other high complexity tumors include hilar tumors, endophytic tumors, or multiple tumors. Recently, the R.E.N.A.L Nephrometry score (Kutikov and Uzzo 2009) and PADUA (Preoperative Aspects and Dimensions Used for an Anatomical) index (Ficarra et al. 2009) have been used to stratify surgical complexity and risk of complications of partial nephrectomy by anatomical characteristics of renal tumor from preoperative images (Table 16.2). Recently, safety and efficacy of RAPN for these complex tumors has also been shown (Abdel Raheem et al. 2016).

In addition, it is also reported that more partial nephrectomies have been performed than radical nephrectomies in hospitals that are equipped with surgical robots (Sivarajan et al. 2015; Patel et al. 2013). Though partial nephrectomy is recommended in guidelines currently, nephron-sparing surgery is not necessarily performed because of the lack of institutional or surgeon experience. The spread of RAPN is expected to decrease the number of unnecessary nephrectomies. Furthermore, RAPN is also expected to increase the adaptation of the nephron-sparing surgery for more complex tumors in the future.

## 16.8 Conclusion

RAPN is a safe and effective approach to nephron-sparing surgery. Though robotic assistance offers many technical advantages that can reduce the difficulty of minimally invasive partial nephrectomy. Nevertheless, the procedure is challenging for the novice robotic surgeon. Henceforth, the secure popularization of RAPN and accumulation of evidence for complex tumors or large tumors are required. Improving the method of RAPN is thought to be crucial to achieving certain oncological stump negative, and to prevent complications while remaining aware of the principle of minimizing ischemia to remaining normal renal parenchyma.

## References


Abdel Raheem A, Alatawi A, Kim DK, Sheikh A, Alabdulaali I, Han WK, et al. Outcomes of high-complexity renal tumours with a Preoperative Aspects and Dimensions Used for an Anatomical (PADUA) score of >/=10 after robot-assisted partial nephrectomy with a median 46.5-month follow-up: a tertiary centre experience. BJU Int. 2016;118(5):770–8. https://doi.org/10.1111/bju.13501.

Albani JM, Novick AC. Renal artery pseudoaneurysm after partial nephrectomy: three case reports and a literature review. Urology. 2003;62(2):227–31.

Alemozaffar M, Chang SL, Kacker R, Sun M, DeWolf WC, Wagner AA. Comparing costs of robotic, laparoscopic, and open partial nephrectomy. J Endourol. 2013;27(5):560–5. https://doi.org/10.1089/end.2012.0462.

Aron M, Koenig P, Kaouk JH, Nguyen MM, Desai MM, Gill IS. Robotic and laparoscopic partial nephrectomy: a matched-pair comparison from a high-volume centre. BJU Int. 2008;102(1):86–92. https://doi.org/10.1111/j.1464-410X.2008.07580.x.

Benway BM, Wang AJ, Cabello JM, Bhayani SB. Robotic partial nephrectomy with sliding-clip renorrhaphy: technique and outcomes. Eur Urol. 2009a;55(3):592–9. https://doi.org/10.1016/j.eururo.2008.12.028.

Benway BM, Bhayani SB, Rogers CG, Dulabon LM, Patel MN, Lipkin M, et al. Robot assisted partial nephrectomy versus laparoscopic partial nephrectomy for renal tumors: a multi-institutional analysis of perioperative outcomes. J Urol. 2009b;182(3):866–72. https://doi.org/10.1016/j.juro.2009.05.037.

Bishoff JT, Allaf ME, Kirkels W, Moore RG, Kavoussi LR, Schroder F. Laparoscopic bowel injury: incidence and clinical presentation. J Urol. 1999;161(3):887–90.

Boger M, Lucas SM, Popp SC, Gardner TA, Sundaram CP. Comparison of robot-assisted nephrectomy with laparoscopic and hand-assisted laparoscopic nephrectomy. JSLS. 2010;14(3):374–80. https://doi.org/10.4293/108680810x12924466007124.

Choi JD, Park JW, Choi JY, Kim HS, Jeong BC, Jeon SS, et al. Renal damage caused by warm ischaemia during laparoscopic and robot-assisted partial nephrectomy: an assessment using Tc 99m-DTPA glomerular filtration rate. Eur Urol. 2010;58(6):900–5. https://doi.org/10.1016/j.eururo.2010.08.044.

Dulabon LM, Kaouk JH, Haber GP, Berkman DS, Rogers CG, Petros F, et al. Multi-institutional analysis of robotic partial nephrectomy for hilar versus nonhilar lesions in 446 consecutive cases. Eur Urol. 2011;59(3):325–30. https://doi.org/10.1016/j.eururo.2010.11.017.

Ellison JS, Montgomery JS, Wolf JS Jr, Hafez KS, Miller DC, Weizer AZ. A matched comparison of perioperative outcomes of a single laparoscopic surgeon versus a multisurgeon robot-assisted cohort for partial nephrectomy. J Urol. 2012;188(1):45–50. https://doi.org/10.1016/j.juro.2012.02.2570.

Ficarra V, Novara G, Secco S, Macchi V, Porzionato A, De Caro R, et al. Preoperative aspects and dimensions used for an anatomical (PADUA) classification of renal tumours in patients who are candidates for nephron-sparing surgery. Eur Urol. 2009;56(5):786–93. https://doi.org/10.1016/j.eururo.2009.07.040.

Gettman MT, Blute ML, Chow GK, Neururer R, Bartsch G, Peschel R. Robotic-assisted laparoscopic partial nephrectomy: technique and initial clinical experience with DaVinci robotic system. Urology. 2004;64(5):914–8. https://doi.org/10.1016/j.urology.2004.06.049.

Gupta GN, Boris RS, Campbell SC, Zhang Z. Tumor enucleation for sporadic localized kidney cancer: pro and con. J Urol. 2015;194(3):623–5. https://doi.org/10.1016/j.juro.2015.06.033.

Haber GP, White WM, Crouzet S, White MA, Forest S, Autorino R, et al. Robotic versus laparoscopic partial nephrectomy: single-surgeon matched cohort study of 150 patients. Urology. 2010;76(3):754–8. https://doi.org/10.1016/j.urology.2010.03.058.

Hughes-Hallett A, Patki P, Patel N, Barber NJ, Sullivan M, Thilagarajah R. Robot-assisted partial nephrectomy: a comparison of the transperitoneal and retroperitoneal approaches. J Endourol. 2013;27(7):869–74. https://doi.org/10.1089/end.2013.0023.

Hyams E, Pierorazio P, Mullins JK, Ward M, Allaf M. A comparative cost analysis of robot-assisted versus traditional laparoscopic partial nephrectomy. J Endourol. 2012;26(7):843–7. https://doi.org/10.1089/end.2011.0522.

Jeong W, Park SY, Lorenzo EI, Oh CK, Han WK, Rha KH. Laparoscopic partial nephrectomy versus robot-assisted laparoscopic partial nephrectomy. J Endourol. 2009;23(9):1457–60. https://doi.org/10.1089/end.2009.0302.

Kural AR, Atug F, Tufek I, Akpinar H. Robot-assisted partial nephrectomy versus laparoscopic partial nephrectomy: comparison of outcomes. J Endourol. 2009;23(9):1491–7. https://doi.org/10.1089/end.2009.0377.

Kutikov A, Uzzo RG. The R.E.N.A.L. nephrometry score: a comprehensive standardized system for quantitating renal tumor size, location and depth. J Urol. 2009;182(3):844–53. https://doi.org/10.1016/j.juro.2009.05.035.

Lane BR, Babineau DC, Poggio ED, Weight CJ, Larson BT, Gill IS, et al. Factors predicting renal functional outcome after partial nephrectomy. J Urol. 2008;180(6):2363–8; discussion 8–9. https://doi.org/10.1016/j.juro.2008.08.036.

Lavery HJ, Small AC, Samadi DB, Palese MA. Transition from laparoscopic to robotic partial nephrectomy: the learning curve for an experienced laparoscopic surgeon. JSLS. 2011;15(3):291–7. https://doi.org/10.4293/108680811x13071180407357.

Leow JJ, Heah NH, Chang SL, Chong YL, Png KS. Outcomes of robotic versus laparoscopic partial nephrectomy: an updated meta-analysis of 4,919 patients. J Urol. 2016;196(5):1371–7. https://doi.org/10.1016/j.juro.2016.06.011.

Long JA, Yakoubi R, Lee B, Guillotreau J, Autorino R, Laydner H, et al. Robotic versus laparoscopic partial nephrectomy for complex tumors: comparison of perioperative outcomes. Eur Urol. 2012;61(6):1257–62. https://doi.org/10.1016/j.eururo.2012.03.012.

Lucas SM, Mellon MJ, Erntsberger L, Sundaram CP. A comparison of robotic, laparoscopic and open partial nephrectomy. JSLS. 2012;16(4):581–7. https://doi.org/10.4293/108680812x13462882737177.

Masson-Lecomte A, Bensalah K, Seringe E, Vaessen C, de la Taille A, Doumerc N, et al. A prospective comparison of surgical and pathological outcomes obtained after robot-assisted or pure laparoscopic partial nephrectomy in moderate to complex renal tumours: results from a French multicentre collaborative study. BJU Int. 2013;111(2):256–63. https://doi.org/10.1111/j.1464-410X.2012.11528.x.

Meeks JJ, Zhao LC, Navai N, Perry KT Jr, Nadler RB, Smith ND. Risk factors and management of urine leaks after partial nephrectomy. J Urol. 2008;180(6):2375–8. https://doi.org/10.1016/j.juro.2008.08.018.

Minervini A, Ficarra V, Rocco F, Antonelli A, Bertini R, Carmignani G, et al. Simple enucleation is equivalent to traditional partial nephrectomy for renal cell carcinoma: results of a nonrandomized, retrospective, comparative study. J Urol. 2011;185(5):1604–10. https://doi.org/10.1016/j.juro.2010.12.048.

Mir MC, Derweesh I, Porpiglia F, Zargar H, Mottrie A, Autorino R. Partial nephrectomy versus radical nephrectomy for clinical T1b and T2 renal tumors: a systematic review and meta-analysis of comparative studies. Eur Urol. 2017;71(4):606–17. https://doi.org/10.1016/j.eururo.2016.08.060.

Patel V. Robotic urologic surgery. London: Springer; 2008.

Patel M, Porter J. Robotic retroperitoneal partial nephrectomy. World J Urol. 2013;31(6):1377–82. https://doi.org/10.1007/s00345-013-1038-y.

Patel HD, Mullins JK, Pierorazio PM, Jayram G, Cohen JE, Matlaga BR, et al. Trends in renal surgery: robotic technology is associated with increased use of partial nephrectomy. J Urol. 2013;189(4):1229–35. https://doi.org/10.1016/j.juro.2012.10.024.

Paulucci DJ, Rosen DC, Sfakianos JP, Whalen MJ, Abaza R, Eun DD, et al. Selective arterial clamping does not improve outcomes in robot-assisted partial nephrectomy: a propensity-score analysis of patients without impaired renal function. BJU Int. 2017;119(3):430–5. https://doi.org/10.1111/bju.13614.

Pierorazio PM, Patel HD, Feng T, Yohannan J, Hyams ES, Allaf ME. Robotic-assisted versus traditional laparoscopic partial nephrectomy: comparison of outcomes and evaluation of learning curve. Urology. 2011;78(4):813–9. https://doi.org/10.1016/j.urology.2011.04.065.

Porpiglia F, Volpe A, Billia M, Scarpa RM. Laparoscopic versus open partial nephrectomy: analysis of the current literature. Eur Urol. 2008;53(4):732–42; discussion 42–3. https://doi.org/10.1016/j.eururo.2008.01.025.

Rogers CG, Metwalli A, Blatt AM, Bratslavsky G, Menon M, Linehan WM, et al. Robotic partial nephrectomy for renal hilar tumors: a multi-institutional analysis. J Urol. 2008a;180(6):2353–6; discussion 6. https://doi.org/10.1016/j.juro.2008.08.022.

Rogers CG, Singh A, Blatt AM, Linehan WM, Pinto PA. Robotic partial nephrectomy for complex renal tumors: surgical technique. Eur Urol. 2008b;53(3):514–21. https://doi.org/10.1016/j.eururo.2007.09.047.

Rogers CG, Laungani R, Bhandari A, Krane LS, Eun D, Patel MN, et al. Maximizing console surgeon independence during robot-assisted renal surgery by using the Fourth Arm and TilePro. J Endourol. 2009;23(1):115–21. https://doi.org/10.1089/end.2008.0416.

Sammon J, Petros F, Sukumar S, Bhandari A, Kaul S, Menon M, et al. Barbed suture for renorrhaphy during robot-assisted partial nephrectomy. J Endourol. 2011;25(3):529–33. https://doi.org/10.1089/end.2010.0455.

Seo IY, Choi H, Boldbaatr Y, Lee JW, Rim JS. Operative outcomes of robotic partial nephrectomy: a comparison with conventional laparoscopic partial nephrectomy. Korean J Urol. 2011;52(4):279–83. https://doi.org/10.4111/kju.2011.52.4.279.

Simmons MN, Schreiber MJ, Gill IS. Surgical renal ischemia: a contemporary overview. J Urol. 2008;180(1):19–30. https://doi.org/10.1016/j.juro.2008.03.022.

Simmons MN, Hillyer SP, Lee BH, Fergany AF, Kaouk J, Campbell SC. Functional recovery after partial nephrectomy: effects of volume loss and ischemic injury. J Urol. 2012;187(5):1667–73. https://doi.org/10.1016/j.juro.2011.12.068.

Sivarajan G, Taksler GB, Walter D, Gross CP, Sosa RE, Makarov DV. The effect of the diffusion of the surgical robot on the hospital-level utilization of partial nephrectomy. Med Care. 2015;53(1):71–8. https://doi.org/10.1097/mlr.0000000000000259.

Wang AJ, Bhayani SB. Robotic partial nephrectomy versus laparoscopic partial nephrectomy for renal cell carcinoma: single-surgeon analysis of >100 consecutive procedures. Urology. 2009;73(2):306–10. https://doi.org/10.1016/j.urology.2008.09.049.

Williams SB, Kacker R, Alemozaffar M, Francisco IS, Mechaber J, Wagner AA. Robotic partial nephrectomy versus laparoscopic partial nephrectomy: a single laparoscopic trained surgeon's experience in the development of a robotic partial nephrectomy program. World J Urol. 2013;31(4):793–8. https://doi.org/10.1007/s00345-011-0648-5.

# 17 Minimally Invasive Ureteral Reimplantation in Children with Vesicoureteral Reflux: History and Current Status

Nikko J. Magsanoc and Michael Chua

**Abstract**

Ureteral reimplant being one of the most complex operative procedures performed in children, it is a rational challenge to incorporate minimally invasive approach of laparoscopy with or without robotic assistance to provide the equivalent clinical advantage seen with complex procedures in adult population. It is important to comprehend the history and current status of this technological application in children and recognizes the clinical factors affecting optimal surgical outcome. Furthermore, it is necessary to grasp the essential technical and technological advancement from current literature to promote better surgical outcome of this challenging yet rewarding procedure among children.

**Keywords**

Pediatric vesicoureteral reflux · Robot-assisted laparoscopy ureteral reimplantation · Extravesical ureteral reimplantation · Intravesical ureteral reimplantation

## Abbreviations

| | |
|---|---|
| 2D | 2-Dimension |
| CAKUT | Congenital anomalies of the kidney and urinary tract |
| UTI | Urinary tract infection |
| UVJ | Ureterovesical junction |
| VCUG | Voiding cystourethrogram |
| VUR | Vesicoureteral reflux |

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## 17.1 Introduction

### 17.1.1 Background

Vesicoureteral reflux (VUR) is a condition with anatomic and/or functional etiology that causes backflow of urine into the upper urinary tract. It is one of the most commonly diagnosed congenital anomalies of the kidney and urinary tract (CAKUT) among children presented with first febrile urinary tract infection (UTI) (Vachvanichsanong et al. 2017). The actual prevalence of the condition is unknown (Tekgul et al. 2017); however, estimated to be affecting 1–3% of infants and children.

Severe form of this condition causes recurrent pyelonephritis and renal scarring, which eventually lead to long term sequale of renal failure. Depending on the severity of VUR, management is catered according to individual patient condition (Arlen and Cooper 2015). Management options include, conservative close monitoring and continuous antibiotics prophylaxis, endoscopic bulking agent injection, minimally invasive procedures of ureteral reimplant using laparoscopic with or without robotic assistance to invasive open surgical approaches (Tekgul et al. 2017; Kim et al. 2017; Peters et al. 2010).

### 17.1.2 Scope

The scope of this chapter is confined to present the literature on minimally invasive approach of ureteral reimplant in children with VUR. Specifically to discuss the history, current status, consideration on the approach and future direction with highlights on Asian setting. For procedural description and technical details, recent publications and video bank are recommended as citations but not illustrated in this chapter (Patel and Ramalingam 2017; Dangle et al. 2014; Diaz et al. 2014; Schober and Jayanthi 2015; Weiss and Shukla 2015; Gundeti et al. 2016). Source of literature reference for this chapter was acquired from Pubmed on November 2017 with


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restriction only for human studies. (Search term strategy in Appendix A.)

## 17.2 History of Minimally Invasive Ureteral Reimplant in Management of Vesicoureteral Reflux Among Children

The conventional open approach of ureteral reimplantation of various techniques has shown high success rate ranging 92–98.3% in the treatment of VUR among children (Kennelly et al. 1995; Heidenreich et al. 2004; Austin and Cooper 2004). With the introduction of minimally invasive approach, laparoscopy was utilized in the early 1990s reported initially on animal model with extravesical technique (Atala et al. 1993; Schimberg et al. 1994; McDougall et al. 1995). Subsequent reports on human series, initially on adult patient, later on pediatric series were then published within the same decade (Reddy and Evans 1994; Ehrlich et al. 1994; Janetschek et al. 1995). The feasibility of the laparoscopic extravesical ureteral reimplant procedure was then established; however, due to the initial experience of technical challenges and time demanding, the approach was not immediately adopted by many (Smaldone et al. 2007). With learning curve being traversed, availability of better laparoscopic equipments and technical modifications, better successful clinical outcomes of the minimally invasive approach had been reported; yet careful selection of suitable patient was strongly recommended to achieve good outcome (Lakshmanan and Fung 2000; Carswell et al. 2003; Shu et al. 2004). Within the parallel timeframe, the adaptation and modification of laparoscopic extravesical ureteral reimplant were being reported in Asian countries with later showing comparable clinical outcomes (Kawauchi et al. 2003; Sakamoto et al. 2003; Ansari et al. 2006; Simforoosh et al. 2007).

In the initial exploration of minimally invasive approach ureteral reimplant, the endovesical approach utilizing both endoscope and laparoscopic instruments, was also reported in Asia (Okamura et al. 1993, 1996, 1999); however, due to limitation of visibility and mobility in using the urethral endoscope, technical difficulty of transvesical port placement and lower success rate (62.5–86%) compared to open approach; this approach was not favoured and became unpopular (Cartwright et al. 1996; Gatti et al. 1999; Gill et al. 2001; Tsuji et al. 2003; El-Ghoneimi 2003). Further animal studies were then performed to explore the feasibility of carbon dioxide insufflations of the bladder modifying the intravesical approach to improve visibility and technical mobility (Lakshmanan et al. 1999; Olsen et al. 2003). Subsequent reports in human series were published from Asian countries as well as north American experience with comparable success rate (91–96%) to open approaches (Yeung et al. 2005; Kutikov et al. 2006; Canon et al. 2007; Schober and Jayanthi 2015; Soulier et al. 2017). To overcome the limited dexterity, 2D spatial image and steep learning curve of pure laparoscopy, robotic system was introduced in 2000 to assist laparoscopic procedure, which gained high popularity for pelvic surgery procedures (Finkelstein et al. 2010). Robotic assisted laparoscopic was then being adapted for ureteral reimplants in children with initial experience reported in the early 2000 (Peters 2004; Peters and Woo 2005; Hayn et al. 2008).

## 17.3 Current Status of Minimally Invasive Approach of Ureteral Reimplant in Children

### 17.3.1 Current Status of Laparoscopic Ureteral Reimplants in Asian Countries

In the past decade, numerous successful intermediate to long term outcome were being reported from the Asian countries for pure laparoscopic ureteral reimplant of both extravesical and intravesical approach with some modifications (Tsai et al. 2008; Chung et al. 2008; Kawauchi et al. 2009; Chan et al. 2010; Hong et al. 2011; Chung et al. 2012; Emir et al. 2012; Moritoki et al. 2012; Bi and Sun 2012; Hayashi et al. 2014; Kim et al. 2015; Javali et al. 2015; Soh et al. 2015; Lau et al. 2017) The reported success rate ranges from 90% to 100% with low number of complications (Table 17.1). Some Asian studies also showed an improving perioperative and long term outcome with the learning curve being traversed (Chung et al. 2012; Choi et al. 2016; Lau et al. 2017).

### 17.3.2 Current Status of Robotic Assisted Laparoscopic Ureteral Reimplants Worldwide and Asian Countries

In the recent years, robot assisted laparoscopic ureteral reimplant is becoming a more prevalent approach for children with VUR (Weiss and Shukla 2015; Bowen et al. 2016). Two reports from Asian country have also demonstrated their early experience and feasibility of robotic assisted laparoscopic ureteral reimplant in children with acceptable outcome (Table 17.1) (Chan et al. 2010; Hayashi et al. 2014). Several literatures from USA are now available to demonstrate the short term to intermediate outcome of this new approach (Casale et al. 2008; Sorensen 2010; Marchini et al. 2011; Smith et al. 2011; Callewaert et al. 2012; Kasturi et al. 2012; Chalmers et al. 2012; Dangle et al. 2013; Gundeti et al. 2013; Schomburg et al. 2014; Akhavan et al. 2014; Dangle et al. 2014; Faasse et al. 2014; Diaz et al. 2014; Silay et al. 2015; Grimsby et al. 2015; Arlen et al. 2016; Herz et al. 2016; Kurtz et al. 2016; Gundeti et al. 2016; Boysen et al. 2017). Although still at its infancy stage, the clinical outcome reported are mostly for extravesical approach and the rate of success varies from 72% to 100% with some factors need to be considered as discussed by some of the authors (Table 17.2).

**Table 17.1** Summary of current literature from Asian countries on Laparoscopic ureteral reimplant in Children since 2008

| | Source | # Children/# ureters | Age (years) mean/ median (SD/ranges) | VUR grade | Approach (techniques)/ modifications | Mean/median OR time (min) Unilateral/bilateral/ overall | Hospital stay (days) | Follow-up time (months) | Success (%) | Complications (%) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tsai et al. (2008) | Taiwan | 9/14 | 3.4 years mean (7 months–5 year) | I–V | Nerve sparing extravesical approach (Lich-Gregoir) | 170/218/– | 1.4 days | 3–4 months VCUG | 13 (92.9%)[a] | 1 ureterovesical stenosis | |
| Chung et al. (2008) | Hong Kong | 9/14 | 7.2 years mean (±4.5) | Not mentioned | Pneumovesical approach (Cohen) | –/–/214.8 ± 34.2 | 9.3 ± 2.4 | 3 months VCUG | ? (>95%) 100% according to 2008 ffup | 2 conversion to open (failure to maintain pneumovesicum and working port dislodgement). No post-op complications | Included VUJO and VUR with prior bulking agent injection therapy. Data compared to open approach showed longer operative time in pneumovesicum |
| Kawauchi (2009) | Japan | 15/27 | 5 years median (1–12 year old) | I–V | Pneumovesical approach (Cohen) | –/–/225 (median) | 0–1 day | 3–6 months VCUG | 26 (96%) | 1 failure—UVJ stenosis | Included adult patients for comparison |
| Chan (2010)[b] | Hong Kong | 3/3 | 5.2 years mean (18 months–10 years) | IV | Extravesical (Lich-Gregoir) | 350/–/– | 3–10 days | Overall mean 38 months (17–46) | 3 (100%)[a] | 1 postop urinary retention | Included 5 PUJO cases in the report |
| Hong et al. (2011) | South Korea | 28/46 | 6 years | II–V | Pneumovesical approach (Cohen) | 166 ± 46.8/188.8 ± 54.2/180 ± 51.7 | 1.38 (1–4) | 8.6 (6–14 months) | 94.6%[c] 35 of 37 | 2 conversion to open due to port dislodgement, 1 intraop complication of ureteral stent migration | Assessment of learning curve showed improvement |
| Kojima et al. (2012) | Japan | 30/51 | 60.8 years mean ± 48.6 | I–V | Extravesical (Lich-Gregoir) | 118 ± 34/209/46 | 6.2 (2–12) | 16.4 ± 7.5 | 47 (92%)[a] | 1 postop urine leak | Included additional analysis on modified technique with ureteral advancement, better success rate with ureteral advancement technique |
| Chung et al. (2012) | South Korea | 48/90 | 3.7 (7 months–13 years) | I–V | Pneumovesical approach (Cohen) | –/–/155.6 ± 42.77 | 1.6 ± 0.91 | 16.3 median | 96.4%[c] 81 of 84 | 3 open conversion (2 port dislodgement, one posterior bladder injury | Assessment of learning curve improvement (Updated data of Hong et al. (2011)) |
| Emir et al. (2012) | Turkey | 11/17 | 6.9 years (2–15) | II–IV | Pneumovesical approach (Cohen) | 217/306/– | 3.8 (3–5) | 4.5 years (3–7) | 94% (16 of 17) | 2 cases had pneumoperitoneum, 1 had recurrent uti | |
| Moritoki et al. (2012) | Japan | 1/2 | 11 months | V | Extravesical (Lich-Gregoir) with diverticulectomy | –/311/– | Not mentioned | 6 months VCUG | 100% | None | Letter to editor, minimal invasive laparoscopic bilateral antireflux surgery with diverticulectomy |

(continued)

**Table 17.1** (continued)

| | Source | # Children/# ureters | Age (years) mean/ median (SD/ranges) | VUR grade | Approach (techniques)/ modifications | Mean/median OR time (min) Unilateral/bilateral/ overall | Hospital stay (days) | Follow-up time (months) | Success (%) | Complications (%) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bi and Sun (2012) | China | 45/61 | 40.16 months (3 months to 10 years) | VUJO | Pneumovesical approach (Cohen) with ureteral tapering | 3.5 h/5.4 h (2–9 h) | 8.3 (4–15) | 19.3 months (1–67 months) | 32 of 48[c] | 2 conversion to open due to difficult dissection and bleeding. 1 stenosis developed at neoureteral opening | Mega-ureter tapering, decrease dilatation in postop ultrasound as definition of success |
| Hayashi et al. (2014)[b] | Japan | 7/10 | 7.6 (2–11) | I–V | Extravesical (Lich-Gregoir) | 159/293/241.1 | 7.3 (7–8) | 3–4 months VCUG | 9 (90%) | None major | Included 2 adults in the report, only peds cases were extracted for this table |
| Choi et al. (2016) | South Korea | 10/18 | 6.9 (4–10) | II–V | Pneumovesical approach (Politano-Leadbetter) | 92.5/133.3/125.1 | 6 (3–9) | 8.9 (3.4–15.7) | All (100%) | 1 intraop ureteral injury, I recurrent UTI | Assessed learning curve |
| Kim et al. (2015) | South Korea | 11/11 | 9.18 (1–24 year old) | Primary megaureter (2 refluxing) | Pneumovesical approach (intravesical detrusorrhaphy) | 214/–/– | 7.3 | 12.6 (5–24 months) | 10 of 11 (91%) | 1 persistent grade 2 hydronephrosis | Mega-ureter tapering, decrease dilatation in postop ultrasound as definition of success (Different timeframe cases from Hong et al. (2011) and Chung et al. (2012)) |
| Javali et al. (2015) | India | 76/98 | 9.5 ± 3.75 (3–16) | I–IV | Extravesical approach (Lich-Gregoir)/ vascular sling modification | 102 ± 26.5/165 ± 18/– | 1.5 ± 1.7 | 3 months VCUG | 96 of 98 (97.9%) | 3 significant bladder mucosal perforation, 1 port infection, I urinary retention | One case with concomitant diverticulectomy |
| Soh et al. (2015) | Japan | 18/28 | 9.1 (4–17) | I–IV | Pneumovesical approach (Politano-leadbetter & Cohen) | 250.4/301.1/– | 3.6 mean (2–8) | 45.1 mean (2–81 months) | 27 of 28 (96.4%) | 1 urine leakage | Included 6 adults in the report, only peds cases were extracted for this table. Compared Politano-Leadbetter versus Cohen. Concluded PL, with better physiologic advantage |
| Lau et al. (2017) | Hong Kong | 31/42 | 6.1 ± 0.6 | IV–V and VUJO | Pneumovesical approach (Cohen) | –/–/221 ± 7 (169–318 min) | 7.4 ± 0.8 (3–22) | 3 months VCUG | 42 (100%)[a] | 4 conversion to open (3 due to diff dissection, 1 port leakage) | Updated data of Chung et al. (2008) Hong Kong |
| Khan et al. (2017) | India | 8/8 | 18.5 | VUJO | Extravesical approach (Lich-Gregoir/ intracorporal tailoring over a dilator) | 95 (115–80)/–/– | 2.5 (2–5) | 3–6 months VCUG | 100% | None major | Mega-ureter tapering, decrease dilatation in postop ultrasound as definition of success |

[a]Success—considers complete resolution and downgrade
[b]Robotic Assisted
[c]Only22 patients had postop vcug

**Table 17.2** Current literature on Robotic Assisted Laparoscopic ureteral reimplants in Children

| | Source | # Children/# ureters | Age (years) mean/median (SD/ranges) | VUR grade | Approach (techniques)/ modifications | Mean/median OR time (min) Unilateral/bilateral/overall | Hospital stay (days) | Follow-up time (months) | Success (%) | Complications (%) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Casale et al. (2008) | USA | 41/82 | 38 months (16–81) | III–V | Extravesical approach | –/2.33 h (1.4–3.19)/– | 26.1 h (18–34) | 3 months VCUG | 40 of 41 (97.6%) | 1 with recurrent pyelonephritis | Mentioned visualization and avoidance of pelvic plexus to avoid post-op bladder dysfunction |
| Lendvay (2008) | USA | 16/– | Not discussed | Not discussed | Extravesical approach | Not discussed | Not discussed | Not discussed | 13 of 16 (81.2%) | No intraoperative complication, 1 postop urinary retention, 1 ureteral leak, 1 transient ureteral obstruction, 1 denovo contralateral reflux development | |
| Sorensen (2010) | USA | 13/18 | 8.4 ± 4.1 | 3.2 (0.9) | Extravesical approach | 309 ± 36/443 ± 57/361 ± 80 | 2.5 (1.5) | 14 month | 11 of 13 (85%) | 1 ureteral obstruction, 1 had urinoma | Compared with open procedure with general recommendation for RAL program initiation |
| Marchini et al. (2011) | USA | 39/76 | 9.9 ± 5.2 (intravesical) 8.6 ± 9.1 (extravesical) | I–V | Intravesical and extravesical approaches | –/–/232.6 ± 37.4 (intravesical); 233.5 ± 60.2 (extravesical) | 1.8 ± 1.2 (intravesical); 1.7 ± 1 (extravesical) | 19.4 ± 18.2 (intravesical); 12 ± 14.3 (extravesical) | Intravesical (92.2%) Extravesical (100%) | Intravesical—2 significant bladder spasm, 1 urinary retention, 4 bladder leaks Extravesical—2 significant bladder spasm, 2 urinary retention, 2 ureteral leaks, 1 UTI | Compared two approaches with open reimplants |
| Smith et al. (2011) | USA | 25/33 | 69 ± 39.1 (3–144) | II–V | Extravesical approach | 177/203/185 ± 41.6 (117–286) | 33 h ± 12.5 (14–57) | 3–4 months VCUG 16 (2–44) | 31 of 33 (97%) | 3 had difficulty voiding postop, no intraop complications | Compared to open approach |
| Callewaert et al. (2012) | Netherland | 5/10 | 6.8 (4–11 year old) | IV | Extravesical approach | –/2.7 h (2.5–3.5) | 24–72 h | 28 months | 9 of 10 (90%) | 1 bladder perforation, 1 marked hydronephrosis on lower pole | |
| Kasturi et al. (2012) | USA | 150/300 | 42.6 (27–111) | III–V | Extravesical approach | –/1.8 h (1.1–3.2)/– | 22.1 h (18–34) | 3 months VCUG 2 years | 149 of 150px (99.3) | 1 pyelonephritis, no intraop complication | Nerve sparing modification |

(continued)

**Table 17.2** (continued)

| | Source | # Children/# ureters | Age (years) mean/median (SD/ranges) | VUR grade | Approach (techniques)/ modifications | Mean/median OR time (min) Unilateral/bilateral/overall | Hospital stay (days) | Follow-up time (months) | Success (%) | Complications (%) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chalmers et al. (2012) | USA | 16/22 | 6.23 ± 3.4 | I–IV | Extravesical approach | 127 min (105–155)/177 min (160–200) | 1.3 ± 0.48 | 11.5 months | 20 of 22 (90.0%) | No intraop complications | |
| Srougi et al. (2013) | USA | 17/– | 1.9 (1.2–2.9) | Not discussed | Extravesical approach | –/–/153.3 ± 57 | Not discussed | 13.6 months | 14 of 17 (82.3%) | No intraop complications, 1 unilateral ureteral stenosis | Operative time and follow-up duration were not stratified only for reimplant. Data report include other pediatric robotic surgery. Complication extracted for reimplant only |
| Bansal et al. (2013) | USA | 14/– | 83 months median (3.6–316.4) | Not discussed | Extravesical approach | 225 median (103–591) | 2 (0–16) | Not discussed | Not discussed | No intraoperative complications, 1 UTI, 1 port site infection | All data were not stratified only for reimplant. Data report include other pediatric robotic surgery. Complication extracted for reimplant only |
| Dangle et al. (2013) | USA | 7/10 | 5.5 (2.8–9.9) | IV | Extravesical approach | 190 (127–297)/215 (194–257) | 2 (2–4) | – | – | No inraop complications | Plexus nerve inconsistently identified intraop |
| Gundeti et al. (2013) | USA | 24/37 | 5.5 (2.8–9.9) | II–V | Extravesical approach | 173.72 (103–297)/217 (194–265)/– | 2.2 (1–4) | 337 days (range 98–889 days) | 30 of 37 (81%) | 9 ureters (28%) developed transient hydronephrosis | Discussed technique development in improvement of clinical outcomes (data from abstract adopted)[a] |
| Schomburg et al. (2014) | USA | 20/25 | 74 months | 2.84 | Extravesical approach | 165/227/– | 1.05 | 13 months | 25 of 25 (100%)[a] | 2 febrile UTI, 1 urine leak and 1 ureteral stenosis | Compared to Open |
| Akhavan et al. (2014) | USA | 50/78 | 6.2 (1.9–18) | (3) 0–V | Extravesical approach | –/–/– | 2 (1–6) | 286 (27–2238) | 72 of 78 (92.3%) | 5 febrile UTI, 2 ileus, 2 ureteral obstruction, 1 ureteral injury, 1 perinephric fluid, 1 transient retention | 5 of 22 unilateral repair had contralateral de novo vur[a] |
| Dangle et al. (2014) | USA | 29/40 | 5.38 (3–10) | III–V | Extravesical approach | –/–/– | 1.8 (1–3) | 4 months VCUG | 32 of 40 (80%) | None discussed | 39 of 40 (97.5%) if downgrade is considered success |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Faasse et al. (2014) and Diaz et al. (2014) | USA | 23/40 | Not discussed | Not discussed | Extravesical approach | Not discussed | Not discussed | Not discussed | 20 of 23 (86.9%) | 1 ileus, 1 transient bilateral obstruction | Compared cautery vs. $CO_2$ laser for detrussor tunnel creation (Faasse et al. 2014 as single report included in Diaz et al. 2014) |
| Silay et al. (2015) | USA | 89/114 | 5.4 ± 1.9 | Not discussed | Extravesical approach | Not discussed | Not discussed | Not discussed | 89 of 91 (97.9%) | 2 temporary urinary retention | Modified top down approach suture without stent placement facilitates suturing |
| Grimsby et al. (2015) | USA | 61/93 | 6.7 (0.6–18) | 3.3 (I–V) | Extravesical approach | Not discussed | Not discussed | 3 months vcug/RNC, 11.7 months (1.2–32.3) | 44 of 61 (72%) | 1 intraop mucosal perforation, 3 ureteral obstruction, 2 urine leak, 1 nausea vomiting | Advised robotic only for bilateral and older children |
| Harel et al. (2015) | USA | 23/33 | 7.5 ± 2.9 | Not discussed | Extravesical approach | –/–/204 ± 34 | Majority after 1 day (87%) | Not discussed | 84% with 3% downgrade | 1 febrile UTI | Assessed objective post-op pain diff between open and robotic |
| Arlen et al. (2016) | USA | 17/20 | 9.3 ± 3.7 year old | 3.4 (1.1) | Extravesical approach | –/–/169.3 ± 45.5 | 1 | 4–12 weeks VCUG | 15 of 17 (88%) radiographic, 94.1% for clinical success | No intraop complication, 1 ileus, 1 uti | Included VUJO into the data. Compared to open. 1 contralateral vur |
| Herz et al. (2016) | USA | 54/72 | 5.2 | 3.43 (I–IV) | Extravesical approach | 206.5 (145–256)/306.2 (229–444)/273.3 | 1.64 days | 4–12 weeks | 61 of 72 (85.2%) | 5 reop for VUR, 4 ureteral obstruction, 2 urine leak, 4 urinary retention, 4 UTI at 4 weeks, 12 worsening BBD | Multivariate analysis to assess variables related to poor outcome |
| Kurtz et al. (2016) | USA | 108/– | 5 median | Not discussed | All approach as revealed from database | –/–/232 (median) IQR 188–270 | 2 median IQR 1–2 | 90 days complication rate | Not discussed | 14 (13%) complications. 2 urinary retention, 4 postop hydronephrosis, 2 UTI, 2 cardiovascular issues, 2 urinary issues and 2 GI issues | Assessed the cost, showing high cost related to robot assisted procedures compared to open. Also assessed factors related to 90 day complications |

(continued)

**Table 17.2** (continued)

| | Source | # Children/# ureters | Age (years) mean/median (SD/ranges) | VUR grade | Approach (techniques)/ modifications | Mean/median OR time (min) Unilateral/bilateral/overall | Hospital stay (days) | Follow-up time (months) | Success (%) | Complications (%) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gundeti et al. (2016) | USA | 58/83 | 5.3 ± 2.2 | III–V | Extravesical approach | Not discussed | 2 (1–6) | 30 (4–69) | 68 of 83 (82%) | No intraop complications reported, 1 transient retention | Modified techniques LUAA (detrusor tunnel length, U stitch, permanent ureterak alignment suture, inclusion of ureteral adventisia) |
| Boysen et al. (2017) | USA | 260/363 | 6.4 ± 3.9 | 0–V | Extravesical approach | 152 ± 56.1/198 ± 57.6/177 ± 61.4 | 1.6 ± 1.1 | 3 months postop ultrasound-VCUG or RNC | 246 in 280 (87.6%) radiographic, 239/260 clinical | 1 conversion excluded from analysis. 21 postop UTI, 25 overall complications (9.6%) 4 transient retention, 4 ureteral obstruction 2 port site hernia, 1 urine leak | 267 of 280 (95.4%) if downgrade considered success. Multivariate variable assessed factor associated with outcomes |

±Reported operative time is overall total
[a]None have persistent VUR

## 17.4 Considerations in Minimally Invasive Approach for Ureteral Reimplants in Children

### 17.4.1 Advantage and Disadvantage of Minimally Invasive Approach in General

Minimally invasive approach using laparoscopic ureteral reimplant for children with VUR has shown to have comparable result with the open counterpart procedure, while sustaining the clinical benefit of less postoperative pain, lower postoperative morbidity of endoscopic procedures (Esposito et al. 2016). Additionally, recent survey reported that urological surgery scars in children seem to influence the decision of parents and patients on the approach of the surgical procedure and favours minimally invasive ureteral reimplant over the open approach (Barbosa et al. 2013). However, some authors contradicts this opinion by describing that small scar may not always be the preference of the family and patient, special consideration must also focused on the scar location for concealment (Gargollo 2011; Garcia-Roig et al. 2017).

Pure laparoscopic approach was said to have limitation on the manipulation of the instrument intracorporally, whereas the robotic assistance improve the dexterity, motion scale, magnification of vision with spatial depth perception and enhance fine movement which could offset the disadvantage of lack of haptic feedback (Schomburg et al. 2014; Phillips and Wang 2012). While still in its infancy stage, laparoscopic with robotic assistance seems to incur higher cost, longer operative time and some related morbidity (Kurtz et al. 2016; Arlen et al. 2016). Recent literature argued that the shorter hospital stay and lesser need for post-operative analgesia may indeed offset the related cost (Smith et al. 2011; Hayashi et al. 2014; Schomburg et al. 2014; Harel et al. 2015).

### 17.4.2 Advantage and Disadvantage of Laparoscopic Extravesical and Intravesical Approach with or Without Robotic Assistance

Majority of the recent minimally invasive approach on ureteral reimplants in children were reported to be robotic assisted laparoscopy (Tables 17.1 and 17.2) and specifically applying the extravesical approach. The extravesical approach of Lich-Gregoir was previously described to have the advantage of its technical simplicity, with avoidance of bladder intrusion and or vesicoureteral anastomosis, which then rendered less post-operative pain, shorter recovery period and some bladder related postoperative morbidities such as hematuria and bladder spasm (Schwentner et al. 2006; Hayashi et al. 2014; Silay et al. 2017). Similar advantage of this approach holds true for minimally invasive ureteral reimplant (Casale et al. 2008; Lopez et al. 2011). Although open extravesical bilateral ureteral reimplant was once reported to have increased incidence of post-operative bladder dysfunction, which was thought to be due to injury of pelvic plexus (Fung et al. 1995; David et al. 2004). However, with the improved visualization of minimally invasive approach, this concern was addressed by precise dissection of the ureter and bladder that avoids the pelvic plexus, which is described to be 1.5 cm dorsal and medial to ureterovesical junction (UVJ) (Chan et al. 2010; Dangle et al. 2014; Marchini et al. 2011; Kasturi et al. 2012; Riquelme et al. 2013). This being said, yet the potential disadvantage of extravesical approach includes the risk of bowel injury (Tsai et al. 2008), ureteral injury (Marchini et al. 2011), unsuitable for ureters that need tailoring (Javali et al. 2015), challenge in creating detrusor channel (Javali et al. 2015; Kojima et al. 2012). As such, it is recommended to incorporate technical modifications and preventive measures to avoid these complications.

Minimally invasive intravesical/pneumovesical approach of ureteral reimplant was described to have the advantage of replicating the gold standard open procedures (such as Cohen, Politano-anderson, Anderson-Leadbetter) with complete extraperitoneal access and reducing the chance of visceral perforation as well as performing concomitant intravesical procedures (Valla et al. 2009; Emir et al. 2012; Bayne et al. 2012). Furthermore, it allows ability to create longer submucosal tunnel and addressing bilateral VURs (Soh et al. 2015). However, the disadvantage lies on the limited intravesical space with short distance and acute angle between the trocars leading to difficult navigation and manipulation of the surgical field (Soh et al. 2015; Hong et al. 2011) The presence of risk for port dislodgement and water tight closure of these ports needs to be assured to prevent complications (Valla et al. 2009; Hong et al. 2011). Likewise, it was described that this approach has steep learning curve, although once traversed good surgical outcome can be achieved (Schober and Jayanthi 2015; Valla et al. 2009).

### 17.4.3 Considerations on Patient Selection and Factors for Good Surgical Outcomes

Several studies have analyzed clinical factors affecting the surgical outcome. Most of the reported initial experiences in laparoscopic ureteral reimplant with or without robotic assistance have recommended careful selection of patient that would be suitable for the procedure. Younger patient (<3 year old) tend to have poor surgical outcome, due to smaller working space; this issue hold true for both intravesical and extravesical approach with or without robostic assistance (Gundeti et al. 2013; Herz et al. 2016). Furthermore, through the intravesical approach, a small bladder volume, specifically less than 130 cc, with narrow pelvic space limits the positioning of the trocar causing issue on clashing instrument and mobility (Kutikov et al. 2006; Hong et al. 2011; Chung et al. 2012; Finkelstein et al. 2015). It may not be ideal to perform minimally invasive approach among patients with prior abdominal surgery with severe intraperitoneal adhesion, which could impede trocar placement and potentially adds excessive operative time for lysis (Sávio and Nguyen 2013; Phillips and Wang 2012). Although some authors suggest that positional modification and appropriate minimally invasive instruments may overcome these limitations and considered them as relative contraindications (Lendvay 2008; Casale and Kojima 2009; Bayne et al. 2012; Sávio and Nguyen 2013) Megaureter or concomitant ureterocoele that needs tailoring is another consideration for their suitability, which needs the surgeons' expertise or further modification of the technique to improve the surgical outcome (Ansari et al. 2006; Bi and Sun 2012; Khan et al. 2017). Patients with co-morbidities such as severe bladder bowel dysfunction or other medical conditions have been shown to be associated with poor surgical outcome, which should need adequate preoperative counselling to make informed decision making. (Herz et al. 2016; Lendvay 2008; Kurtz et al. 2016).

### 17.4.4 Considerations on Potential Complications and Respective Management

Although reported with low occurrence of complication associated with laparoscopic ureteral reimplant with or without robotic assistance, these complications should be adequately managed or even prevented. Table 17.3 summarizes the approximate occurrence of complications base on the current literature with study series of 20 or more cases and their proposed management (Marchini et al. 2011; Hong et al. 2011; Chung et al. 2012; Weiss and Shukla 2015).

**Table 17.3** Perioperative complications of minimally invasive ureteral reimplant for VUR in Children

| Intraoperative complications | Estimated incidence[a] (%) | Recommended management | Remarks |
|---|---|---|---|
| Bleeding | 4 | Careful dissection with coagulation and pressure control. | |
| Ureteral injury/bladder mucosal injury | 2–10 | Early identification and intraoperative management. Field visualization and surveillance, avoid aggressive dissection and vascular compromise of ureter. Low coagulation setting on dissection. | Most reported in extravesical approach |
| Port dislodgement | 3–7 | Anchoring sutures on the ports. Proper suspension of the bladder wall. | Reported among intravesical approach |
| Bowel Injury | <1 | Early identification and intraoperative management. Field visualization and surveillance. | In extravesical approach |
| Postoperative complications | | | |
| Transient ureteral edema | 4–28 | Atraumatic intrap handling of ureter. Ureteral stent placement to avoid azotemia in solitary kidney. | |
| Bladder spasm or urinary retention | 1–12 | Preoperative diagnosis and assessment of bladder bowel dysfunction or constipation and manage accordingly. Suprapubic tube placement for severe BBD patients. Pelvic plexus avoidance on dissection to prevent possible neuropraxia. | Intraop bladder spasm may due to increased intravesical pressure. Post op spasm due to ureteral stents and or catheters. More reports from bilateral extravesical approach |
| Recurrent UTI | 2–10 | Treat BBD, or prophylaxis as appropriate. | Pre-op UTI increased risk |
| Urine leak/urinoma | 1–10 | Prolong indwelling catheter, stent placement or drain. | |
| Ureteral stenosis | 1.5–7 | Avoid aggressive dissection of ureter and preserve vascular supply. | |
| Ileus | 2–4 | Decrease narcotic use and early ambulation. | Mostly reported in extravesical approach |
| Port hernia or infection | <1 | Port site fascial closure. | |

[a]Estimated incidence based on studies with ≥20 patient series

## 17.5 Advancement of Technology and Techniques in Minimally Invasive Ureteral Reimplant in Children

In addressing some inherent limitation of minimally invasive approach of ureteral reimplant in children, technique modifications and new technique application have been proposed by several recent studies to improve surgical outcome. A good amount of Asian literatures are available in describing new techniques to improve perioperative outcomes (Okamura et al. 1996; Ansari et al. 2006; Tsai et al. 2008; Chan et al. 2010; Kojima et al. 2012; Hong et al. 2011; Chung et al. 2012; Soh et al. 2015; Javali et al. 2015). The following bullet points summarize the available literatures on innovative techniques and application of new technologies to improve surgical outcomes:

- Application of balloon or rocking trocar ports to prevent inadvertent port dislodgement (Okamura et al. 1996; Dangle et al. 2014)
- Diamond flex retractor or vessel loop over the ureter thru an extraport to ensure atraumatic handling of ureter (Lakshmanan 2000)
- Intravesical pressure limited within 6–8 mmHg not over 10 mmHg to prevent intraoperative bladder spasm and optimise intravesical suturing and manipulation (Kutikov et al. 2006)
- Extracorporeal ureteral tailoring thru an instrument port (Ansari et al. 2006)
- Lower coagulation setting on dissection at UVJ to avoid ureteral compromise and prevent post-operative ureteral edema, stenosis and urine leak (Canon et al. 2007)
- Pelvic nerve sparing ureteral dissection for extravesical approach to prevent post-operative bladder dysfunction (Casale et al. 2008; Tsai et al. 2008; Chan et al. 2010; Dangle et al. 2014)
- Urethral route on instrument placement (Kawauchi et al. 2009)
- Intracorporeal ureteral tailoring to maintain rotational orientation or dislodge of the ureter (Faasse et al. 2014)
- Anterior bladder hitch stitch to improve exposure (Chalmers et al. 2012)
- To lengthen the mucosal tunnel by performing ureteral advancement suture with empty bladder to ensure good visualization of UVJ (Kojima et al. 2012)
- Bladder wall anchoring suture to prevent port dislodgement; lateral placement of trocar to achieve wide angle for mucosal tunnel procedure, vessel loop tagging on the lower ureteral segment for bidirectional tunnelling thru the neohiatus (Hong et al. 2011; Chung et al. 2012)
- Carbon dioxide laser detrussoraphy (Faasse et al. 2014; Diaz et al. 2014)
- Endoscopic/cystoscopic assisted procedure (Soh et al. 2015)
- Detrusor top down anchoring suture without stent placement (Silay et al. 2015)
- Intravesical detrusorraphy with Politano-Leadbetter technique to create long submucosal tunnel and being more effective for higher grade VUR and rendering orthotopic location of orifice (Soh et al. 2015)
- Maintaining bladder volume at one-third full for easy visualization of UVJ while preventing tense bladder predisposing to bladder mucosal perforation (Javali et al. 2015)
- Recently described surgical points to ensure good surgical outcome, in particular for extravesical approach is called LUAA to represent adequate length of detrusor tunnel of 5 cm (L), use of a U stitch (U), placement of permanent ureteral alignment suture (A), and inclusion of ureteral adventitia (A) in detrusorraphy to prevent ureter slipping off the tunnel while not inducing obstruction (Gundeti et al. 2016)

## 17.6 Training in Asia

Aside from careful selection of suitable patient to achieve successful surgical outcome with minimally invasive approach ureteral reimplant in children, the literature has enumerated other key factors. Such as (1) Incurring high volume cases to traversing the steep learning curve. (2) Availability of minimally invasive program (Casale et al. 2008; Sorensen 2010; Hong et al. 2011; Chung et al. 2012; Choi 2016; Schober and Jayanthi 2015; Weiss and Shukla 2015; Gundeti et al. 2016; Boysen et al. 2017). Although there are several publications reported from Asian countries; however these were confined to only few centers (Table 17.1). The reason for this could be due to lack of minimally instruments and robotic facility secondary to limited resources, and availability of minimally invasive experts in the region. To address these constraints, initiation of training centers for minimally invasive procedures in Asia is recommended. Sorensen et al. (2010) has shared their experience and proposed guidelines to initiate robotic minimally invasive surgery program (Sorensen 2010). The general recommendations includes: dedicated surgical team, dedicated operative days, committed administration, robotic/minimally invasive surgeon subspecialization, innovation to expand minimally invasive approach application and recognize technical differences in individual pediatric patients (Sorensen 2010).

## 17.7 Controversies and Future Directions

Being critical on appraising the current literature, several factors need to be considered. Most of the available studies are retrospective in nature, with inherent limitation of uncontrolled confounding factors, selection bias as well as reporting bias. Presence of publication bias with favourable results is likely being published may give an overestimation of clinical success or underestimation of complication rate with minimally invasive approach ureteral reimplant in children (Grimsby et al. 2015). Likewise, with the decrease trend of post-operative voiding cystourethrogram (VCUG) in assessing surgical success, where the recent studies comparing efficacy with open procedure might not be able to give an actual picture of VUR resolution (Herz et al. 2016). Future prospective studies with multi-institutional collaboration to assess patient characteristics and technical difference that render long term optimal clinical outcome are therefore recommended.

To date, even with the application of robotic system to address the ergonomic aspect of the approach, or traversing the steep learning and technical modification; the perioperative outcome of minimally invasive ureteral reimplant compared to open procedure still showed longer operative time (Arlen et al. 2016; Kurtz et al. 2016; Gundeti et al. 2016). Hence, promoting the development and application of new technology and or further technical modification to improve procedural efficiency and safety are still imperative.

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## Appendix

Literature search date: November 9, 2017

Medical database source: Pubmed

Search term strategy: ((“laparoscopy”[MeSH Terms] OR “laparoscopy”[All Fields] OR “laparoscopic”[All Fields]) OR (“laparoscopy”[MeSH Terms] OR “laparoscopy”[All Fields])) AND (reimplant[All Fields] OR VUR[All Fields] OR (“vesico-ureteral reflux”[MeSH Terms] OR (“vesico-ureteral”[All Fields] AND “reflux”[All Fields]) OR “vesico-ureteral reflux”[All Fields] OR (“vesicoureteral”[All Fields] AND “reflux”[All Fields]) OR “vesicoureteral reflux”[All Fields])) OR “laparoscopic ureteral reimplantation”

## References

Akhavan A, Avery D, Lendvay TS. Robot-assisted extravesical ureteral reimplantation: outcomes and conclusions from 78 ureters. J Pediatr Urol. 2014;10(5):864–8. https://doi.org/10.1016/j.jpurol.2014.01.028.

Ansari MS, Mandhani A, Khurana N, Kumar A. Laparoscopic ureteral reimplantation with extracorporeal tailoring for megaureter: a simple technical nuance. J Urol. 2006;176(6 Pt 1):2640–2.

Arlen AM, Cooper CS. Controversies in the management of vesicoureteral reflux. Curr Urol Rep. 2015;16(9):64. https://doi.org/10.1007/s11934-015-0538-2.

Arlen AM, Broderick KM, Travers C, Smith EA, Elmore JM, Kirsch AJ. Outcomes of complex robot-assisted extravesical ureteral reimplantation in the pediatric population. J Pediatr Urol. 2016;12(3):169.e1–6. https://doi.org/10.1016/j.jpurol.2015.11.007.

Atala A, Kavoussi LR, Goldstein DS, Retik AB, Peters CA. Laparoscopic correction of vesicoureteral reflux. J Urol. 1993;150:748–51.

Austin JC, Cooper CS. Vesicoureteral reflux: surgical approaches. Urol Clin North Am. 2004;31(3):543–57, x.

Bansal D, Defoor WR Jr, Reddy PP, Minevich EA, Noh PH. Complications of robotic surgery in pediatric urology: a single institution experience. Urology. 2013;82(4):917–20. https://doi.org/10.1016/j.urology.2013.05.046.

Barbosa JA, Barayan G, Gridley CM, Sanchez DC, Passerotti CC, Houck CS, Nguyen HT. Parent and patient perceptions of robotic vs open urological surgery scars in children. J Urol. 2013;190(1):244–50. https://doi.org/10.1016/j.juro.2012.12.060.

Bayne AP, Shoss JM, Starke NR, Cisek LJ. Single-center experience with pediatric laparoscopic extravesical reimplantation: safe and effective in simple and complex anatomy. J Laparoendosc Adv Surg Tech A. 2012;22(1):102–6. https://doi.org/10.1089/lap.2011.0299.

Bi Y, Sun Y. Laparoscopic pneumovesical ureteral tapering and reimplantation for megaureter. J Pediatr Surg. 2012;47(12):2285–8. https://doi.org/10.1016/j.jpedsurg.2012.09.020.

Bowen DK, Faasse MA, Liu DB, Gong EM, Lindgren BW, Johnson EK. Use of pediatric open, laparoscopic and robot-assisted laparoscopic ureteral reimplantation in the United States: 2000 to 2012. J Urol. 2016;196(1):207–12. https://doi.org/10.1016/j.juro.2016.02.065.

Boysen WR, Ellison JS, Kim C, Koh CJ, Noh P, Whittam B, Palmer B, Shukla A, Kirsch A, Gundeti MS. Multi-institutional review of outcomes and complications of robot-assisted laparoscopic extravesical ureteral reimplantation for treatment of primary vesicoureteral reflux in children. J Urol. 2017;197(6):1555–61. https://doi.org/10.1016/j.juro.2017.01.062.

Callewaert PR, Biallosterski BT, Rahnama’i MS, Van Kerrebroeck PE. Robotic extravesical anti-reflux operations in complex cases: technical considerations and preliminary results. Urol Int. 2012;88(1):6–11. https://doi.org/10.1159/000332953.

Canon SJ, Jayanthi VR, Patel AS. Vesicoscopic cross-trigonal ureteral reimplantation: a minimally invasive option for repair of vesicoureteral reflux. J Urol. 2007;178(1):269–73, discussion 273.

Carswell BM, Fefer SD, Fung LC. Laparoscopic bilateral extravesical ureteral reimplantation is associated with superior post-operative voiding efficiency—five years results. J Urol. 2003;169(4 Suppl):489A.

Cartwright PC, Snow BW, Mansfield JC, Hamilton BD. Percutaneous endoscopic trigonoplasty: a minimally invasive approach to correct vesicoureteral reflux. J Urol. 1996;156(2 Pt 2):661–4.

Casale P, Kojima Y. Robotic-assisted laparoscopic surgery in pediatric urology: an update. Scand J Surg. 2009;98(2):110–9.

Casale P, Patel RP, Kolon TF. Nerve sparing robotic extravesical ureteral reimplantation. J Urol. 2008;179(5):1987–9; discussion 1990. https://doi.org/10.1016/j.juro.2008.01.062.

Chalmers D, Herbst K, Kim C. Robotic-assisted laparoscopic extravesical ureteral reimplantation: an initial experience. J Pediatr Urol. 2012;8(3):268–71. https://doi.org/10.1016/j.jpurol.2011.04.006.

Chan KW, Lee KH, Tam YH, Sihoe JD. Early experience of robotic-assisted reconstructive operations in pediatric urology. J Laparoendosc Adv Surg Tech A. 2010;20(4):379–82. https://doi.org/10.1089/lap.2009.0340.

Choi H, Park JY, Bae JH. Initial experiences of laparoscopic intravesical detrusorraphy using the Politano-Leadbetter technique. J Pediatr Urol. 2016;12(2):110.e1–7. https://doi.org/10.1016/j.jpurol.2015.07.014.

Chung PH, Tang DY, Wong KK, Yip PK, Tam PK. Comparing open and pneumovesical approach for ureteric reimplantation in pediatric patients—a preliminary review. J Pediatr Surg. 2008;43(12):2246–9. https://doi.org/10.1016/j.jpedsurg.2008.08.057.

Chung MS, Han SW, Jung HJ, Im YJ, Han HH, Na JC, Hong CH. Transvesicoscopic ureteral reimplantation in children with bilateral vesicoureteral reflux: surgical technique and results. J Laparoendosc Adv Surg Tech A. 2012;22(3):295–300. https://doi.org/10.1089/lap.2011.0318.

Dangle PP, Razmaria AA, Towle VL, Frim DM, Gundeti MS. Is pelvic plexus nerve documentation feasible during robotic assisted laparoscopic ureteral reimplantation with extravesical approach? J Pediatr Urol. 2013;9(4):442–7. https://doi.org/10.1016/j.jpurol.2012.10.018.

Dangle PP, Shah A, Gundeti MS. Robot-assisted laparoscopic ureteric reimplantation: extravesical technique. BJU Int. 2014;114(4):630–2. https://doi.org/10.1111/bju.12813.

David S, Kelly C, Poppas DP. Nerve-sparing extravesical repair of bilateral vesico-ureteral reflux. Description of technique and evaluation of urinary retention. J Urol. 2004;172:1617–20.

Diaz EC, Lindgren BW, Gong EM. Carbon dioxide laser for detrusor tunnel creation in robot-assisted laparoscopic extravesical ureteral reimplant. J Pediatr Urol. 2014;10(6):1283.e1–2. https://doi.org/10.1016/j.jpurol.2014.07.006.

Ehrlich RM, Gershman A, Fuchs G. Laparoscopic vesicoureteroplasty in children: initial case reports. Urology. 1994;43(2):255–61.

El-Ghoneimi A. Paediatric laparoscopic surgery. Curr Opin Urol. 2003;13(4):329–35.

Emir H, Mammadov E, Elicevik M, Buyukunal C, Soylet Y. Transvesicoscopic cross-trigonal ureteroneocystostomy in children: a single-center experience. J Pediatr Urol. 2012;8(1):83–6. https://doi.org/10.1016/j.jpurol.2010.10.005.

Esposito C, Escolino M, Lopez M, Farina A, Cerulo M, Savanelli A, La Manna A, Caprio MG, Settimi A, Varlet F. Surgical management of pediatric vesicoureteral reflux: a comparative study between endoscopic, laparoscopic, and open surgery. J Laparoendosc Adv Surg Tech A. 2016;26(7):574–80. https://doi.org/10.1089/lap.2016.0055.

Faasse MA, Lindgren BW, Gong EM. Robot-assisted laparoscopic ureteral reimplantation with excisional tailoring for refluxing megaureter. J Pediatr Urol. 2014;10(4):773.e1–2. https://doi.org/10.1016/j.jpurol.2014.01.023.

Finkelstein J, Eckersberger E, Sadri H, Taneja SS, Lepor H, Djavan B. Open versus laparoscopic versus robot-assisted laparoscopic prostatectomy: the European and US experience. Rev Urol. 2010;12(1):35–43.

Finkelstein JB, Levy AC, Silva MV, Murray L, Delaney C, Casale P. How to decide which infant can have robotic surgery? Just do the math. J Pediatr Urol. 2015;11(4):170.e1–4. https://doi.org/10.1016/j.jpurol.2014.11.020.

Fung LC, Mc Lorie GA, Jain U, et al. Voiding efficiency after ureteral reimplantation: a comparison of extravesical and intravesical techniques. J Urol. 1995;153:1972–5.

Garcia-Roig ML, Travers C, McCracken C, Cerwinka W, Kirsch JM, Kirsch AJ. Surgical scar location preference for pediatric kidney and pelvic surgery: a crowdsourced survey. J Urol. 2017;197(3 Pt 2):911–9. https://doi.org/10.1016/j.juro.2016.11.033.

Gargollo PC. Hidden incision endoscopic surgery: description of technique, parental satisfaction and applications. J Urol. 2011;185(4):1425–31. https://doi.org/10.1016/j.juro.2010.11.054.

Gatti JM, Cartwright PC, Hamilton BD, Snow BW. Percutaneous endoscopic trigonoplasty in children: long-term outcomes and modifications in technique. J Endourol. 1999;13:581–4.

Gill IS, Ponsky LE, Desai M, Kay R, Ross JH. Laparoscopic cross-trigonal Cohen ureteroneocystostomy: novel technique. J Urol. 2001;166(5):1811–4.

Grimsby GM, Dwyer ME, Jacobs MA, Ost MC, Schneck FX, Cannon GM, Gargollo PC. Multi-institutional review of outcomes of robot-assisted laparoscopic extravesical ureteral reimplantation. J Urol. 2015;193(5 Suppl):1791–5. https://doi.org/10.1016/j.juro.2014.07.128.

Gundeti MS, Kojima Y, Haga N, Kiriluk K. Robotic-assisted laparoscopic reconstructive surgery in the lower urinary tract. Curr Urol Rep. 2013;14(4):333–41. https://doi.org/10.1007/s11934-013-0328-7.

Gundeti MS, Boysen WR, Shah A. Robot-assisted laparoscopic extravesical ureteral reimplantation: technique modifications contribute to optimized outcomes. Eur Urol. 2016;70(5):818–23. https://doi.org/10.1016/j.eururo.2016.02.065.

Harel M, Herbst KW, Silvis R, Makari JH, Ferrer FA, Kim C. Objective pain assessment after ureteral reimplantation: comparison of open versus robotic approach. J Pediatr Urol. 2015;11(2):82.e1–8. https://doi.org/10.1016/j.jpurol.2014.12.007.

Hayashi Y, Mizuno K, Kurokawa S, Nakane A, Kamisawa H, Nishio H, Moritoki Y, Tozawa K, Kohri K, Kojima Y. Extravesical robot-assisted laparoscopic ureteral reimplantation for vesicoureteral reflux: initial experience in Japan with the ureteral advancement technique. Int J Urol. 2014;21(10):1016–21. https://doi.org/10.1111/iju.12483.

Hayn MH, Smaldone MC, Ost MC, Docimo SG. Minimally invasive treatment of vesicoureteral reflux. Urol Clin North Am. 2008;35(3):477–88, ix. https://doi.org/10.1016/j.ucl.2008.05.006.

Heidenreich A, Ozgur E, Becker T, Haupt G. Surgical management of vesicoureteral reflux in pediatric patients. World J Urol. 2004;22(2):96–106.

Herz D, Fuchs M, Todd A, McLeod D, Smith J. Robot-assisted laparoscopic extravesical ureteral reimplant: a critical look at surgical outcomes. J Pediatr Urol. 2016;12(6):402.e1–9. https://doi.org/10.1016/j.jpurol.2016.05.042.

Hong CH, Kim JH, Jung HJ, Im YJ, Han SW. Single-surgeon experience with transvesicoscopic ureteral reimplantation in children with vesicoureteral reflux. Urology. 2011;77(6):1465–9. https://doi.org/10.1016/j.urology.2010.11.023.

Janetschek G, Radmayr C, Bartsch G. Laparoscopic ureteral anti-reflux plasty reimplantation. First clinical experience. Ann Urol (Paris). 1995;29:101–5.

Javali T, Pathade A, Nagaraj HK. Laparoscopic extravesical detrusorraphy, a minimally invasive treatment option for vesicoureteral reflux: a single centre experience. J Pediatr Urol. 2015;11(2):88.e1–6. https://doi.org/10.1016/j.jpurol.2015.01.007.

Kasturi S, Sehgal SS, Christman MS, Lambert SM, Casale P. Prospective long-term analysis of nerve-sparing extravesical robotic-assisted laparoscopic ureteral reimplantation. Urology. 2012;79(3):680–3. https://doi.org/10.1016/j.urology.2011.10.052.

Kawauchi A, Fujito A, Soh J, Ukimura O, Mizutani Y, Miki T. Laparoscopic correction of vesicoureteral reflux using the Lich-Gregoir technique: initial experience and technical aspects. Int J Urol. 2003;10(2):90–3.

Kawauchi A, Naitoh Y, Soh J, Hirahara N, Okihara K, Miki T. Transvesical laparoscopic cross-trigonal ureteral reimplantation for correction of vesicoureteral reflux: initial experience and comparisons between adult and pediatric cases. J Endourol. 2009;23(11):1875–8. https://doi.org/10.1089/end.2009.0239.

Kennelly MJ, Bloom DA, Ritchey ML, Panzl AC. Outcome analysis of bilateral Cohen cross-trigonal ureteroneocystostomy. Urology. 1995;46(3):393–5.

Khan A, Rahiman M, Verma A, Bhargava R. Novel technique of laparoscopic extravesical ureteric reimplantation in primary obstructive megaureter. Urol Ann. 2017;9(2):150–2. https://doi.org/10.4103/0974-7796.204182.

Kim SW, Lim NL, Lee YS, Han SW, Im YJ. Laparoscopic intravesical detrusorrhaphy with ureteral plication for megaureter: a novel technique. Urology. 2015;86(1):187–91. https://doi.org/10.1016/j.urology.2015.02.023.

Kim SW, Lee YS, Han SW. Endoscopic injection therapy. Investig Clin Urol. 2017;58(Suppl 1):S38–45. https://doi.org/10.4111/icu.2017.58.S1.S38.

Kojima Y, Mizuno K, Umemoto Y, Yasui T, Hayashi Y, Kohri K. Ureteral advancement in patients undergoing laparoscopic extravesical ureteral reimplantation for treatment of vesicoureteral reflux. J Urol. 2012;188(2):582–7. https://doi.org/10.1016/j.juro.2012.04.018.

Kurtz MP, Leow JJ, Varda BK, Logvinenko T, Yu RN, Nelson CP, Chung BI, Chang SL. Robotic versus open pediatric ureteral reimplantation: costs and complications from a nationwide sample. J Pediatr Urol. 2016;12(6):408.e1–6. https://doi.org/10.1016/j.jpurol.2016.06.016.

Kutikov A, Guzzo TJ, Canter DJ, Casale P. Initial experience with laparoscopic transvesical ureteral reimplantation at the Children's Hospital of Philadelphia. J Urol. 2006;176(5):2222–5; discussion 2225–6.

Lakshmanan Y, Fung LC. Laparoscopic extravesicular ureteral reimplantation for vesicoureteral reflux: recent technical advances. J Endourol. 2000;14(7):589–93; discussion 593–4.

Lakshmanan Y, Mathews RI, Cadeddu JA, Chen RN, Slaughenhoupt BL, Moore RG, Docimo SG. Feasibility of total intravesical endoscopic surgery using mini-instruments in a porcine model. J Endourol. 1999;13(1):41–5.

Lau CT, Lan LC, Wong KK, Tam PK. Pneumovesical ureteric reimplantation in pediatric patients: an intermediate term result. J Laparoendosc Adv Surg Tech A. 2017;27(2):203–5. https://doi.org/10.1089/lap.2016.0236.

Lendvay T. Robotic-assisted laparoscopic management of vesicoureteral reflux. Adv Urol. 2008;2008:732942. https://doi.org/10.1155/2008/732942.

Lopez M, Melo C, François M, Varlet F. Laparoscopic extravesical transperitoneal approach following the Lich-Gregoir procedure in refluxing duplicated collecting systems: initial experience. J Laparoendosc Adv Surg Tech A. 2011;21(2):165–9. https://doi.org/10.1089/lap.2010.0127.

Marchini GS, Hong YK, Minnillo BJ, Diamond DA, Houck CS, Meier PM, Passerotti CC, Kaplan JR, Retik AB, Nguyen HT. Robotic assisted laparoscopic ureteral reimplantation in children: case matched comparative study with open surgical approach. J Urol. 2011;185(5):1870–5. https://doi.org/10.1016/j.juro.2010.12.069.

McDougall EM, Urban DA, Kerbl K, Clayman RV, Fadden P, Royal HD, Chandhoke PS, Stone AM. Laparoscopic repair of vesicoureteral reflux utilizing the Lich-Gregoir technique in the pig model. J Urol. 1995;153:497–500.

Moritoki Y, Kojima Y, Kohri K. Laparoscopic extravesical ureteral reimplantation with diverticulectomy for refluxing ureters associated with paraureteral diverticula. Int J Urol. 2012;19(5):488–9. https://doi.org/10.1111/j.1442-2042.2012.02969.x.

Okamura K, Ono Y, Yamada Y, Kate T, Ohshima S, Miyuke K. Endoscopic trigonoplasty for primary vesicoureteral reflux: initial case report. Jap J Endourol ESWL. 1993;6:226.

Okamura K, Yamada Y, Tsuji Y, Sakakibara T, Kondo A, Ono Y, Ohshima S, Miyake K. Endoscopic trigonoplasty in pediatric patients with primary vesicoureteral reflux: preliminary report. J Urol. 1996;156(1):198–200.

Okamura K, Kato N, Tsuji Y, et al. A comparative study of endoscopic trigonoplasty for vesicoureteral reflux in children and in adults. Int J Urol. 1999;6:562–6.

Olsen LH, Deding D, Yeung CK, Jorgensen TM. Computer assisted laparoscopic pneumovesical ureter reimplantation a.m. Cohen: initial experience in a pig model. APMIS Suppl. 2003:23–5.

Patel VR, Ramalingam M, editors. Operative atlas of laparoscopic and robotic reconstructive urology [electronic resource]. 2nd ed. Cham: Springer International Publishing; 2017.

Peters CA. Robotically assisted surgery in pediatric urology. Urol Clin North Am. 2004;31(4):743–52.

Peters CA, Woo R. Intravesical robotically assisted bilateral ureteral reimplantation. J Endourol. 2005;19:618–21.

Peters CA, Skoog SJ, Arant BS Jr, Copp HL, Elder JS, Hudson RG, Khoury AE, Lorenzo AJ, Pohl HG, Shapiro E, Snodgrass WT, Diaz M. Summary of the AUA guideline on management of primary vesicoureteral reflux in children. J Urol. 2010;184(3):1134–44. https://doi.org/10.1016/j.juro.2010.05.065.

Phillips EA, Wang DS. Current status of robot-assisted laparoscopic ureteral reimplantation and reconstruction. Curr Urol Rep. 2012;13(3):190–4. https://doi.org/10.1007/s11934-012-0250-4.

Reddy PK, Evans RM. Laparoscopic ureteroneocystostomy. J Urol. 1994;152(6 Pt 1):2057–9.

Riquelme M, Lopez M, Landa S, Mejia F, Aranda A, Rodarte-Shade M, Rodriguez-Gomez J, Torres-Riquelme J. Laparoscopic extravesical ureteral reimplantation (LEVUR): a multicenter experience with 95 cases. Eur J Pediatr Surg. 2013;23(2):143–7. https://doi.org/10.1055/s-0032-1329708.

Sakamoto W, Nakatani T, Sakakura T, Takegaki Y, Ishi K, Kamikawa S, Sugimoto T. Extraperitoneal laparoscopic Lich-Gregoir antireflux plasty for primary vesicoureteral reflux. Int J Urol. 2003;10(2):94–7; discussion 98.

Sávio LF, Nguyen HT. Robot-assisted laparoscopic urological surgery in children. Nat Rev Urol. 2013;10(11):632–9. https://doi.org/10.1038/nrurol.2013.220.

Schimberg W, Wacksman J, Rudd R, Lewis AG, Sheldon CA. Laparoscopic correction of vesicoureteral reflux in the pig. J Urol. 1994;151:1664–7.

Schober MS, Jayanthi VR. Vesicoscopic ureteral reimplant: is there a role in the age of robotics? Urol Clin North Am. 2015;42(1):53–9. https://doi.org/10.1016/j.ucl.2014.09.005.

Schomburg JL, Haberman K, Willihnganz-Lawson KH, Shukla AR. Robot-assisted laparoscopic ureteral reimplantation: a single surgeon comparison to open surgery. J Pediatr Urol. 2014;10(5):875–9. https://doi.org/10.1016/j.jpurol.2014.02.013.

Schwentner C, Oswald J, Lunacek A, Deibl M, Koerner I, Bartsch G, Radmayr C. Lich-Gregoir reimplantation causes less discomfort than Politano-Leadbetter technique: results of a prospective, randomized, pain scale-oriented study in a pediatric population. Eur Urol. 2006;49(2):388–95.

Shu T, Cisek LJ Jr, Moore RG. Laparoscopic extravesical reimplantation for postpubertal vesicoureteral reflux. J Endourol. 2004;18(5):441–6.

Silay MS, Baek M, Koh CJ. Robot-assisted laparoscopic extravesical ureteral reimplantation in children: top-down suturing technique without stent placement. J Endourol. 2015;29(8):864–6. https://doi.org/10.1089/end.2014.0815.

Silay MS, Turan T, Kayalı Y, Başıbüyük İ, Gunaydin B, Caskurlu T, Karaman Mİ. Comparison of intravesical (Cohen) and extravesical (Lich-Gregoir) ureteroneocystostomy in the treatment of unilateral primary vesicoureteric reflux in children. J Pediatr Urol. 2017. pii: S1477-5131(17)30404-7. https://doi.org/10.1016/j.jpurol.2017.09.014.

Simforoosh N, Nadjafi-Semnani M, Shahrokhi S. Extraperitoneal laparoscopic trigonoplasty for treatment of vesicoureteral reflux: novel technique duplicating its open counterpart. J Urol. 2007;177(1):321–4.

Smaldone MC, Polsky E, Ricchiuti DJ, Docimo SG. Advances in pediatric urologic laparoscopy. ScientificWorldJournal. 2007;7:727–41.

Smith RP, Oliver JL, Peters CA. Pediatric robotic extravesical ureteral reimplantation: comparison with open surgery. J Urol. 2011;185(5):1876–81. https://doi.org/10.1016/j.juro.2010.12.072.

Soh S, Kobori Y, Shin T, Suzuki K, Iwahata T, Sadaoka Y, Sato R, Nishi M, Iwamura M, Okada H. Transvesicoscopic ureteral reimplantation: Politano-Leadbetter versus Cohen technique. Int J Urol. 2015;22(4):394–9. https://doi.org/10.1111/iju.12702.

Sorensen MD, Johnson MH, Delostrinos C, Bice JB, Grady RW, Lindsay TS. Initiation of a paediatric robotic surgery program: institutional challenges and realistic outcomes. Surg Endosc. 2010;24(11):2803–8.

Soulier V, Scalabre AL, Lopez M, Li CY, Thach S, Vermersch S, Varlet FO. Laparoscopic vesico-ureteral reimplantation with Lich-Gregoir approach in children: medium term results of 159 renal units in 117 children. World J Urol. 2017;35(11):1791–8. https://doi.org/10.1007/s00345-017-2064-y.

Srougi V, Yorioka M, Sanchez DC, Onal B, Houck CS, Nguyen HT. The feasibility of robotic urologic surgery in infants and toddlers. J Pediatr Urol. 2013;9(6Pt B):1198–203. https://doi.org/10.1016/j.jpurol.2013.05.011.

Tekgul S, Dogan HS, Kocvara R, Nijman JM, Radmayr C, Stein R, Silay MS, Undre S, Quaedackers J. European Association of Urology (EAU) Guidelines in Paediatric Urology, presented at the EAU Annual Congress London 2017. Arnhem, The Netherlands: EAU Guidelines Office. 978-90-79754-91-5. https://uroweb.org/guidelines/. Accessed 21 Nov 2017.

Tsai YC, Wu CC, Yang SS. Minilaparoscopic nerve-sparing extravesical ureteral reimplantation for primary vesicoureteral reflux: a preliminary report. J Laparoendosc Adv Surg Tech A. 2008;18(5):767–70. https://doi.org/10.1089/lap.2007.0241.

Tsuji Y, Okamura K, Nishimura T, Okamoto N, Kobayashi M, Kinukawa T, Ohshima S. A new endoscopic ureteral reimplantation for primary vesicoureteral reflux (endoscopic trigonoplasty II). J Urol. 2003;169(3):1020–2.

Vachvanichsanong P, Dissaneewate P, McNeil E. What did we find from imaging studies in childhood urinary tract infection and which studies are mandatory? Urology 2017; 2. pii: S0090-4295(17)31047-6. doi:https://doi.org/10.1016/j.urology.2017.09.014.

Valla JS, Steyaert H, Griffin SJ, Lauron J, Fragoso AC, Arnaud P, Léculée R. Transvesicoscopic Cohen ureteric reimplantation for vesicoureteral reflux in children: a single-centre 5-year experience. J Pediatr Urol. 2009;5(6):466–71. https://doi.org/10.1016/j.jpurol.2009.03.012.

Weiss DA, Shukla AR. The robotic-assisted ureteral reimplantation: the evolution to a new standard. Urol Clin North Am. 2015;42(1):99–109. https://doi.org/10.1016/j.ucl.2014.09.010.

Yeung CK, Sihoe JD, Borzi PA. Endoscopic cross-trigonal ureteral reimplantation under carbon dioxide bladder insufflation: a novel technique. J Endourol. 2005;19(3):295–9.

# Robotic-Assisted Renal Autotransplantation: Preliminary Studies and Future Directions

18

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**Abstract**

The indications for renal autotransplantation (RATx) include renal vascular trauma, thrombosis, stenosis, aneurysm, complex ureteral injuries, renal cell carcinoma, urolithiasis, retroperitoneal fibrosis, and loin pain-hematuria syndrome. Unfortunately, RATx is underutilized because of its invasiveness. The current gold standard approach to RATx is laparoscopic nephrectomy and open autotransplantation, which requires a large pelvic incision. Robotic-assisted renal autotransplantation (robotic RATx) is a new, minimally invasive approach that has been used since 2014. The first completely intracorporeal robotic RATx, used to repair a ureteral injury, was reported in 2014. Since then, only three cases have been reported, all from North America. After an initial porcine study, we conducted the fourth robotic RATx procedure. Robotic surgery has multiple advantages, such as providing a three-dimensional magnified view, navigating in narrow spaces, and fine suturing and dissection, which are particularly helpful in cases with desmoplastic changes. Most robotic RATx procedures have been used to repair ureteral injuries. These cases tend to have desmoplastic changes due to previous surgeries. Nephrectomy and RATx are technically challenging, hence robotic surgery may be the best option in patients with complex and severe desmoplastic changes. The disadvantages of robotic RATx include the length of surgery and cost. However, with continued use, both the operative time and the cost should decrease. In conclusion, robotic RATx is a new, minimally invasive approach to renal preservation.

**Keywords**

Renal autotransplantation · Robotic surgery · Laparoscopic surgery · Ureteral injury

## 18.1 Introduction

In 1963, the first renal autotransplantation (RATx) was reported, in which a high ureteric injury was repaired (Hardy and Eraslan 1963). Since then, the indications of RATx have expanded to include renal vascular trauma, thrombosis, stenosis, and aneurysm, as well as complex ureteral injuries, renal cell carcinoma, urolithiasis, retroperitoneal fibrosis, and loin pain-hematuria syndrome (Bluebond-Langner et al. 2004; Gordon et al. 2014). The benefit of RATx surgery is preservation of a kidney that would otherwise be removed by nephrectomy. Nephrectomy increases the incidence and severity of chronic kidney disease (CKD) and CKD is associated with a high risk of cardiovascular disease, end-stage renal disease (ESRD), infection, malignancy, and mortality

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(Snyder and Collins 2009; Stevens et al. 2013). Although the risk of death due to cardiovascular disease is much higher than the risk of eventually requiring dialysis, dialysis decreases quality of life and life expectancy. In many countries, the incidence of CKD is as high as 200 cases per million patients per year (Levey and Coresh 2012). It is close to 400 cases per million in the USA, Taiwan, and some regions in Mexico, and has risen fastest in older populations. Therefore, preservation of renal function by RATx has important implications. However, RATx is underutilized because of its invasiveness. For example, conventional open RATx requires a large incision (Gordon et al. 2014; Ratner et al. 1997). In order to address this shortcoming, many institutions have replaced open nephrectomy with a laparoscopic approach. In fact, the current gold standard approach to RATx is a laparoscopic nephrectomy and open autotransplantation (Lee et al. 2015). However, this approach still requires a large pelvic incision.

## 18.2 Robotic Renal Autotransplantation

Although relatively new, robotic surgery has been adopted worldwide. As of December 2016, more than 3900 da Vinci surgical systems (Intuitive Surgical, Sunnyvale, CA, USA) had been distributed and more than 750,000 robotic surgeries were being performed each year (data from Intuitive). The strengths of the da Vinci system include a three-dimensional magnified view and the ability to perform precise movements that enable fine dissection and suturing.

Robotic-assisted renal transplantation has been performed since 2002 (Hoznek et al. 2002). The first case was a deceased donor renal transplantation performed in a 26-year-old man using an incision in the left lower quadrant with the aid of a self-retaining retractor. The first completely robot-assisted laparoscopic renal allograft transplant was reported in 2010 by a group from the University of Illinois (Giulianotti et al. 2010) and several other groups have since reported similar experiences. Early reports have suggested comparable graft function and lower complication rates relative to open surgery (Menon et al. 2014a; Oberholzer et al. 2013; Tsai et al. 2014; Lee and Ordon 2016). A similar technique has now been applied to RATx. Unlike renal allograft transplantation surgery, in RATx the graft kidney is already located intra-corporeally. Furthermore, if both the donor nephrectomy and the RATx are performed with minimally invasive surgical techniques and the allograft is maintained intracorporeally, the morbidity associated with a large skin incision might be completely avoided (Lee and Ordon 2016). However, the procedure can be extremely technically complex and requires not only intracorporeal preparation of the graft but complete intracorporeal perfusion and hypothermia management.

In 2014, Abaza and colleagues performed the first completely intracorporeal robotic RATx to repair a ureteral injury (Gordon et al. 2014). The patient was a 56-year-old man with extensive left ureteral damage after failed ureteroscopy for ureterolithiasis. Immediately after dividing the vessels, a perfusion cannula was inserted into the transected artery. The cannula was continuously flushed with ice-cold lactated Ringer solution until clear fluid flushed from the renal vein. The warm ischemia time was 2.3 min and the cold ischemia time was 95.5 min. After donor nephrectomy, vascular anastomoses and ureteroureterostomy were performed in the ipsilateral pelvis, with a total overall surgeon console time of 334 min. Venous and arterial anastomosis times were 17.3 min and 21.3 min, respectively. Estimated blood loss was less than 50 mL. The patient's postoperative course was uneventful and there were no complications. The patient was discharged home on postoperative day 1 after a normal Doppler ultrasound of the transplanted kidney. Postoperatively renal scan at 6 weeks, intravenous urogram at 8 weeks, and computerized tomography urography at 5 months revealed normal renal function and successful ureteral reconstruction. Since this initial report, two more cases have been performed in North America (the third case was performed in the USA, and was presented at the American Urological Annual Association meeting in 2016, but has not been published to date. Ref: http://www.aua2016.org/abstracts/files/session_BladderOncologyTestisTransplantationTrauma.cfm).

The second report was from Canada (Lee et al. 2015). The patient was a 38-year-old patient who had undergone a failed laparoscopic pyeloplasty resulting in a large upper ureteral stricture with complete ureteral obstruction. A right, completely robot-assisted RATx was performed with intraperitoneal cold perfusion. Immediately upon completing the donor nephrectomy, a cannula was inserted into the transected artery and secured in place with a vicryl Endoloop device (Ethicon US, LLC). The kidney was perfused with 1 L of histidine-tryptophan-ketoglutarate (HTK) solution that had been cooled to 4 °C. The external iliac vessels were dissected for vessel anastomosis. The kidney was then repositioned into the right iliac fossa and placed anterior to the bladder flap. The kidney was perfused continuously with 4 °C normal saline throughout repositioning. The total operative time was 6.5 h, with a total ischemia time of only 79 min (4 min of warm ischemia, 48 min of cold ischemia, and 27 min re-warming time). The authors reported that the ischemic times were comparable to those observed during the gold standard approach to RATx.

The third patient was a 31-year-old man with a history of a malrotated left kidney, recurrent renal stones, and resultant hematuria-loin-pain syndrome (not published to date). A completely intracorporeal left RATx was performed robotically at the Cleveland Clinic, OH, USA. Intraoperative repositioning was required in order to perform the pelvic portion of the procedure. The warm ischemia time was 6 min. Intracorporeal cold ischemia was achieved with intra-arterial irrigation of Wisconsin fluid and ice slush. Hypothermia was achieved with the use of a laparoscopic specimen bag without extracting the organ from the body. Renal hypothermia was assessed in real time with a thermocoupler needle probe. The cold ischemia was 148 min. The total operating time was 433 min. Estimated blood loss was 100 cc. Immediately after surgery and on the first post-operative day, the patient underwent renal Doppler ultrasound with good results and demonstrable renal viability. He was discharged home on the third post-operative day.

## 18.3 Okayama University Experience

To the best of our knowledge, we performed the fourth robotic RATx in the world, and the first case outside of North America (Araki et al. 2017).

Prior to this case, we prepared extensively by performing robotic-assisted RATx in a porcine model (unpublished data). Briefly, three pigs underwent robotic RATx. Robotic nephrectomy was performed on the left in all cases, and robotic RATx was performed on the left side in all cases. Two 12-mm ports and two 8-mm ports were used. A Gelport (Applied Medical, Santa Ranchero, CA, USA) was placed 15 cm below the xiphoid process (Fig. 18.1). Position changes and re-docking were not required. In case 1, the kidney was taken out through the Gelport and was immediately irrigated on ice with Ringer's solution. In the other two cases (cases 2 and 3), complete intracorporeal RATx was performed. End-to-side anastomoses were performed between the renal vein and the external iliac vein and between the renal artery and the external iliac artery. Ureteroneocystostomy was also performed in case 3. All cases were performed robotically without the need for open conversion. The average console time was less than 4 h. The average warm ischemia time was less than 5 min, and the average cold ischemia time was less than 2 h.

Laparoscopic RATx was first reported in a porcine model in 2001 (Meraney et al. 2001). Prior to starting the survival arm of that study, inanimate dry suturing models and seven farm pigs were used to practice laparoscopic vascular suturing techniques and to determine intraoperative logistical details. After this initial preparation, the authors performed laparoscopic RATx in six pigs. The mean operating time was 6.2 h (range 5.3–7.9 h) without ureteroneocystostomy, which is 1.5 times longer than the present study. The venous anastomosis time was 33 min (range 22–46 min), and the arterial anastomosis time was 31 min (range 27–35 min), which is two times longer than our study. This comparison demonstrates the superiority of robotic RATx over the laparoscopic approach, especially with regards to suturing. Based on these results, we felt that robotic RATx was feasible and had the potential to be a new, minimally invasive alternative to conventional open surgery.

Following extensive preparation, including animal studies, we performed the first human robotic RATx at our institution (Araki et al. 2017). Briefly, the patient was a 38-year-old woman with left ureteral stenosis. She had undergone an emergent Caesarean section for intraperitoneal bleeding secondary to left ovarian rupture 4 years prior. The surgery was difficult due to massive adhesions secondary to

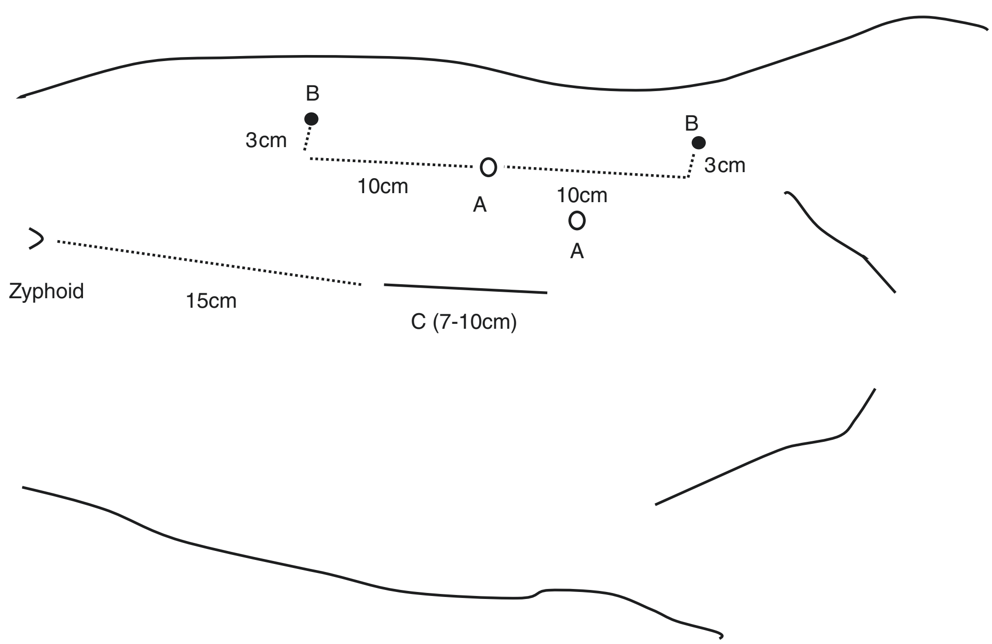


**Fig. 18.1** Port configuration for the animal study. The animal was placed in the right decubitus position and a 4-port transperitoneal laparoscopic technique was used. A Gelport was also placed. A 10-mm, 30° laparoscope was utilized. A. 12 mm port, B. 8 mm port, C. Gelport

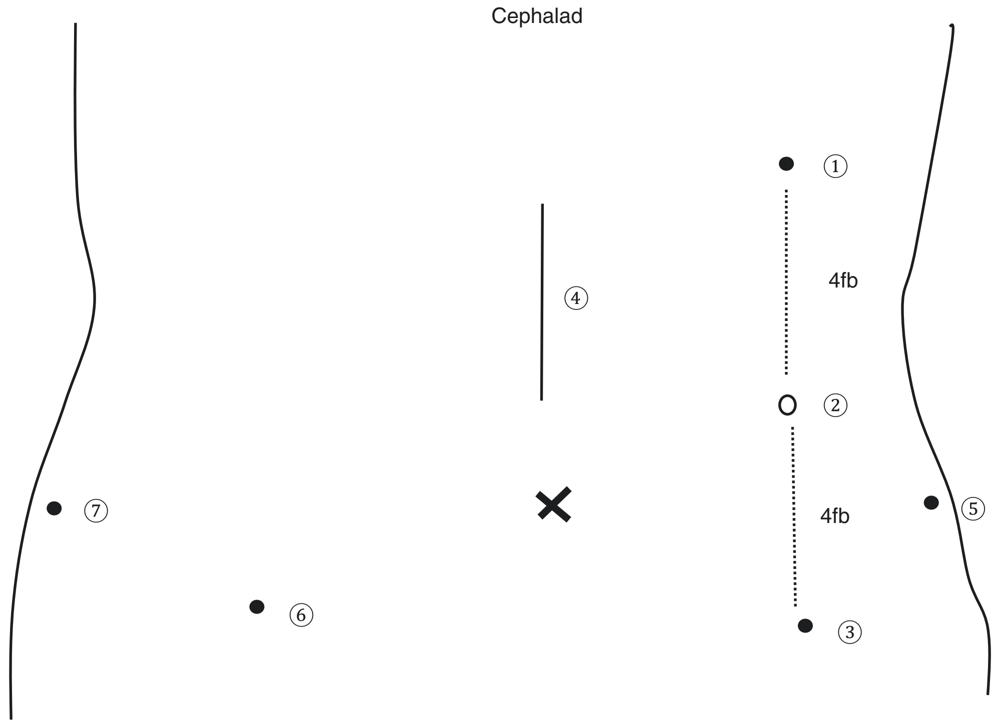


**Fig. 18.2** Port configuration for Patient #1. Four ports were used for the nephrectomy (① 8 mm, ② 12 mm, ③ 8 mm, and ④ 7 cm for the Gelport). Five ports were used for the renal autotransplant (③ 8 mm, ④ 7 cm for the Gelport, ⑤ 8 mm, ⑥ 8 mm, and ⑦ 12 mm)

severe endometriosis. The estimated blood loss was 4 L. She underwent left internal iliac artery embolization for postoperative bleeding. Although the procedure was life-saving, it caused a 2.7-cm left ureteral stenosis that required multiple ureteral stent exchanges. Ureteroscopic balloon dilations and laser incisions were not successful. Retrograde pyelography also showed a possible left ureteropelvic junction obstruction (UPJO). Of note, left hydronephrosis was noted during her pregnancy. RATx should be considered in patients with extensive ureteric disease and in selected patients for whom urinary diversion is not an option (Wotkowicz and Libertino 2004). Nephrectomy was undesirable considering her young age. Ureteroureterostomy, ureteroneocystostomy with or without psoas hitch, and Boari flap were considered technically difficult for the following reasons: (1) Considering the massive adhesions due to her previous surgery and endometriosis, as well as the prior left internal iliac artery embolization, ureteral dissection had the potential to cause ischemic injury to the ureter, (2) None of the options helped the possible left UPJO, and (3) The patient's bladder capacity was very small (200 mL). Another option was ileal interposition, but this was not ideal considering her young age and the possibility of severe bowel adhesions, complications related to bowel resection, and renal impairment secondary to bowel reabsorption of urine when she became older. RATx was offered, but the patient was reluctant because of the procedure's invasiveness at that time.

Four years later (8 years after the Caesarean section), she returned for reconsideration of surgery. The patient elected to undergo robotic RATx since it was less invasive than conventional RATx. The procedure was performed transperitoneally using the da Vinci Surgical System at our hospital in Okayama, Japan. She was placed in the left nephrectomy position. Robotic left nephrectomy was performed with three ports on the mid-clavicular line and a Gelport though a 7-cm supra-umbilical midline incision (Fig. 18.2). We used Gelport instead of a completely intracorporeal approach because the suspected UPJO required an intraoperative assessment. Furthermore, Gelport enables graft cooling in a gauze jacket filled with ice (Menon et al. 2014b). The left kidney was removed through the Gelport, and it was perfused on ice with Euro-Collins solution. The warm ischemia time was 4 min 5 sec. The shape and patency of the UPJ was examined with a vessel dilator and it did not demonstrate obstruction. If an obstruction had been observed, ureteropelvic or vesicopelvic anastomosis would have been considered. The patient was repositioned to a low lithotomy position with a steep Trendelenburg tilt. The robot was also re-docked. The kidney was brought through the Gelport and placed over the bladder. A running end-to-side anastomosis was created between the renal vessels and the EIV or EIA using CV-5 or CV-6 Gore-Tex suture (Figs. 18.3 and 18.4). A ureteroneocystostomy was performed by the Lich-Gregoir extravesical method over a 5 Fr ureteral stent in running fashion with 4-zero Vicryl suture. The surgeon console time was 507 min. The cold ischemia time was 249 min.

The patient's postoperative course was uneventful. The ureteral stent was removed 1 month postoperatively. The preoperative serum creatinine (SCr) was 0.60 mg/dL, and it increased to 0.67 mg/dL 12 months postoperatively.

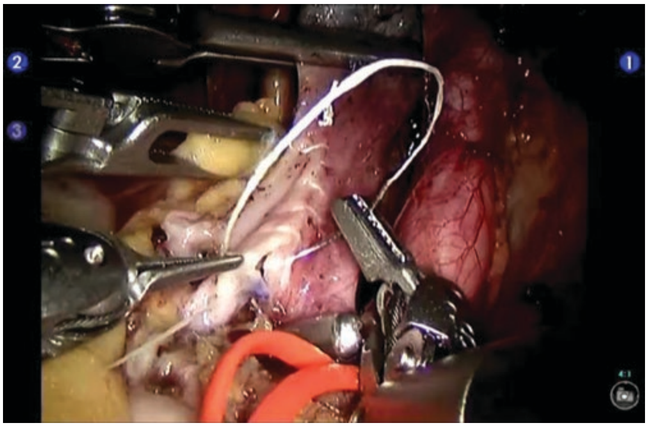

**Fig. 18.3** Venous anastomosis. A running end-to-side anastomosis was created between the renal vein and the EIV using CV-5 Gore-Tex suture

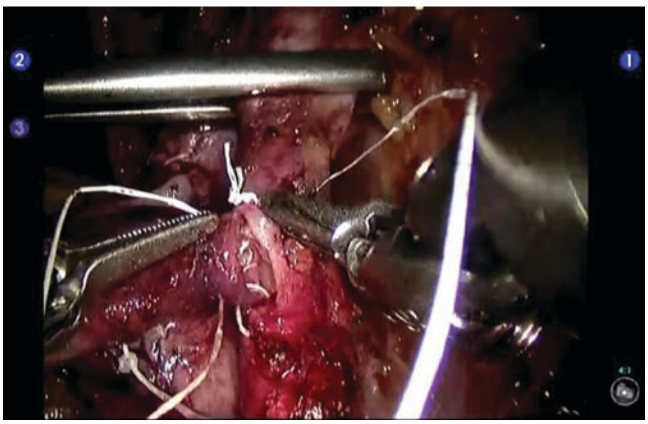

**Fig. 18.4** Arterial anastomosis. A running end-to-side arterial anastomosis was created using CV-6 Gore-Tex suture. Hemostasis was confirmed

Currently, the patient voids without any discomfort and is extremely happy being stent-free 8 years after the Caesarean section.

Two 99mTc-MAG3 scans performed 3 and 12 months postoperatively showed good blood flow and revealed no ureteral obstruction. The preoperative split function (left [graft]: right) was 51:49, and it remained stable at 43:57 and 52:48 at 3 and 12 months postoperatively, respectively. Computed tomography urography obtained 3, 7, and 12 months postoperatively showed patent vascular anastomoses and revealed no ureteral obstructions.

## 18.4 The Future of Robotic Renal Autotransplantation

Robotic surgery has many advantages over traditional surgery, including the ability to perform fine suturing and dissection. Fine dissection is particularly helpful in patients with desmoplastic changes. To date, three out of four robotic RATx have been performed to repair ureteral injuries. Ureteral injuries are often associated with desmoplastic changes because of previous surgeries and urine leakage resulting in urinoma. Nephrectomy prior to renal autotransplant is technically challenging. Therefore, robotic nephrectomy may be a reasonable option, considering the complex and severe desmoplastic changes in many of these cases. The disadvantage of robotic RATx is the length and cost of surgery. However, with continued use, both the operative time and the cost of robotic RATx should decrease.

In the initial animal studies, we attempted both intra- and extra-corporeal irrigation of the renal autograft. The benefit of intracorporeal irrigation is minimizing the number and size of incisions. However, intracorporeal irrigation with ice-cold lactated Ringer's solution does not achieve the degree of hypothermia that can be reached with irrigation of the autograft placed on ice. Many laparoscopic techniques have been explored in an attempt to cool the kidney during partial nephrectomy (Menon et al. 2014b; Gill et al. 2003; Janetschek et al. 2004; Landman et al. 2003; Navarro et al. 2008; Weld et al. 2007). However, these techniques are not routinely used because they are cumbersome and the results have not been reproducible. Inadequate hypothermia during cold ischemia may predispose kidneys to ischemia-reperfusion injury. Inadequate hypothermia is also associated with worsened CKD (Veeratterapillay et al. 2016). The benefit of extracorporeal irrigation is adequate hypothermia. Extracorporeal irrigation can achieve temperatures as cold as those used in renal allo-transplantation. The disadvantage of extracorporeal irrigation is the need for an additional incision to remove the autograft. Robotic renal transplantation with regional hypothermia has recently been reported, using a well described and reproducible technique (Menon et al. 2014b). We modified this technique by placing a Gelport in all porcine experiments as a safety measure, regardless of the modality of irrigation. We anticipate that the use of the Gelport will be discontinued once we have more experience with this approach.

## 18.5 Conclusion

Robotic RATx is a new, minimally invasive alternative to conventional open RATx.

## References


Araki, M, Wada K, Mitsui Y, Sadahira T, Kubota R, Nishimura S, et al. Robotic renal autotransplantation: first case outside of North America. Acta Med Okayama 2017;71(4):351–55.

Bluebond-Langner R, Rha KH, Pinto PA, Varkarakis J, Douyon E, Komotar RJ, et al. Laparoscopic-assisted renal autotransplantation.

Urology. 2004;63(5):853–6. https://doi.org/10.1016/j.urology.2003.12.019.
Gill IS, Abreu SC, Desai MM, Steinberg AP, Ramani AP, Ng C, et al. Laparoscopic ice slush renal hypothermia for partial nephrectomy: the initial experience. J Urol. 2003;170(1):52–6. https://doi.org/10.1097/01.ju.0000072332.02529.10.
Giulianotti P, Gorodner V, Sbrana F, Tzvetanov I, Jeon H, Bianco F, et al. Robotic transabdominal kidney transplantation in a morbidly obese patient. Am J Transplant. 2010;10(6):1478–82. https://doi.org/10.1111/j.1600-6143.2010.03116.x.
Gordon ZN, Angell J, Abaza R. Completely intracorporeal robotic renal autotransplantation. J Urol. 2014;192(5):1516–22. https://doi.org/10.1016/j.juro.2014.02.2589.
Hardy JD, Eraslan S. Autotransplantation of the kidney for high ureteral injury. J Urol. 1963;90:563–74.
Hoznek A, Zaki SK, Samadi DB, Salomon L, Lobontiu A, Lang P, et al. Robotic assisted kidney transplantation: an initial experience. J Urol. 2002;167(4):1604–6.
Janetschek G, Abdelmaksoud A, Bagheri F, Al-Zahrani H, Leeb K, Gschwendtner M. Laparoscopic partial nephrectomy in cold ischemia: renal artery perfusion. J Urol. 2004;171(1):68–71. https://doi.org/10.1097/01.ju.0000101040.13244.c4.
Landman J, Venkatesh R, Lee D, Vanlangendonck R, Morissey K, Andriole GL, et al. Renal hypothermia achieved by retrograde endoscopic cold saline perfusion: technique and initial clinical application. Urology. 2003;61(5):1023–5. https://doi.org/10.1016/S0090-4295(02)02566-9.
Lee J, Ordon M. Innovative applications of robotic surgery: renal allograft and autologous transplantation. F1000Res. 2016;5. https://doi.org/10.12688/f1000research.7343.1.
Lee JY, Alzahrani T, Ordon M. Intra-corporeal robotic renal autotransplantation. Canadian Urol Assoc J. 2015;9(9–10):E748–9. https://doi.org/10.5489/cuaj.3015.
Levey AS, Coresh J. Chronic kidney disease. Lancet. 2012;379(9811):165–80. https://doi.org/10.1016/S0140-6736(11)60178-5.
Menon M, Sood A, Bhandari M, Kher V, Ghosh P, Abaza R, et al. Robotic kidney transplantation with regional hypothermia: a step-by-step description of the Vattikuti Urology Institute-Medanta technique (IDEAL phase 2a). Eur Urol. 2014a;65(5):991–1000. https://doi.org/10.1016/j.eururo.2013.12.006.
Menon M, Abaza R, Sood A, Ahlawat R, Ghani KR, Jeong W, et al. Robotic kidney transplantation with regional hypothermia: evolution of a novel procedure utilizing the IDEAL guidelines (IDEAL phase 0 and 1). Eur Urol. 2014b;65(5):1001–9. https://doi.org/10.1016/j.eururo.2013.11.011.
Meraney AM, Gill IS, Kaouk JH, Skacel M, Sung GT. Laparoscopic renal autotransplantation. J Endourol. 2001;15(2):143–9. https://doi.org/10.1089/089277901750134403.
Navarro AP, Sohrabi S, Colechin E, Griffiths C, Talbot D, Soomro NA. Evaluation of the ischemic protection efficacy of a laparoscopic renal cooling device using renal transplantation viability assessment criteria in a porcine model. J Urol. 2008;179(3):1184–9. https://doi.org/10.1016/j.juro.2007.10.025.
Oberholzer J, Giulianotti P, Danielson KK, Spaggiari M, Bejarano-Pineda L, Bianco F, et al. Minimally invasive robotic kidney transplantation for obese patients previously denied access to transplantation. Am J Transplant. 2013;13(3):721–8. https://doi.org/10.1111/ajt.12078.
Ratner LE, Kavoussi LR, Schulam PG, Bender JS, Magnuson TH, Montgomery R. Comparison of laparoscopic live donor nephrectomy versus the standard open approach. Transplant Proc. 1997;29(1–2):138–9.
Snyder JJ, Collins AJ. Association of preventive health care with atherosclerotic heart disease and mortality in CKD. J Am Soc Nephrol. 2009;20(7):1614–22. https://doi.org/10.1681/ASN.2008090954.
Stevens PE, Levin A, Kidney Disease: Improving Global Outcomes Chronic Kidney Disease Guideline Development Work Group Members. Evaluation and management of chronic kidney disease: synopsis of the kidney disease: improving global outcomes 2012 clinical practice guideline. Ann Intern Med. 2013;158(11):825–30. https://doi.org/10.7326/0003-4819-158-11-201306040-00007.
Tsai MK, Lee CY, Yang CY, Yeh CC, Hu RH, Lai HS. Robot-assisted renal transplantation in the retroperitoneum. Transplant Int. 2014;27(5):452–7. https://doi.org/10.1111/tri.12279.
Veeratterapillay R, Addla SK, Jelley C, Bailie J, Rix D, Bromage S, et al. Early surgical outcomes and oncological results of robot-assisted partial nephrectomy: a multicentre study. BJU Int 2016. doi:https://doi.org/10.1111/bju.13743.
Weld KJ, Koziol S, Montiglio C, Sorenson P, Cespedes RD, Bishoff JT. Feasibility of laparoscopic renal cooling with near-freezing saline irrigation delivered with a standard irrigator aspirator. Urology. 2007;69(3):465–8. https://doi.org/10.1016/j.urology.2006.12.002.
Wotkowicz C, Libertino JA. Renal autotransplantation. BJU Int. 2004;93(3):253–7.

# Robot-Assisted Laparoscopic Surgery for Upper Tract Urothelial Carcinoma

19

Sung Yul Park and Young Eun Yoon

**Abstract**

When initially robot-assisted laparoscopic surgery was introduced in urologic field, the focus was on radical prostatectomy and partial nephrectomy. It was quite true that upper tract urothelial carcinoma (UTUC), which had no major problem with laparoscopic operations, was late in the introduction of robotic surgery. One of the reasons for the late introduction of the robot for UTUC was difficulty in port placement due to relatively wide operation field. However, through various port arrangement modification, lots of UTUCs are treated with robot-assisted laparoscopic surgeries.

This chapter focuses on nephroureterectomy, the gold standard of UTUC treatment. We will discuss the preparation of robot-assisted laparoscopic nephroureterectomy, perioperative and oncologic outcome, and lymph node dissection, and will look into robotic LESS nephroureterectomy, which is a more advanced and less invasive than conventional robot surgery. We also look into what kind of robot-assisted laparoscopic surgery could be performed instead of nephroureterectomy when nephron saving procedure is needed.

**Keywords**

Urothelial cancer · Robot-assisted surgery Nephroureterectomy · Urinary tract

## 19.1 Introduction

Although upper tract urothelial cancer (UTUC) is about 5–10% of all transitional cell carcinoma (Siegel et al. 2013), it is often aggressive and so needs radical treatment. The 5-year disease-specific survival rate is similar or slightly lower than bladder tumor (Moussa et al. 2010; Catto et al. 2007). Conservative treatment such as segmental ureterectomy or distal ureterectomy could be performed; however gold standard treatment is still nephroureterectomy with bladder cuff excision (Colin et al. 2012).

As robotic surgery was actively performed in the whole urinary tract, it was recently applied to the treatment of UTUC. The first report of nephroureterectomy was in 2006 by Rose et al. and distal ureterectomy and segmental ureterectomy have also been attempted (Rose et al. 2006; Uberoi et al. 2007; Raheem et al. 2017). As with most robotic surgeries, there are still few reports of safety or oncologic outcome. However, short to intermediate term results suggest that robotic surgery can be used safely for UTUC treatment (Eandi et al. 2010). Although robotic surgery for UTUC is more expensive than laparoscopic surgery, postoperative complications are reported to be less (Trudeau et al. 2014). In this chapter, we will review the role of surgical robot in UTUC treatment and its future development.

## 19.2 Nephroureterectomy

After the first report of robotic nephroureterectomy by Rose et al., many surgeons reported the results of their initial cases of robotic nephroureterectomy (Rose et al. 2006; Hu et al. 2008; Ozdemir et al. 2012; Park et al. 2008). Robotic surgery patients were more likely have less blood loss, less perioperative complications, and shorter hospital stays than conventional laparoscopic or open surgery (Hu et al. 2015). The short- and intermediate-term oncologic outcome was comparable to other approaches (Yang et al. 2014). Because of the need of robot re-docking, robotic approach was associated with longer operation time and higher cost compared to laparoscopic and open approach (Trudeau et al. 2014). However, the operation time is being overcome with the development of many techniques, and there is a view that robotic nephroureterectomy could become a future gold

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standard for the surgical management of UTUC because of the fundamental advantages of robotic platform (Borghesi et al. 2014).

### 19.2.1 Port Placement

In the early days of robotic surgery, it was difficult to operate the upper tract (kidney) and the lower tract (ureterectomy and bladder cuff excision) at once. Re-docking of robot was necessary for bladder cuff excision (Eandi et al. 2010; Marshall and Stifelman 2014). That is, docking the patient in the lateral position for nephrectomy first, then the patient was repositioned to lithotomy and robot was re-docked between the patient's legs. Additional ports placement is needed. Some surgeons did not use robots at all for bladder cuff excision and used conventional open technique after nephrectomy. There was also a report of opening the bladder dome and performing a distal ureterectomy with a transvesical technique (Nanigian et al. 2006). To solve these problem, hybrid ports technique was devised (Eun et al. 2007). Park et al. suggested new technique to reduce the operating time by using a 'hybrid' port placement and 'telescoping' the 8-mm robotic ports into 12-mm laparoscopic ports (Fig. 19.1) (Park et al. 2009). With this new technique, the authors reported that they could reduce surgical time by 50 min without any complication, as no more additional ports replacement, de-docking and re-docking of robot were necessary.

A further development has been proposed to allow bladder cuff excision as well as nephrectomy without intraoperative position change (Hemal et al. 2011). After the patient is positioned in a modified flank position with the

**Fig. 19.1** The hybrid port technique (Park et al. 2009). The 8 mm port for robotic arm was inserted into 12 mm port for distal ureterectomy to avoid insertion of additional port

disease side up, the patient is placed in a slight Trendelenburg position of approximately 15°. The position of trocars is as follows: (1) 12-mm camera port is placed at the level of the umbilicus, lateral to the rectus sheath, (2) The first 8-mm robotic port is placed 7–8 cm cranial to the camera port. (3) The second 8-mm robotic port is placed 7–8 cm caudal to the camera port. (4) The third 8-mm robotic port is placed approximately 5 cm cranial to the iliac crest, in the anterior axillary line. (5) A 12-mm assistant port is placed in the midline, approximately 2–3 cm cranial to the umbilicus (Hemal et al. 2011). With this new method, the authors performed 15 robotic nephroureterectomies with bladder cuff excision safely. They occasionally performed lymphadenectomy, nevertheless, the operation time was greatly reduced to 184 min. Besides, various attempts have been reported, including removing a robot arm and inserting two assistant ports (Yang et al. 2014; Badani et al. 2014; Zargar et al. 2014).

However, these problems were solved when da Vinci Xi platform came out in the robot market. The biggest change in da Vinci Xi platform is that its boom feature and the smaller camera size (8 mm in diameter). This allowed ports to be placed in a row on the paramedian line (Fig. 19.2a, b), making the surgeon more comfortable to operate without any requirement intraoperative patient repositioning/robot re-docking (Patel et al. 2015). Various methods have been devised for da Vinci Xi's ports array. Darwiche et al. positioned four robotic ports positioned in an oblique straight line starting with a robotic port located two finger breadths below the costal margin just lateral to the rectus abdominis muscle with a minimum distance of 6–8 cm between the ports (Darwiche et al. 2015). A 12 mm assistant port is placed closer to the midline and between the two most cephalad robotic ports (Fig. 19.2c). With this position, bladder cuff excision could be performed without difficulty. Besides, Argun et al. reported that four ports were placed in rhombus (Fig. 19.2d) (Argun et al. 2016). As we have seen so far, the location of the ports can vary greatly from one operator to another. In fact, there is no correct answer to port position. The most safe and preferred method according to the surgeon is considered to be the most important.

### 19.2.2 Lymph Node Dissection

UTUC is more likely to invade muscle than bladder cancer (Hall et al. 1998). For muscle-invasive bladder cancer, extended lymph node dissection has been recommended. However, in nephroureterectomy, the role of lymph node dissection is yet to be determined. Several studies have suggested that lymph node dissection affects disease specific survival and disease recurrence in patients with UTUC, so

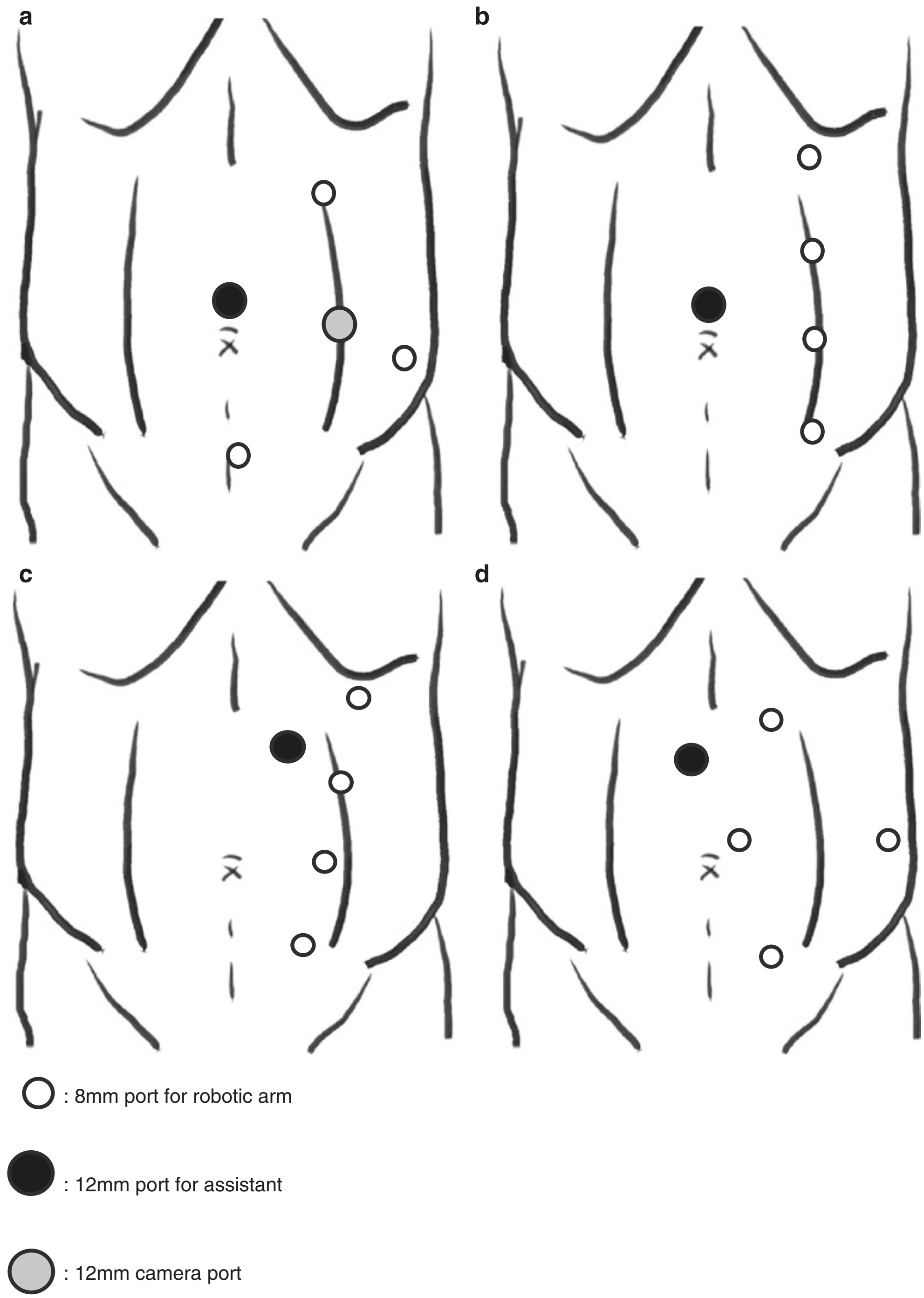


**Fig. 19.2** Various port placements for robotic left nephroureterectomy. (**a**) Placement of ports for da Vinci Si Platform by Patel et al. (2015). (**b**) Placement of ports for da Vinci Xi Platform by Patel et al. (**c**) Straight and oblique ports placement for da Vinci Xi platform (Darwiche et al. 2015). (**d**) Rhombic ports placement for da Vinci Xi platform (Argun et al. 2016)

recent advances in lymph node dissection in nephroureterectomy have proved to be convincing (Lughezzani et al. 2010; Kondo et al. 2014, 2010). Therefore, lymph node dissection is also performed in robotic nephroureterectomy. However, in their retrospective study for laparoscopic and robotic nephroureterectomy, Azawi et al. reported that there was no difference in overall survival and cancer specific survival between patients with or without lymph node metastasis (Azawi et al. 2017). Since reports of lymph node dissection in nephroureterectomy are almost retrospective studies, prospective, multicenter, and large-scale studies are needed (Alvarez-Maestro et al. 2016).

Lymph node dissection has been reported to be more effective and successful when performed with robot than conventional laparoscopy (Pugh et al. 2013). Melquist et al. reported that, when compared with conventional laparoscopy, robotic nephroureterectomy with lymph node dissection resulted in longer operative times (5.1 h vs. 3.9 h) and hospital stays (5 days vs. 3 days) but was associated with significantly higher LN yield (21 vs. 11) and lower blood transfusion requirements (8% vs. 30%) (Melquist et al. 2016). These results are similar in a matched comparison of laparoscopic and robotic nephroureterectomy (Ambani et al. 2014). Comparing with open nephroureterectomy, robotic nephroureterectomy with retroperitoneal lymph node dissection tends to result longer operation time (Rao et al. 2012).

### 19.2.3 Oncologic Outcome

There are several early reports on the feasibility of a robot (Eandi et al. 2010; Hu et al. 2008; Hemal et al. 2011; Uffort and Jensen 2010). Eandi et al. reported that among 11 patient who underwent robotic nephroureterectomy, with a mean follow-up of 15.2 months (range 2–31 months), 4 patients experienced recurrence, and 2 died from metastatic disease. Ambani et al. published a paper comparing their initial series with laparoscopic surgery, the authors described that after a median follow-up of 10 months for robotic surgery and 15 months for laparoscopic surgery, no significant difference was seen in the rate of bladder (36% vs. 37%) or distant (32% vs. 23%) recurrence, with similar median time to any recurrence (9 months vs. 4 months, P = 0.32) (Ambani et al. 2014).

Lim et al. reported their intermediate-term outcomes of robotic nephroureterectomy (n = 32); median follow-up was 45.5 months (Lim et al. 2013). At 2 and 5 years, overall survival was 81.3% and 60.9%; cancer-specific survival was 87.3% and 75.8%, and non-urothelial recurrence-free survival was 71.5% and 68.1%, respectively (Lim et al. 2013). The authors concluded that intermediate-term oncological outcomes seem comparable with those of open and laparoscopic nephroureterectomy. In a larger series (n = 65), 2 and 5 years overall survival was 86.9% and 62.6%, cancer specific survival was 92.9% and 69.5%, and recurrence-free survival was 65.3% and 57.1%, respectively (Aboumohamed et al. 2015).

### 19.2.4 Robotic LESS Nephroureterectomy

After Kaouk et al. reported the initial results of robotic single-port transumbilical surgery, outcomes of many robotic LESS surgeries were reported (Kaouk et al. 2009). Nephroureterectomy is also one of them (Won Lee et al. 2011).

In their single-center experience with the first 100 LESS series, White et al. reported that they performed 1 robotic LESS nephroureterectomy, but the authors did not mention the details (White et al. 2009). Khanna et al. reported three robotic LESS nephrectomies using TriPort (Advanced Surgical Concepts, Dublin, Ireland) and GelPort (Applied Medical, Rancho Santa Margarita, CA, USA) (Khanna et al. 2012). The operation time was 300 min, blood loss was 183 mL, and mean length of stay was 3.3 days. The authors also reported that they needed a conversion to laparoscopic surgery because of difficulty in visualizing and accessing the upper pole of the kidney when the single port was placed through a Gibson incision (Khanna et al. 2012).

Lim et al. compared robotic LESS (n = 17) and multiport (or conventional) robotic nephroureterectomy (n = 21), concluding that although the oncological and perioperative outcomes of patients who underwent robotic LESS compared well with those who underwent multiport robotic nephroureterectomy, robotic LESS nephroureterectomy might result in greater intraoperative blood loss (Lim et al. 2014).

## 19.3 Distal Ureterectomy and Ureteral Reimplantation

Seventy-five percent of ureter tumors occur in the distal ureter. Distal ureterectomy and ureteral reimplantation may be an important treatment option if the tumor is localized within the ureter. Robotic distal ureterectomy was first reported in 2007 (Uberoi et al. 2007). The authors described their technique and concluded that robotic distal ureterectomy can be performed even when a psoas hitch is necessary to complete the vesicoureteral anastomosis. In addition to the psoas hitch, the Boari flap could be safely and effectively performed using robotics, so it can be safely handled even if the remnant ureter is expected to be short after distal ureterectomy (Schimpf and Wagner 2008; Yang et al. 2011).

Trocar placement is not strictly defined, but is slightly different for each surgeon (Fig. 19.3). There is a group that uses only three arms, including a camera (Eandi et al. 2010), and a group that uses the fourth arm. Glinianski et al. described that they placed the fourth arm of the robot to opposite side of the involved ureter (Glinianski et al. 2009). But the fourth arm is not always necessary. The position of the suction port also depends on the surgeon's preferred position (Schimpf and Wagner 2009).

Oncologic outcome is comparative to open and laparoscopic distal ureterectomy. Eandi et al. reported that with a mean follow-up of 30.5 months (12–48), only one patient among four required adjuvant treatment for recurrent disease (Eandi et al. 2010).

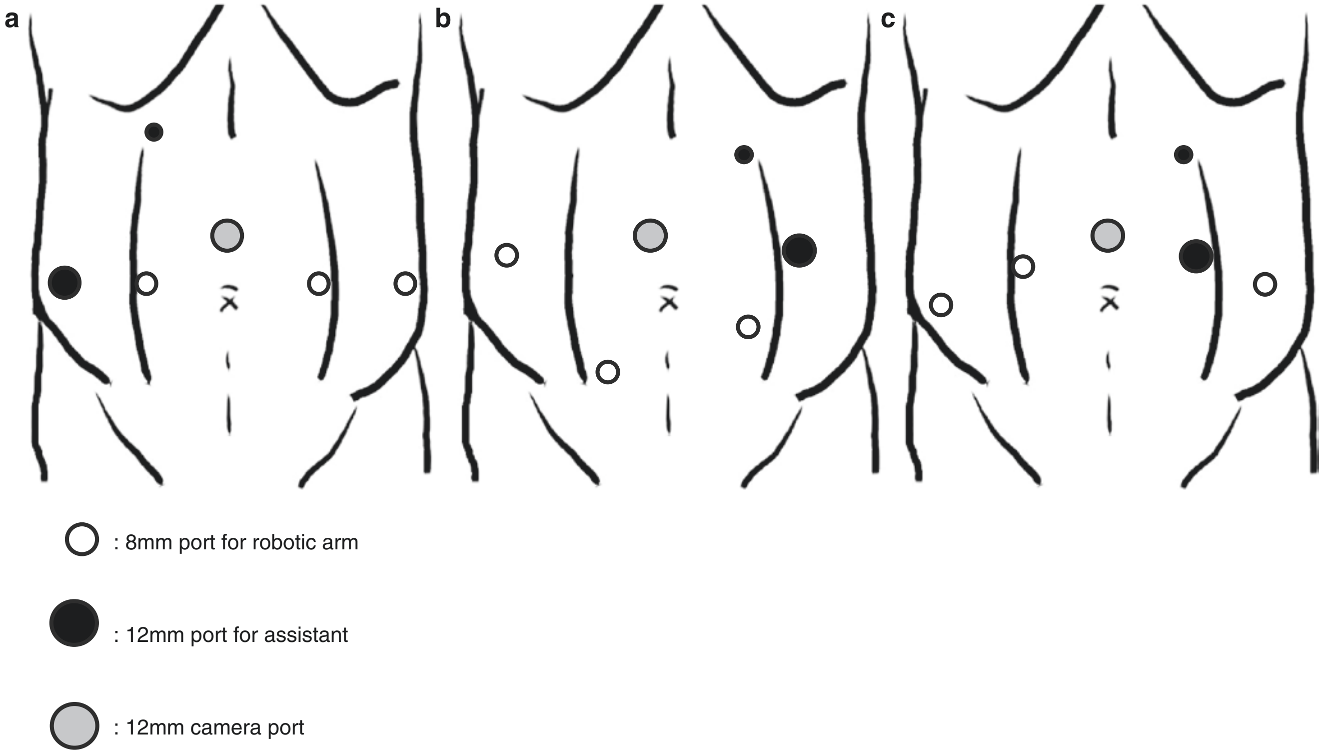


**Fig. 19.3** Various port placements for robotic right distal ureterectomy. Reported (**a**) by Eandi et al. (2010), (**b**) by Glinianski et al. (2009), (**c**) by Schimpf and Wagner (2009)

## 19.4 Segmental Ureterectomy and Ureteroureterostomy

There are not many reports of segmental ureterectomy in conventional open or laparoscopic surgery as well as robot surgery (Jeldres et al. 2010; Simonato et al. 2012; Lughezzani et al. 2009). Segmental ureterectomy differs from distal ureterectomy in that the cut ureter is procedure by end-to-end anastomosis. Because the vast majority of ureteral cancers occur in the lower ureter, the frequency of their use is low. It is usually performed in patients with single kidney or high medical comorbidity. And for oncologic outcome, it should be performed only in the low stage below T2.

McClain et al. reported their perioperative data and oncologic outcome of robotic ureterectomies (McClain et al. 2012). In their series, two patients who had midureteral tumor were treated by segmental ureterectomy and ureteroureterostomy. The operation time was 197 min and 278 min, respectively, and there was no recurrence during 36 and 31 months of follow-up period. Raheem et al. reported robotic segmental ureterectomy and ureteroureterostomy in an 80-year old male patient with high medical comorbidity. They described that the operation was performed easily and console time was only 60 min. Postoperative serum creatinine was 1.2 mg/dL and surgical margin was negative.

Ureteroureterostomy is often performed in various benign diseases such as ureteral stricture or impacted ureteral stone, the result of the robot ureteroureterostomy itself is not very different from the conventional surgical method (Lee et al. 2013). Tension-free anastomosis is important and could be assisted by extensive ureteral dissection and downward nephropexy if necessary.

## References

Aboumohamed AA, Krane LS, Hemal AK. Oncologic outcomes following robot-assisted laparoscopic nephroureterectomy with bladder cuff excision for upper tract urothelial carcinoma. J Urol. 2015;194(6):1561–6.

Alvarez-Maestro M, Rivas JG, Gregorio SA, Guerin CC, Gomez AT, Ledo JC. Current role of lymphadenectomy in the upper tract urothelial carcinoma. Cent Eur J Urol. 2016;69(4):384–90.

Ambani SN, Weizer AZ, Wolf JS Jr, He C, Miller DC, Montgomery JS. Matched comparison of robotic vs laparoscopic nephroureterectomy: an initial experience. Urology. 2014;83(2):345–9.

Argun OB, Mourmouris P, Tufek I, Tuna MB, Keskin S, Obek C, et al. Radical nephroureterectomy without patient or port repositioning using the da Vinci Xi robotic system: initial experience. Urology. 2016;92:136–9.

Azawi NH, Berg KD, Thamsborg AKM, Dahl C, Jepsen JV, Kroman-Andersen B, et al. Laparoscopic and robotic nephroureterectomy: does lymphadenectomy have an impact on the clinical outcome? Int Urol Nephrol. 2017;49:1785–92.

Badani KK, Rothberg MB, Bergman A, Silva MV, Shapiro EY, Nieder A, et al. Robot-assisted nephroureterectomy and bladder cuff excision without patient or robot repositioning: description of modified port placement and technique. J Laparoendosc Adv Surg Tech A. 2014;24(9):647–50.

Borghesi M, Brunocilla E, Schiavina R, Martorana G. Robot-assisted radical nephroureterectomy for upper urinary tract urothelial carcinoma: a promising alternative to open surgery or a future "gold standard"? Clin Genitourin Cancer. 2014;12(2):e65–6.

Catto JW, Yates DR, Rehman I, Azzouzi AR, Patterson J, Sibony M, et al. Behavior of urothelial carcinoma with respect to anatomical location. J Urol. 2007;177(5):1715–20.

Colin P, Ouzzane A, Pignot G, Ravier E, Crouzet S, Ariane MM, et al. Comparison of oncological outcomes after segmental ureterectomy or radical nephroureterectomy in urothelial carcinomas of the upper urinary tract: results from a large French multicentre study. BJU Int. 2012;110(8):1134–41.

Darwiche F, Swain S, Kallingal G, Punnen S, Manoharan M, Parekh DJ, et al. Operative technique and early experience for robotic-assisted laparoscopic nephroureterectomy (RALNU) using da Vinci Xi. Springerplus. 2015;4:298.

Eandi JA, Nelson RA, Wilson TG, Josephson DY. Oncologic outcomes for complete robot-assisted laparoscopic management of upper-tract transitional cell carcinoma. J Endourol. 2010;24(6):969–75.

Eun D, Bhandari A, Boris R, Rogers C, Bhandari M, Menon M. Concurrent upper and lower urinary tract robotic surgery: strategies for success. BJU Int. 2007;100(5):1121–5.

Glinianski M, Guru KA, Zimmerman G, Mohler J, Kim HL. Robot-assisted ureterectomy and ureteral reconstruction for urothelial carcinoma. J Endourol. 2009;23(1):97–100.

Hall MC, Womack S, Sagalowsky AI, Carmody T, Erickstad MD, Roehrborn CG. Prognostic factors, recurrence, and survival in transitional cell carcinoma of the upper urinary tract: a 30-year experience in 252 patients. Urology. 1998;52(4):594–601.

Hemal AK, Stansel I, Babbar P, Patel M. Robotic-assisted nephroureterectomy and bladder cuff excision without intraoperative repositioning. Urology. 2011;78(2):357–64.

Hu JC, Silletti JP, Williams SB. Initial experience with robot-assisted minimally-invasive nephroureterectomy. J Endourol. 2008;22(4):699–704.

Hu CY, Yang CK, Huang CY, Ou YC, Hung SF, Chung SD, et al. Robot-assisted laparoscopic nephroureterectomy versus hand-assisted laparoscopic nephroureterectomy for upper urinary tract urothelial carcinoma: a matched comparison study. Biomed Res Int. 2015;2015:918486.

Jeldres C, Lughezzani G, Sun M, Isbarn H, Shariat SF, Budaus L, et al. Segmental ureterectomy can safely be performed in patients with transitional cell carcinoma of the ureter. J Urol. 2010;183(4):1324–9.

Kaouk JH, Goel RK, Haber GP, Crouzet S, Stein RJ. Robotic single-port transumbilical surgery in humans: initial report. BJU Int. 2009;103(3):366–9.

Khanna R, Stein RJ, White MA, Isac W, Laydner H, Autorino R, et al. Single institution experience with robot-assisted laparoendoscopic single-site renal procedures. J Endourol. 2012;26(3):230–4.

Kondo T, Hashimoto Y, Kobayashi H, Iizuka J, Nakazawa H, Ito F, et al. Template-based lymphadenectomy in urothelial carcinoma of the upper urinary tract: impact on patient survival. Int J Urol. 2010;17(10):848–54.

Kondo T, Hara I, Takagi T, Kodama Y, Hashimoto Y, Kobayashi H, et al. Possible role of template-based lymphadenectomy in reducing the risk of regional node recurrence after nephroureterectomy in patients with renal pelvic cancer. Jpn J Clin Oncol. 2014;44(12):1233–8.

Lee Z, Llukani E, Reilly CE, Mydlo JH, Lee DI, Eun DD. Single surgeon experience with robot-assisted ureteroureterostomy for pathologies at the proximal, middle, and distal ureter in adults. J Endourol. 2013;27(8):994–9.

Lim SK, Shin TY, Kim KH, Chung BH, Hong SJ, Choi YD, et al. Intermediate-term outcomes of robot-assisted laparoscopic nephroureterectomy in upper urinary tract urothelial carcinoma. Clin Genitourin Cancer. 2013;11(4):515–21.

Lim SK, Shin TY, Kim KH, Han WK, Chung BH, Hong SJ, et al. Laparoendoscopic single-site (LESS) robot-assisted nephroureterectomy: comparison with conventional multiport technique in the management of upper urinary tract urothelial carcinoma. BJU Int. 2014;114(1):90–7.

Lughezzani G, Jeldres C, Isbarn H, Sun M, Shariat SF, Alasker A, et al. Nephroureterectomy and segmental ureterectomy in the treatment of invasive upper tract urothelial carcinoma: a population-based study of 2299 patients. Eur J Cancer. 2009;45(18):3291–7.

Lughezzani G, Jeldres C, Isbarn H, Shariat SF, Sun M, Pharand D, et al. A critical appraisal of the value of lymph node dissection at nephroureterectomy for upper tract urothelial carcinoma. Urology. 2010;75(1):118–24.

Marshall S, Stifelman M. Robot-assisted surgery for the treatment of upper urinary tract urothelial carcinoma. Urol Clin North Am. 2014;41(4):521–37.

McClain PD, Mufarrij PW, Hemal AK. Robot-assisted reconstructive surgery for ureteral malignancy: analysis of efficacy and oncologic outcomes. J Endourol. 2012;26(12):1614–7.

Melquist JJ, Redrow G, Delacroix S, Park A, Faria EE, Karam JA, et al. Comparison of single-docking robotic-assisted and traditional laparoscopy for retroperitoneal lymph node dissection during nephroureterectomy with bladder cuff excision for upper-tract urothelial carcinoma. Urology. 2016;87:216–23.

Moussa S, Yafi FA, El-Hakim A, Fahmy N, Aprikian A, Tanguay S, et al. Outcome of surgical treatment of patients with upper versus lower urinary tract urothelial carcinoma: stage-by-stage comparison. Urol Int. 2010;84(1):50–5.

Nanigian DK, Smith W, Ellison LM. Robot-assisted laparoscopic nephroureterectomy. J Endourol. 2006;20(7):463–5; discussion 5–6.

Ozdemir AT, Altinova S, Asil E, Balbay MD. Robotic-assisted laparoscopic nephroureterectomy and bladder cuff excision. J Soc Laparoendosc Surgeons. 2012;16(2):320–4.

Park SY, Jeong W, Choi YD, Chung BH, Hong SJ, Rha KH. Yonsei experience in robotic urologic surgery-application in various urological procedures. Yonsei Med J. 2008;49(6):897–900.

Park SY, Jeong W, Ham WS, Kim WT, Rha KH. Initial experience of robotic nephroureterectomy: a hybrid-port technique. BJU Int. 2009;104(11):1718–21.

Patel MN, Aboumohamed A, Hemal A. Does transition from the da Vinci Si to Xi robotic platform impact single-docking technique for robot-assisted laparoscopic nephroureterectomy? BJU Int. 2015;116(6):990–4.

Pugh J, Parekattil S, Willis D, Stifelman M, Hemal A, Su LM. Perioperative outcomes of robot-assisted nephroureterectomy for upper urinary tract urothelial carcinoma: a multi-institutional series. BJU Int. 2013;112(4):E295–300.

Raheem AA, Alatawi A, Kim DK, Sheikh A, Rha KH. Feasibility of Robot-assisted segmental ureterectomy and ureteroureterostomy in patient with high medical comorbidity. Int Braz J Urol. 2017;43(4):779–80.

Rao SR, Correa JJ, Sexton WJ, Pow-Sang JM, Dickinson SI, Lin HY, et al. Prospective clinical trial of the feasibility and safety of modified retroperitoneal lymph node dissection at time of nephroureterectomy for upper tract urothelial carcinoma. BJU Int. 2012;110(11 Pt B):E475–80.

Rose K, Khan S, Godbole H, Olsburgh J, Dasgupta P. Robotic assisted retroperitoneoscopic nephroureterectomy—first experience and the hybrid port technique. Int J Clin Pract. 2006;60(1):12–4.

Schimpf MO, Wagner JR. Robot-assisted laparoscopic Boari flap ureteral reimplantation. J Endourol. 2008;22(12):2691–4.

Schimpf MO, Wagner JR. Robot-assisted laparoscopic distal ureteral surgery. J Soc Laparoendosc Surgeons. 2009;13(1):44–9.

Siegel R, Naishadham D, Jemal A. Cancer statistics, 2013. CA Cancer J Clin. 2013;63(1):11–30.

Simonato A, Varca V, Gregori A, Benelli A, Ennas M, Lissiani A, et al. Elective segmental ureterectomy for transitional cell carcinoma of the ureter: long-term follow-up in a series of 73 patients. BJU Int. 2012;110(11 Pt B):E744–9.

Trudeau V, Gandaglia G, Shiffmann J, Popa I, Shariat SF, Montorsi F, et al. Robot-assisted versus laparoscopic nephroureterectomy for upper-tract urothelial cancer: a population-based assessment of costs and perioperative outcomes. Canadian Urol Assoc J. 2014;8(9–10):E695–701.

Uberoi J, Harnisch B, Sethi AS, Babayan RK, Wang DS. Robot-assisted laparoscopic distal ureterectomy and ureteral reimplantation with psoas hitch. J Endourol. 2007;21(4):368–73; discussion 72–3.

Uffort EE, Jensen JC. Two-year outcomes after robotic renal surgery: a single surgeon's experience. J Robot Surg. 2010;4(4):205–10.

White WM, Haber G-P, Goel RK, Crouzet S, Stein RJ, Kaouk JH. Single-port urological surgery: single-center experience with the first 100 cases. Urology. 2009;74(4):801–4.

Won Lee J, Arkoncel FR, Rha KH, Choi KH, Yu HS, Chae Y, et al. Urologic robot-assisted laparoendoscopic single-site surgery using a homemade single-port device: a single-center experience of 68 cases. J Endourol. 2011;25(9):1481–5.

Yang C, Jones L, Rivera ME, Verlee GT, Deane LA. Robotic-assisted ureteral reimplantation with Boari flap and psoas hitch: a single-institution experience. J Laparoendosc Adv Surg Tech A. 2011;21(9):829–33.

Yang CK, Chung SD, Hung SF, Wu WC, Ou YC, Huang CY, et al. Robot-assisted nephroureterectomy for upper tract urothelial carcinoma: the Taiwan Robot Urological Surgery Team (TRUST) experience. World J Surg Oncol. 2014;12:219.

Zargar H, Krishnan J, Autorino R, Akca O, Brandao LF, Laydner H, et al. Robotic nephroureterectomy: a simplified approach requiring no patient repositioning or robot redocking. Eur Urol. 2014;66(4):769–77.

# 20 Laparoscopic Living Donor Nephrectomy

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**Abstract**

Laparoscopic donor nephrectomy was first introduced by Ratner et al. in 1995 and has since evolved into the preferred approach for procuring kidneys from living donors. Since it was first reported, the technique has evolved and many modifications have been done to improve donor safety and recipient outcome showing superior results in terms of postoperative pain, cosmetics, convalescence, and return to normal daily activities. A multidisciplinary team evaluates/screens all donors physically and psychologically. As part of the preoperative workup, CT angiography is performed in order to accurately assess the donor's genitourinary tract prior to donor nephrectomy. It will help identify vascular issues such as early prehilar branches or short renal vessels which may aid the urologist in deciding if the donor will be a suitable candidate for donation. Kidney size and vasculature will decide which side to harvest. Left sided laparoscopic kidney donation has been more preferable compared to right sided donation—due to the significantly greater length offered by the left renal vein. This facilitates an easier venous anastomosis in the recipient which potentially decreases recipient operative time and venous anastomotic complication rates, such as venous thrombosis. However, a minority of surgeons have reported that right sided laparoscopic donor nephrectomy is easier to perform because of the lack of side branches of the right renal vein and the decreased risk of splenic laceration. Both approaches are discussed within this chapter. Postoperative management and complications are discussed as well.

**Keywords**

Laparoscopic donor nephrectomy · Transperitoneal donor nephrectomy

## 20.1 Introduction

The number of patients with end-stage renal disease have increased through the years but unfortunately, the living and cadeveric donor pool haven't increased at the same rate. Living donors are difficult to come by primarily due to the increased analgesic requirement and prolonged recuperation. Minimally invasive techniques have been developed through the years to help increase this living donor pool.

Laparoscopic donor nephrectomy (LDN) was first introduced by Ratner et al. in 1995 and has since evolved into the preferred approach for procuring kidneys from living donors (Ratner et al. 1995). Live donor nephrectomy is a unique surgical challenge due to the fact that the donors are healthy individuals—thus it is important to maintain the complication rates of live donors as low as possible.

In contrast, open donor nephrectomy (ODN) is associated with significant thoracoabdominal wall trauma, a long flank incision, longer hospital stay or recovery period and more pain. To decrease the morbidity associated with open kidney retrieval, minimally invasive surgical techniques like mini-incision donor nephrectomy and LDN have been developed. Since it was first reported in 1995, the technique of LDN has evolved and many modifications have been done to improve donor safety and recipient outcome showing superior results in terms of postoperative pain, cosmetics, convalescence, and return to normal daily activities. Due to this minimally invasive approach, the number of willing live kidney donors has been noted to increase. In a study by Chung et al., the main reason for choosing LDN over ODN was the earlier return to work (54%), followed by less postoperative pain (33%) (Chung et al. 2007).

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## 20.2 Patient Selection and Preparation and Preoperative Considerations

### 20.2.1 Patient Selection and Preparation

Patient screening and evaluation is done in order to ensure that donor nephrectomy will not significantly compromise renal function. In every transplant center, a multidisciplinary team is created in order to evaluate all donors physically and psychologically. Since the pool of living donors have expanded to include patients of advancing age as well as those with previous malignancies, more specialties have been added to the multidisciplinary team (Shah and Schwartz 2017).

CT angiography is performed in order to accurately assess the donor's genitourinary tract prior to donor nephrectomy. It will help identify vascular issues such as early prehilar branches or short renal vessels which may aid the urologist in deciding if the donor will be a suitable candidate for donation (Shah and Schwartz 2017).

Renal function assessment with radionuclide glomerular filtration rate scans may not be an absolute indication in all candidates for kidney donation. Kidney size and vasculature play a more important role in deciding which side to harvest (Shah and Schwartz 2017).

### 20.2.2 Laterality

Left sided laparoscopic kidney donation has been more preferable compared to right sided donation. The main reason for this has been the significantly greater length offered by the left renal vein compared to the short right renal vein. The longer length of the left vein facilitates an easier venous anastomosis in the recipient which potentially decreases recipient operative time and venous anastomotic complication rates, such as venous thrombosis (Mandal et al. 2001; Ratner et al. 1998). Indeed, several reports documented increased frequencies of graft loss, vascular (venous) complications requiring back-table reconstruction, and delayed graft function (DGF) in right kidneys procured laparoscopically (Mandal et al. 2001; Ratner et al. 1998).

However, a minority of surgeons have reported that right sided LDN is easier to perform because of the lack of side branches of the right renal vein and the decreased risk of splenic laceration (Lind et al. 2002).

A single-center randomized controlled trial revealed no differences between left- and right-sided donor nephrectomy in terms of—hospital stay, quality of life, donor and recipient complication rates, or graft survival (Minnee et al. 2008a). Even with these data showing comparable results for left- and right- sided LDN, left kidneys are preferentially chosen if the renal vasculature and function are comparable.

### 20.2.3 Vascular Anomalies

Multiple renal arteries are found in 12–33% of individuals (Roza et al. 1989). Earlier studies have shown an association of increased incidence of vascular (thrombosis) and urologic complications (ureteral ischemia) with implantation of kidneys' with multiple arteries (Guerra et al. 1992). However, more recent reports state that renal transplantation can be performed safely in case of multiple arteries (Kok et al. 2008; Li-El-Dein et al. 2003; Minnee et al. 2008b). There is no clinically demonstrated negative effect on kidney function if the warm ischemia time is less than 10 min, which is the case in almost all laparoscopic series including those with multiple vessels (Simforoosh et al. 2006).

The inferior pole accessory renal arteries often provide substantial blood supply to the renal pelvis and ureter, thus special care should be taken to preserve it otherwise urological complications may arise (urinoma, stricture formation).

Multiple renal veins are found in 5–10% (Belzer et al. 1972). Most small caliber accessory renal veins can safely be ligated, however care should be taken to preserve/handle such veins since occasionally reconstruction to gain length of a short right renal vein or repair of a damaged vein causes additional venous reconstruction necessary.

It can be concluded that regardless of which technique (open or laparoscopic) used, multiple vessels are not a contraindication.

### 20.2.4 Obesity

With the worldwide increasing trend of obesity, there is likewise an increasing pool of obese donors. Obesity is recognized as an independent cardiovascular risk factor and has been recently recognized as an independent risk factor for end stage renal disease (Hsu et al. 2006).

In a retrospective study of 73 patients, Praga et al. reported that 13 out of 14 (92%) obese donors (BMI >30) developed proteinuria and renal impairment after a mean follow-up of 10 years compared with 12% of non-obese donors (Praga et al. 2000). A study by Kuo et al. comparing donors undergoing laparoscopic nephrectomy and with a body mass index of >31 or <31 kg/m$^2$ (obesity being defined as a body mass index of ≥30) showed no significant difference in perioperative morbidity or technical difficulty (Kuo et al. 2000).

Careful preoperative evaluation to exclude cardiovascular, respiratory and renal disease should be done for obese patients. They should be counseled regarding the increased perioperative risk and potential long-term risk of renal disease and advised to lose weight prior to donation and encouraged to adopt a healthy lifestyle.

### 20.2.5 Contraindications

The absolute contraindications to living laparoscopic donor nephrectomy are uncorrected coagulopathy, medical renal disease and an active infection.

There are several relative contraindications. Previous abdominal surgery resulting in dense adhesions is a relative contraindication to LDN. However, surgeon's expertise plays a big factor in the success of the procedure. Other contraindications to kidney donation per se such as a history of renal stone disease or other medical comorbidities that may affect long-term renal function; the presence of any communicable disease; and deficiency in mental status remain to be contraindications to the laparoscopic procedure as well.

## 20.3 Patient Preparation and Positioning

A Foley catheter and a nasogastric tube (NGT) are placed right before the procedure. The catheter allows for accurate urine output monitoring. Oliguria is a known sequelae of any laparoscopic procedure. Adequate hydration is necessary to prevent a significant decrease in the renal blood flow intraoperatively. An NGT allows complete decompression of the stomach which may obscure the superior pole of the left kidney during dissection. It also functions as an indicator in case there is inadvertent gastric injury during the mobilization of the splenic flexure. The extraction site (Pfannenstiel incision) is marked prior to positioning the patient in the lateral decubitus position so as to maintain wound symmetry. Sequential compression devices are applied for deep venous thrombosis prophylaxis.

The patient is then placed on a full flank position with the kidney donor side elevated (Fig. 20.1). Gel rolls/sand bags are placed on the patient's back to maintain this position (Fig. 20.2). An axillary roll is placed to prevent any neural compression. The dependent arm is extended perpendicularly on an arm board for easy accessibility as needed by the anesthesiologist. The contralateral arm is similarly placed in a well-cushioned arm board positioned above the dependent arm. To prevent brachial plexus injury, arm extension should be limited to 90° or less. The dependent leg is flexed at the knee and hip with the contralateral leg left extended with a pillow placed in between. All bony protuberances should be adequately padded. The patient is then secured to the bed with padded wide tape along the chest and hip.

**Fig. 20.1** Patient positioning during left laparoscopic donor nephrectomy

**Fig. 20.2** Gel rolls applied on the patient's back to maintain/support position

### 20.3.1 Trocar Placement

The initial/camera port (11 mm) is placed over the left paramedian line approximately two fingerbreadths superior and lateral of the umbilicus via the open method (Hasson technique) (Fig. 20.3). The abdomen is then insufflated at 12–15 mmHg. Two additional trocars are then added under

**Fig. 20.3** Trocar placement

direct visualization—a 10–12 mm port midway between the anterior superior iliac spine and the umbilicus; and a 5 mm subcostal port along the midclavicular line.

## 20.4 Transperitoneal Left Laparoscopic Donor Nephrectomy

### 20.4.1 Colon Mobilization

Colon mobilization is facilitated by incising the white line of Toldt—the peritoneal lining 1 cm lateral to the descending colon is incised with monopolar cautery shears. The surgeon should be using a blunt-tipped grasper for traction while the other hand uses the monopolar shears for sharp/blunt dissection. The avascular plane between the mesentery and Gerota's fascia is then developed by blunt and sharp dissection. A helpful tip to differentiate the two planes is to note the more yellowish hue of the mesenteric fat compared to that of the Gerota's fascia (Fig. 20.4). The descending colon should be retracted medially so as to facilitate identification and proper dissection of this avascular plane. Dissection should be carried out cephalad towards the splenorenal ligament and caudad to expose the ureter down to the level of the common iliac vessels. Caution should be advised to avoid dissecting too laterally (posterolateral portion of the kidney) to prevent the kidney from falling down medially.

### 20.4.2 Upper Pole Dissection

To expose the upper pole of the kidney, the splenorenal ligament is divided using Harmonic scalpel or LigaSure. This step will also cause the spleen and pancreas to fall, exposing the medial aspect of the kidney.

### 20.4.3 Renal Hilum Dissection

To facilitate exposure of the renal hilum, adequate mobilization of the colon, spleen and pancreas should be done. If visualization of the hilum is still not sufficient such as in cases of dilated bowels, a paddle retractor may be used through a trocar from the Pfannenstiel incision.

The left gonadal vein and ureter are then identified. The fascia overlying the gonadal vein is incised; the gonadal vein and ureter are then dissected together away from the psoas muscle. Gentle upward traction is applied on the gonadal vein as the dissection is carried out cephalad towards the renal vein—doing so will develop the plane between the posterior portion of the kidney and the underlying psoas muscle (Fig. 20.5). Applying anterior traction on the posterior portion of the kidney will greatly facilitate exposure and dissection of the hilum. The gonadal vein, lumbar vein and adrenal vein are then identified, ligated with 10-mm titanium clips and divided. The renal vein is further skeletonized to ensure adequate length for transplantation.

### 20.4.4 Adrenal Gland Dissection

The Gerota's fascia just above the renal vein is incised and carried down to the renal capsule. The dissection is carried out superiorly where the plane between the adrenal gland and the upper pole of the left kidney is then developed. The adrenal gland can be readily identified by its golden yellow color. The adrenal is separated from the kidney by slight lateral traction on the fat around the upper pole of the kidney and dissection is performed with use of a Harmonic scalpel or LigaSure for adequate hemostasis (Fig. 20.6). The surgeon should watch out for aberrant arterial branches to the upper pole which are usually encountered during this dissection.

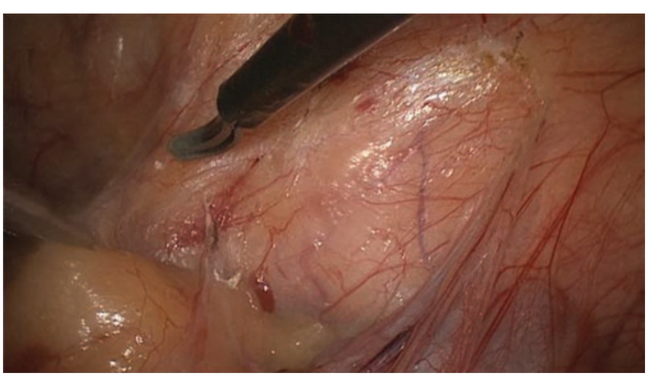

**Fig. 20.4** The more yellowish hue of the mesenteric fat is noted on the right lateral edge of the picture

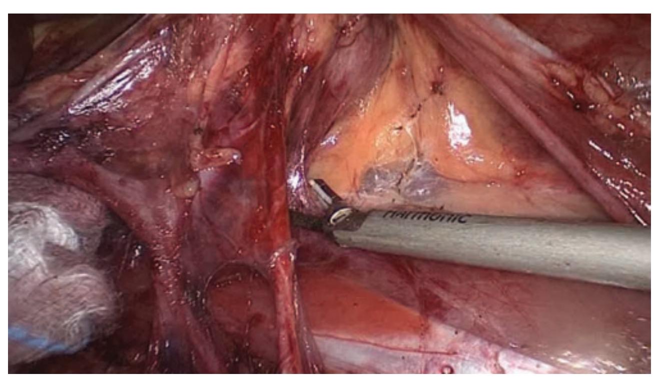

**Fig. 20.5** Developing the plane between the posterior portion of the kidney and underlying psoas muscle while upward traction is applied on the gonadal vein and ureter

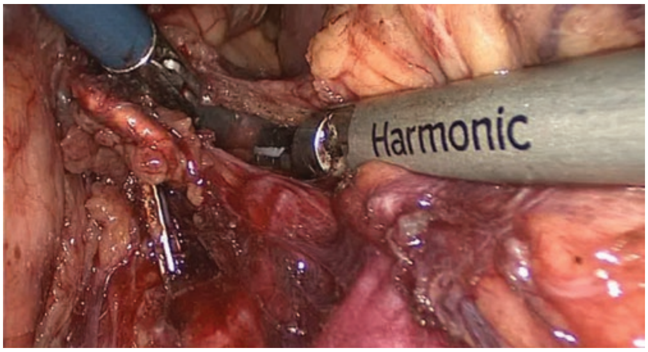


**Fig. 20.6** Adrenal dissection using harmonic scalpel

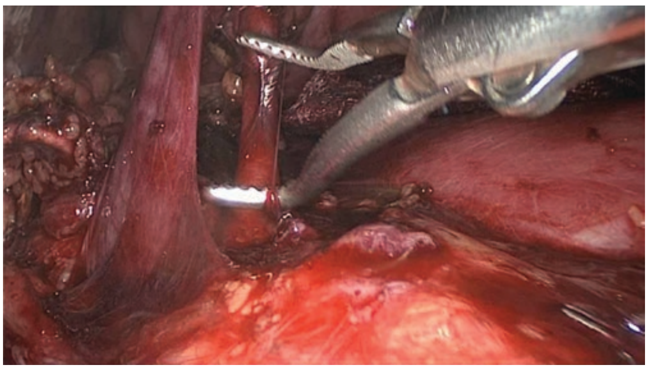

**Fig. 20.7** Renal artery dissection

### 20.4.5 Renal Artery Dissection

The renal artery can be identified behind the renal vein. Dissection can be facilitated with the use of a suction device or a right angle dissector (Fig. 20.7). The artery should be dissected as close to its origin at the aorta as possible. Additional arterial branches should be preserved and likewise skeletonized to preserve length. Avoid unnecessary manipulation of the renal artery to avoid vasospasm.

### 20.4.6 Ureteral Dissection

Care should be taken during dissection of the ureter in order to preserve its blood supply. As the ureter is dissected at its distal limit at the level of the iliac crossing, the ureter should be dissected with a generous amount of periureteral fatty tissue remaining.

### 20.4.7 Lateral Dissection

A window is created above the lateral border of the distal ureter, a suction device is inserted into the window to provide medial traction while the lateral attachments of the ureter and kidney are successively divided by use of a Harmonic scalpel or LigaSure towards the upper pole of the kidney. A small amount of tissue may be retained on the lateral aspect of the superior pole to prevent the kidney from falling medially which may cause kinking of the renal hilum and subsequent reduction in renal blood flow.

### 20.4.8 Preparation of Extraction Site

The marked Pfannenstiel site is incised and carried down to the rectus fascia which is opened transversely. The rectus fascia is dissected away from the underlying muscle superiorly towards the umbilicus and inferiorly towards the pubic bone to create more space for easier extraction of the kidney. The linea alba of the rectus muscle is divided and the muscle bellies are retracted laterally to expose the underlying peritoneum which is left intact until delivery of the kidney. A 11 mm trocar may be inserted to allow for additional retraction if necessary. The extraction site is then packed with wet gauze.

### 20.4.9 Ureteral and Hilar Ligation

Once the transplant team is ready to receive the kidney, the ureter, renal artery and vein are sequentially ligated and divided. The ureter is ligated at the level of the common iliac vessel bifurcation using 10 mm titanium clips. Ligation of the ureter may be performed through the Pfannenstiel port for easier access. Placement of a blunt forceps or suction device in between the skeletonized artery and vein provides excellent exposure of the renal hilum. The renal artery is ligated using a combination of two locking plastic clips (Hem-o-lok) and a metal clip, and divided to ensure an adequate cuff of 1–2 mm on the clipped stump (Fig. 20.8). Alternatively, an endovascular stapling device or three titanium clips may be used. There have been reports of bleeding complications associated with the use of Hem-o-lok clips. However, in our personal experience, there have been no such incidences of

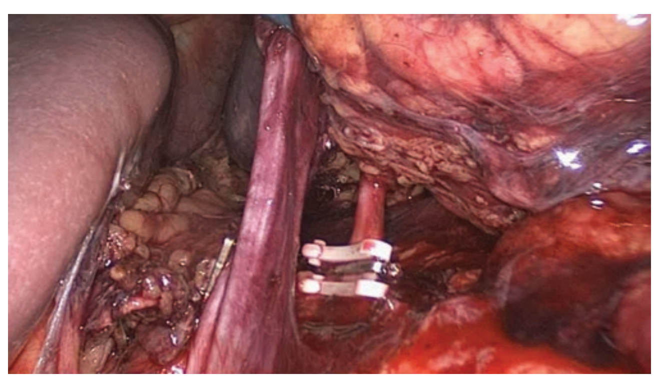

**Fig. 20.8** Ligation of renal artery using Hem-o-lok and metal clips

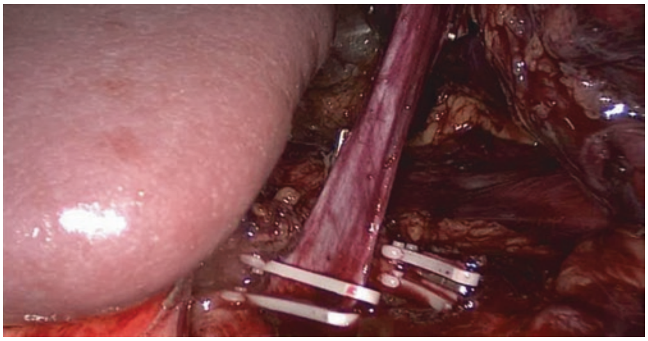

**Fig. 20.9** Ligation of renal vein using Hem-o-lok clips

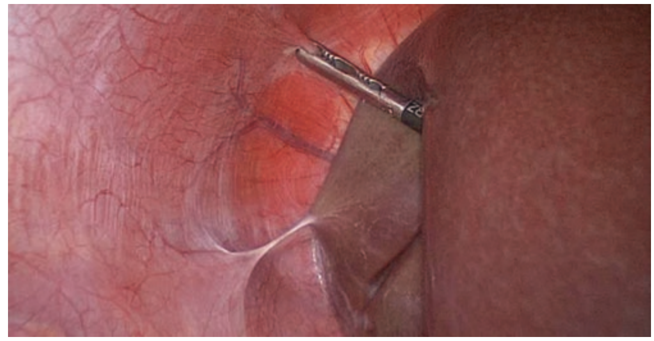

**Fig. 20.10** Liver retraction by using an additional subxiphoid trocar with a locking grasper attached to the peritoneal reflection

bleeding complications in almost 1000 of cases performed at our institution. The renal vein is then ligated with two locking plastic clips (Hem-o-lok) or with an endovascular stapling device (Fig. 20.9). Maintaining anterior traction on the kidney during ligation of the vessels ensures maximal length.

## 20.5 Kidney Extraction

The kidney is extracted through the Pfannenstiel incision, and flushed with preservation fluid and stored on ice. Extraction of the kidney can be performed directly through the incision with the surgeon's hand or by using a special endoscopic specimen retrieval bag.

### 20.5.1 Closure

The rectus fascia is closed and pneumoperitoneum re-established, allowing inspection for hemostasis. Closure of the peritoneum or rectus muscle bellies is at the preference of the surgeon. Careful inspection and hemostasis at area of the hilar/ureteral stumps, adrenal gland and spleen should be done under low insufflation pressure (6–7 mmHg). Higher pressures may tamponade small but persistent venous bleeding. Trocar sites 10 mm or larger are closed at the level of the fascia with either a suture passing device or externally placed sutures to prevent incisional hernia. Pneumoperitoneum is evacuated, and the trocar and Pfannenstiel incisions are closed.

## 20.6 Transperitoneal Right Laparoscopic Donor Nephrectomy

Trocar placement is similar to that of left sided laparoscopic donor nephrectomy except that usually an additional subxiphoid 5-mm trocar is used for liver retraction. A locking grasper is used to bypass the inferior liver edge and grasp the peritoneal reflection laterally thereby achieving liver retraction Fig. 20.10).

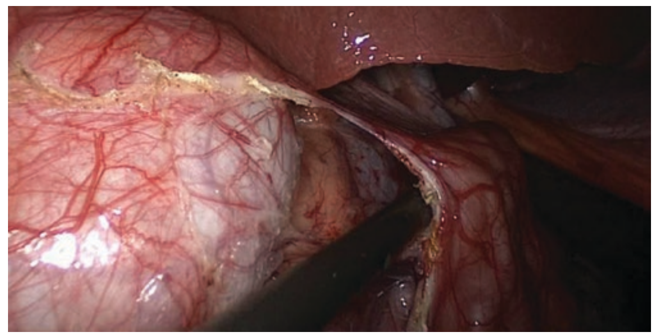

**Fig. 20.11** The duodenum is dissected away from the kidney

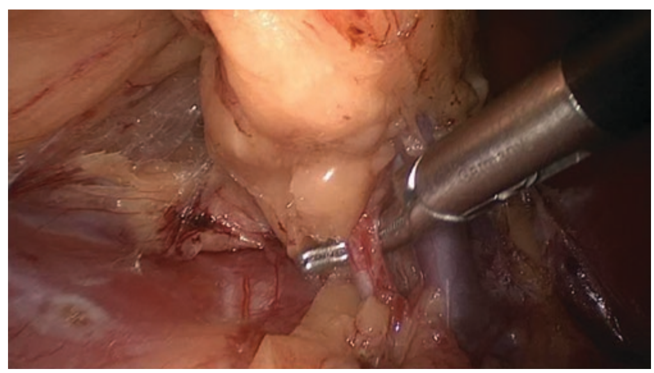

**Fig. 20.12** Right renal hilum dissection

The same surgical steps are used for that of right sided laparoscopic donor nephrectomy with some supplementary concerns. Exposure of the renal hilum requires mobilization of the duodenum (Fig. 20.11). Sharp dissection should be used to release the lateral attachments of the duodenum; use of electrocautery should be avoided to decrease the risk of bowel injury. Once the lateral attachments are released, the duodenum can be bluntly dissected downwards to expose the vena cava and renal artery.

As mentioned earlier, there are concerns regarding the shorter renal vein on the right. As such, the renal vein is skeletonized and dissected down to the vena cava to maximize length (Fig. 20.12). Care should be practiced in using an endovascular stapling device to ligate the right renal artery in the interaortocaval space. Using a stapler in this space may cause significant shear force on the artery resulting in hemorrhage due to the proximity of the device tip against the vertebral body. Alternatively, three 10 mm titanium clips or two Hem-o-lok clips can be used to safely ligate the right renal artery.

## 20.7 Post-operative Management

### 20.7.1 Diet

Immediately after surgery, the patient may be started on general liquids. If this is tolerated within the day, the patient may be progressed to soft diet. On the first post-operative day, the patient may be started on a regular diet if he tolerates soft diet and has passed flatus. Intravenous fluids may be discontinued on the first or second post-operative day once the patient tolerates soft diet.

### 20.7.2 Management of Foley Catheter

The Foley catheter inserted prior to the procedure is maintained in order to monitor the patients initial urine output. If the patient produces adequate urine output, the catheter may be removed on the first post-operative day. This will allow the patient to ambulate freely without a catheter.

### 20.7.3 Pain Control

Pain requirements are less for patients who undergo LDN compared to the open procedure. Oral pain medications may be started on the first or second post-operative day. Most patients tolerate ambulation by the second post-operative day.

### 20.7.4 Activity

Patients who undergo LDN are often required to get out of bed and ambulate by the first post-operative day. This is one of the biggest advantages of LDN is good pain control. Since pain is minimal, these patients must be encouraged to ambulate early in order to avoid post-operative complications such as ileus and pneumonia.

### 20.7.5 DVT Prophylaxis

Patients are maintained on compressive stockings during the procedure and continued until patient is ambulatory. Patients are encouraged to start ambulation soon after the procedure to prevent DVT and other early complications such as ileus and respiratory issues.

### 20.7.6 Antibiotic Coverage

Aside from the dose of antibiotics given prior to surgery, no subsequent antibiotics are required for patients who undergo LDN.

### 20.7.7 Discharge

Patients undergoing LDN are often discharged on the first or second post-operative day once soft diet is tolerated and flatus is passed. By this time, the patient's pain is adequately controlled with oral pain relievers. Oftentimes, patients haven't had bowel movement by the day of discharge. They are assured that this shouldn't be a concern and that bowel movement will come thereafter.

## 20.8 Complications

### 20.8.1 Intraoperative Complications

Numerous intraoperative complications have been identified in laparoscopic procedures. Bleeding is the most common complication that has been reported. Bleeding may occur in every step of LDN—from trocar insertion to dissection of the renal hilum. Extensive dissection of the kidney and renal hilum is needed in order to maximize the length of the renal vessels as well as to avoid inadvertent vascular injuries that may compromise subsequent renal function. Dissection is carried out very close to the aorta, vena cava and other vascular structures increasing the risk for bleeding.

Bowel injury is another potential complication of any laparoscopic procedure. This may occur upon insertion of the initial trocar and well as the subsequent ports. Throughout the procedure, bowel injury may occur as well. Mobilization of the colon is performed in order to access the kidney and renal hilum. During this part of the procedure, injury to the colon may occur. Adequate bowel preparation may help reduce the size and distention of the bowels. This facilitates mobilization of the colon during dissection and may also help prevent bowel injury.

One complication unique to LDN is the inadvertent injury to the renal hilum and its branches. Such injuries may compromise the resultant function of the donated kidney. Extreme caution is taken during the dissection of the renal hilum. A generous amount of perihilar fat is maintained in order to avoid injury to segmental vessels. CT renal angiography may help identify prehilar vessels prior to surgery.

### 20.8.2 Early Complications

Bleeding remains to be one of the more common early complications of LDN. It is important to make sure that there is good hemostasis prior to closure. Common areas where bleeding may be noted are: the adrenal gland, the area near the stumps of the renal vessels, and the stump of the gonadal vein and distal ureter. Decreasing the intraabdominal pressure to 6–7 mmHg and asking the anesthesiologist to do a valsalva maneuver helps identify potential bleeding sites. Drains are not commonly placed in LDN however, if significant bleeding occurs, it may be prudent to maintain a Jackson-Pratt drain for a day or two to monitor for any recurrence of bleeding and to evacuate the blood that may collect on the contralateral gutter.

Ileus is another potential early complication of LDN especially in the transperitoneal approach. Early ambulation and deep breathing exercises may help the patient regain bowel function. Delayed bowel injuries are rare but may occur. Usually this is result of thermal injury from hemostatic devices or shears. Patients may present with fever, leucocytosis and delayed recuperation. Abdominal examination may be equivocal. Suspicion is the key to early diagnosis.

Early respiratory complications include atelectasis and pneumonia. Deep breathing exercises with an incentive spirometer and early ambulation may help prevent these complications.

### 20.8.3 Late Complications

Certain late complications may occur as a result of accumulation of retained blood or lymph within the peritoneal cavity. Retained accumulation of fluids in the abdominal cavity may lead to the formation of an intraabdominal abscess or a lymphocoele. Percutaneous drainage of this collection usually results in complete resolution.

Note: all photos incorporated in this chapter were taken with the consent of our patient and with full disclosure of the intent to publish.

## References

Belzer FO, Schweizer RT, Kountz SL. Management of multiple vessels in renal transplantation. Transplant Proc. 1972;4(4):639–44.

Chung E, Grant ABF, Hibberd AD, et al. Why potential live renal donors prefer laparoscopic nephrectomy: a survey of live donor attitudes. BJU Int. 2007;100:1344–6. https://doi.org/10.1111/j.1464-410X.2007.07126.x.

Guerra EE, Didone EC, Zanotelli ML, et al. Renal transplants with multiple arteries. Transplant Proc. 1992;24(5):1868.

Hsu CY, McCulloch CE, Iribarren C, et al. Body mass index and risk for end-stage renal disease. Ann Intern Med. 2006;144(1):21–8.

Kok NF, Dols LF, Hunink MG, et al. Complex vascular anatomy in live kidney donation: imaging and consequences for clinical outcome. Transplantation. 2008;85(12):1760–5.

Kuo PC, Plotkin JS, Stevens S, et al. Outcomes of laparoscopic donor nephrectomy in obese patients. Transplantation (Baltimore). 2000;69:180–2.

Li-El-Dein B, Osman Y, Shokeir AA, et al. Multiple arteries in live donor renal transplantation: surgical aspects and outcomes. J Urol. 2003;169(6):2013–7. 40.

Lind MY, et al. Right-sided laparoscopic live-donor nephrectomy: is reluctance still justified? Transplantation. 2002;74(7):1045–8.

Mandal AK, Cohen C, Montgomery RA, et al. Should the indications for laparoscopic live donor nephrectomy of the right kidney be the same as for the open procedure? Anomalous left renal vasculature is not a contraindication to laparoscopic left donor nephrectomy. Transplantation. 2001;71(5):660–4.

Minnee RC, Bernelman WA, Maartense S, et al. Left or right kidney in hand-assisted donor nephrectomy? A randomized controlled trial. Transplantation. 2008a;85(2):203–8.

Minnee RC, Surachno S, Bemelman F, et al. Impact of additional vascular reconstructions on survival of kidney transplants. Int Surg. 2008b;93(2):111–5.

Praga M, Hernandez E, Herrero JC, et al. Influence of obesity on the appearance of proteinuria and renal insufficiency after unilateral nephrectomy. Kidney Int. 2000;58(5):2111–8.

Ratner LE, Ciseck LJ, Moore RG, et al. Laparoscopic live donor nephrectomy. Transplantation. 1995;60(9):1047–9.

Ratner LE, Kavoussi LR, Chavin KD, et al. Laparoscopic live donor nephrectomy: technical considerations and allograft vascular length. Transplantation. 1998;65(12):1657–8.

Roza AM, Perloff LJ, Naji A, et al. Living-related donors with bilateral multiple renal arteries. A twenty-year experience. Transplantation. 1989;47(2):397–9.

Shah PH, Schwartz MJ. Laparoscopic live donor nephrectomy. In: Bishoff JT, Kavoussi LR, editors. Atlas of laparoscopic and robotic urologic surgery. Philadelphia: Elsevier; 2017. p. 143–51.

Simforoosh N, Basiri A, Shakhssalim N, et al. Effect of warm ischemia on graft outcome in laparoscopic donor nephrectomy. J Endourol. 2006;20(11):895–8.

# 21 Robotic Pyeloplasty

Ill Young Seo

**Abstract**

Pyeloplasty is one of the most effective treatments for ureteropelvic junction obstruction (UPJO). Laparoscopic pyeloplasty has been performed as a less invasive surgery, and its success rates are similar to those of open surgery. Long-term follow-up results also indicate that laparoscopic pyeloplasty is one of the standard treatment for UPJO. However, intracorporeal suture has remained a technical weakness. The da Vinci surgical robot system can address this difficulty. The first case of robot-assisted laparoscopic pyeloplasty was performed in 2000. After that, number of surgeries has been gradually increasing. The robot allows the surgeon to overcome the technical difficulties with intracorporeal suturing, which is the rate-limiting step in laparoscopic surgery. However, there are a few relevant papers for the robotic pyeloplasty, and the number of patients is small. If the number of the robotic pyeloplasty increases and a lot of related papers are published, the safety and effectiveness of the operation will be proven, and it will be the standard treatment for UPJO.

**Keywords**

Ureteropelvic junction obstruction · Robotics · Pyeloplasty

## 21.1 Background: Surgical Treatment for UPJO

Ureteropelvic junction obstruction (UPJO) is defined as an anatomic or functional impedance of urinary flow from the renal pelvis into the upper ureter. The obstruction is caused by a congenital intrinsic narrowing of the lumen or by external compression. UPJO is the most common congenital anomaly of the urinary tract. Approximately 1 in 20,000 live births present with UPJO (Tripp and Homsy 1995). Various reconstructive procedures have been described for the management of UPJO, and three kinds of methods have generally been introduced.

Open pyeloplasty has traditionally been the gold standard for UPJO. It has a high success rate of 90–100% and extensive indications (Notley and Beaugie 1973; Persky et al. 1977). It also shows excellent results in long-term follow-up study (O'Reilly et al. 2001). However, it has significant operative morbidities and prolonged recovery times (Brooks et al. 1995). These shortcomings necessitated a new surgical procedure with minimal invasiveness. Initially endopyelotomy was reported in the early 1900s, and the concept of Davis intubated ureterotomy was applied (Davis 1947). The procedure has evolved rapidly over the past three decades with the advent of minimally invasive treatments for UPJO, compared with standard open pyeloplasty. Cold-knife, electrocautery, and holmium laser incision are used to incise the obstruction, and a ureteral cutting balloon (Acucise, Applied Medical Resources, Laguna Hills, CA, USA) is also used (Nakada and Johnson 2000; McClinton et al. 1993). However, the indication is limited and the success rate does not exceed 80%, which is mainly determined by surgeon's experience and causes of UPJO (Bernardo and Smith 1999; Gerber and Kim 2000; Meretyk et al. 1992). It also has increased risk for perioperative hemorrhage (Cassis et al. 1991; Motola et al. 1993).

Laparoscopic pyeloplasty was first performed in 1993 (Schuessler et al. 1993; Kavoussi and Peters 1993). It was introduced for the minimal invasive treatment of UPJO to decrease operative morbidity like endourological management and keep the high success rate like open pyeloplasty (Inagaki et al. 2005; Siqueira et al. 2002). Its rate of use has increased dramatically to overtake open pyeloplasty, and it is now considered a standard treatment for UPJO. However, it is still hampered by technical difficulties and long operative time, demanding a steep learning

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curve. Especially because of the need for skill and proficiency with intracorporeal suturing, it remains technically challenging operation and limited widespread use (Jarrett et al. 2002; Seo et al. 2014; Yanke et al. 2008; Rassweiler et al. 2008). And it also lacks of long-term operative results.

## 21.2 Robotic Pyeloplasty (Robot-Assisted Laparoscopic Pyeloplasty)

### 21.2.1 Technical Aspects

The da Vinci surgical robot system (Intuitive Surgical, Sunnyvale, CA) has made these laparoscopic techniques easier to be performed with greater ease and, in the process, has expanded the use of laparoscopy in urologic practice. The robot has several advantages to improve operative techniques, including greater precision from tremor control, 1:5 motion scaling, and three-dimensional visualization, improved dexterity and increased range of motion from 6-degree of freedom. For this reason, the robot has an excellent advantage in suture. Passerotti et al. evaluated the advantage and effectiveness of the robot system in suturing, compared with open and conventional laparoscopic techniques in a swine model (Passerotti et al. 2009). This study showed that even inexperienced surgeons could perform high quality anastomosis with short learning curves using robot assistance when compared with pure laparoscopic approach. Therefore the robot allows the surgeon easy to overcome technical difficulties with intracorporeal suturing in pyeloplasty, which is the rate-limiting step in laparoscopic pyeloplasty (Erdeljan et al. 2010). And the robot provides good view of the surgical field to find aberrant blood vessels and narrowed portion of the ureteroplevic junction. These advantages have led to shorter operative times with similar or better success rates when compared with the standard laparoscopic approach (Gettman et al. 2002a; Weise and Winfield 2006; Link et al. 2006). As a whole, the robot has benefits similar to laparoscopic approach, such as advantages of a minimally invasive approach, such as smaller incisions, less pain, and less blood loss (Babbar and Hemal 2011).

The da Vinci robot was adopted to pyeloplasty from 2001 after getting approval of the Food and Drug Administration (FDA) of the United States (Gettman et al. 2002b; Palese et al. 2005). Since then, it has been carried out a lot and its experience has increased. However it might has drawback of increase in costs. There are a few papers and presentations for robotic pyeloplasty, most of which are just small series, and lack of long-term results should be carefully evaluated.

### 21.2.2 Outcomes

For the first time, Gettman et al. reported robot-assisted laparoscopic pyeloplasty series in 2002 (Gettman et al. 2002b). They operated nine patients with UPJO using the da Vinci robot. The mean operative time of the Anderson-Hynes dismembered pyeloplasty was 138.8 min, and the mean suturing time was 62.4 min. There was no intraoperative complications or open conversions. The estimated blood loss was less than 50 mL in all cases. The mean length of hospitalization was 4.7 days. Postoperatively, one patient required open exploration to repair a defect in the renal pelvis. At a mean follow-up of 4.1 months, all procedures were successful on the basis of the subjective and radiographic data. Palese et al. reviewed their 38 cases of robotic dismembered pyeloplasty (Palese et al. 2005). The mean operative time and suturing time were 225.6 min and 64.2 min. The average estimated blood loss was minimal at 77.3 mL. The mean length of hospitalization was 69.6 h. There was no intraoperative complications and open conversion. A mean follow-up of 12.2 months revealed a success rate of 94.7%. Kim et al. also presented their initial experience (Kim et al. 2009). For five cases of robotic pyeloplasty, the mean operative time was 276 min, and the average length of the postoperative hospital stay was 4.2 days. There were no intraoperative complications or transfusion. The success rate was 80%. These initial reports showed the technical feasibility of robotic pyeloplasty, which were performed as same steps of conventional laparoscopic pyeloplasty.

After the initial reports, several institutes have presented their experiences of robotic pyeloplasty and have shown expecting and promising results with outcomes comparable with open and laparoscopic approaches. Studies with large patient cohorts that underwent robotic pyeloplasty are listed in Table 21.1 (Erdeljan et al. 2010; Autorino et al. 2014; Samarasekera and Stein 2014; Schwentner et al. 2007; Mufarrij et al. 2008; Gupta et al. 2009; Etafy et al. 2011; Minnillo et al. 2011; Lucas et al. 2012; Sivaraman et al. 2012; Tobis et al. 2013; Niver et al. 2012; Hopf et al. 2016). In these ten large series, it showed acceptable results: 189.6 min of the mean operation time, 9.0% of complication rate, 2.4 days of hospital stay, and 94.5% of success rate. The success rate was defined with a radiographic patency, which demonstrated persistent obstruction. Major complications included urine leaks, urinoma, and stent migration. However it could not show long-term operative outcomes, because the mean follow-up time was 24.0 months. Anyway, as experience gathers, robotic pyeloplasty has shown good surgical outcomes, and many surgeons have become comfortable surgery (Figs. 21.1 and 21.2).

There have been several studies to investigate the related factors to improve the success rate of the robot pyeloplasty. Lucas et al. presented a retrospective multi-center study to date comparing the two approaches (Lucas et al. 2012). They

**Table 21.1** Outcomes of robotic pyeloplasty from ten large studies

| Study | No. of cases | OP time (min) | Complication (%) | Hospital stay (days) | Follow-up (months) | Success rate (%) |
|---|---|---|---|---|---|---|
| Schwentner et al. (2007) | 92 | 108 | 3.3 | 4.6 | 39.1 | 96.7 |
| Mufarrij et al. (2008) | 140 | 217 | 10 (major 7.1%) | 2.1 | 29 | 95.7 |
| Gupta et al. (2009) | 85 | 121 | 8.2 | 2.5 | 13.6 | 96.5 |
| Erdeljan et al. (2010) | 88 | 167 | 9.1 | 2.5 | 14.1 | 93 |
| Etafy et al. (2011) | 61 | 335 | 11.4 (major: 4.9%) | 2 | 18 | 81 |
| Minnillo et al. (2011) | 155 | 198.5 | 7.7 | 1.9 | 31.7 | 96 |
| Lucas et al. (2012) | 485 | 204 | 5.4 | – | 11 | 96.7 |
| Sivaraman et al. (2012) | 168 | 134.9 | 6.6 | 1.5 | 39 | 97.6 |
| Tobis et al. (2013) | 100 | 192 | 13 (major: 3%) | 2 | 22.8 | 96 |
| Niver et al. (2012) | 97 | 218.7 | 15.5 | 2.5 | 21.9 | 96.1 |

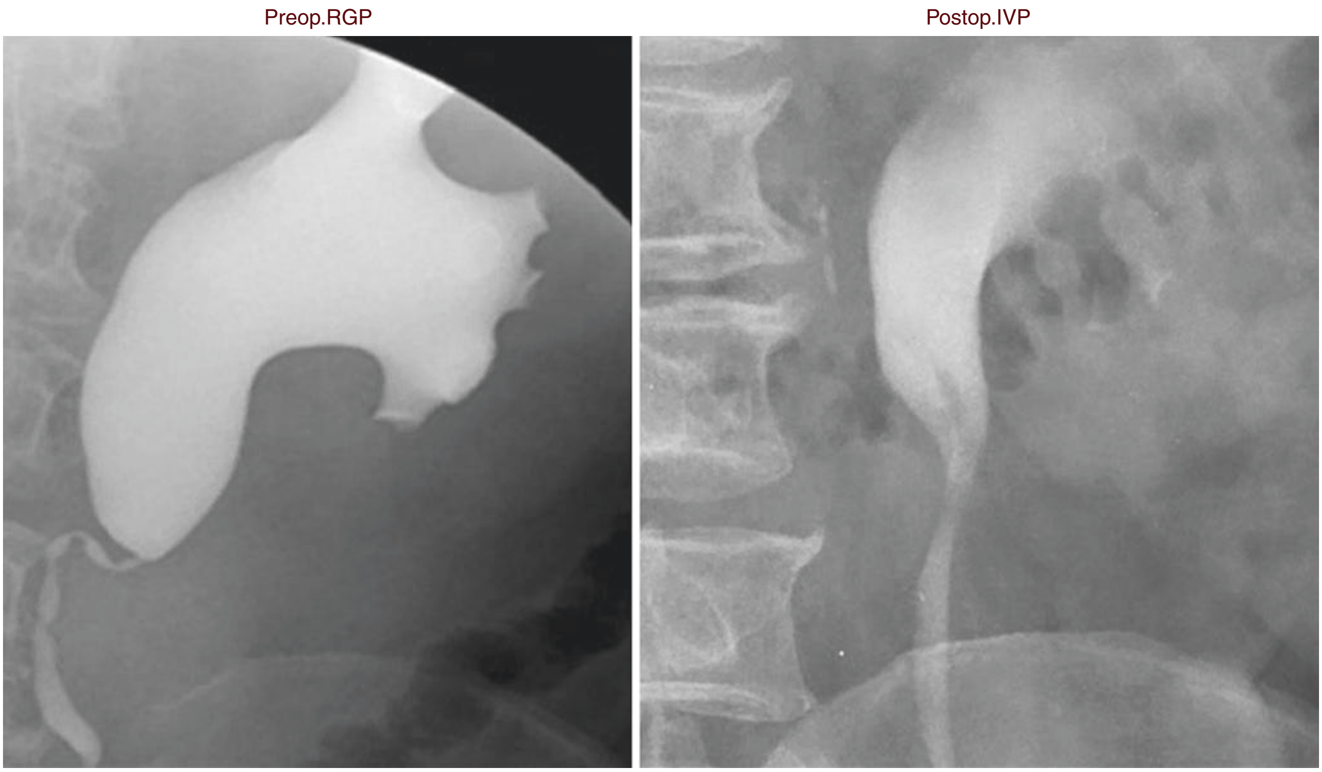


**Fig. 21.1** Pre and postoperative radiologic images. Dilated ureteropelvic junction and spatulated renal pelvis after robotic pyeloplasty on postoperative image

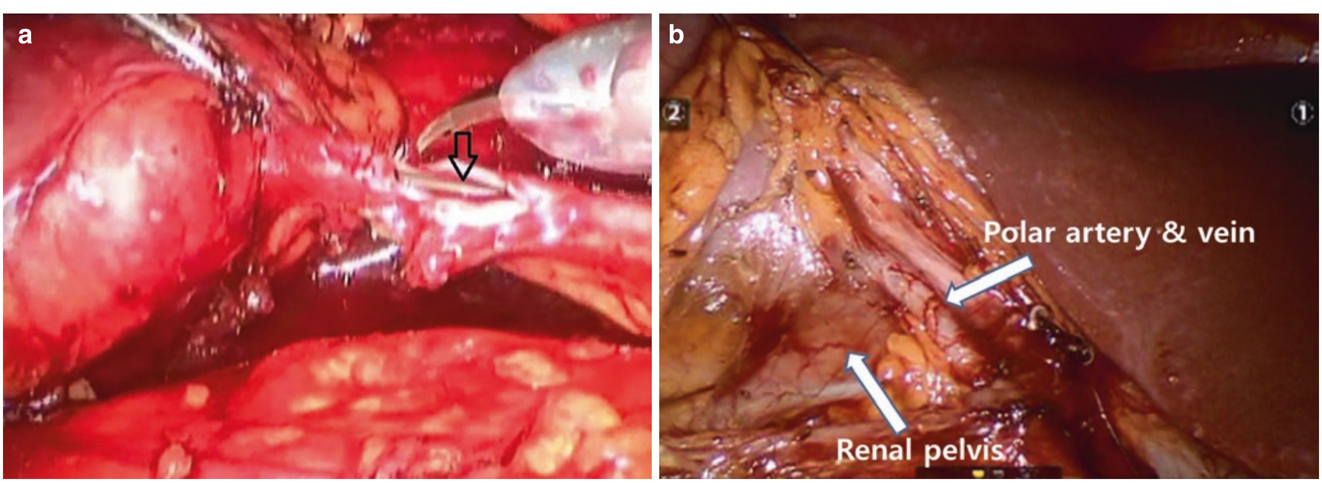


**Fig. 21.2** Operative images. (**a**) Obstructed ureteropelvic junction and a guide wire, preoperatively inserted (arrow). (**b**) Aberrant vessels and dilated renal pelvis (arrows)

included 274 cases of laparoscopic pyeloplasties and 465 cases of robotic pyeloplasties. They suggested that previous endopyelotomy and crossing vessels around UPJ were associated with a decreased freedom from secondary procedures. However, the approach, laparoscopic or robotic, was not significant.

### 21.2.3 Comparative Studies: Robotic Pyeloplasty vs. Laparoscopic Pyeloplasty

There have been a number of comparative analyses comparing the conventional laparoscopic approach, with robotics. However, prospective randomized data comparing laparoscopic and robotic pyeloplasty does not exist, and the most studies are retrospective multi-center studies and a meta-analysis. Braga et al. assessed the impact of robot pyeloplasty over conventional laparoscopic pyeloplasty, focusing on operative time, length of hospital stay, postoperative complications and success rate (Braga et al. 2009). In their meta-analysis of eight studies, robot pyeloplasty was associated with a significantly shorter hospital stay. There were no significant differences between the two approaches with regards to technical success or complications. Bird et al. presented comparative analysis which included 172 cases (98 robotic and 74 laparoscopic pyeloplasties) in a single center (Bird et al. 2011). They reported no difference in operative time, complication rates, and radiographic success rates at 6 months. The cost of surgery should be considered in comparing the two surgical methods.

Several studies have compared costs for robotic and laparoscopic pyeloplasty. The issue of cost effectiveness with regards to robotics remains a relevant issue, as increasingly more procedures are done using this approach. There have been several authors that have directly compared costs for robotic and laparoscopy pyeloplasty. Bhayani et al. compared their robotic pyeloplasties with a matched cohort of laparoscopic cases to find cost-effectiveness of the robotic surgery in the United States (Bhayani et al. 2005). If the operation time of the robot surgery was less than 130 min and more than 500 operations were performed each year, robotic surgery would be as cost effective as laparoscopic surgery. Seideman et al. also revealed similar report (Seideman et al. 2012a). Although robotic surgery has a shorter operative times and hospital stays, it was fundamentally expensive because of the high cost of consumables and maintenance of the machine. They revealed that if robotic pyeloplasty could be performed in 96 min or less, it would be cost effective. However, these findings should be applied differently in different countries. Because the insurance system and the operation cost are different in each country.

## 21.3 Robotic Pyeloplasty in Children

Although the number of cases is small, a few studies have demonstrated the efficacy and safety of pediatric robotic pyeloplasty. Retroperitoneal access is the common approach for pyeloplasty in children. Small retroperitoneal space of the children and larger instruments of the robotic system make modification and transformation of the retroperitoneal access necessary (Samarasekera and Stein 2014). Olsen et al. described the first series of retroperitoneoscopic robotic pyeloplasties in 13 children (Olsen and Jorgensen 2004). Median ages was 6.7 years. Median operative time was 173 min and there were no perioperative complications. Median hospital stay after operation was 2 days. Two patients had postoperative complications related to the double-J stent. All patients showed satisfactory surgical results during the preliminary follow-up period of 1–7 months. Transperitoneal approach was also used. Minnillo et al. included 155 patients aged 11.5 years on average (Minnillo et al. 2011). In their study, 98% of the cases were done via the transperitoneal approach, which was based on surgeon preference. The mean operative time was 198.5 min. The primary technical success rate was 96%. They suggested that a pediatric urology training program with collaboration between the surgeons, anesthesiologists, and nursing staff can lead to shorter operative times and hospital stays, and achieve functional results comparable to the open surgery. As experience has accumulated, several papers of robotic pyeloplasty in children have been published (Table 21.2) (Olsen and Jorgensen 2004; Hollis et al. 2015; Atug et al. 2005; Kutikov et al. 2006; Olsen et al. 2007; Chan et al. 2010; Singh et al. 2012). Both approaches, transperitoneal or retroperitoneal, are available. Their mean age was 9.2 years (range, 0.3–18), and the mean operative

**Table 21.2** Outcomes of robotic pyeloplasty in children from seven large studies

| Study | No. of cases | Age (years) | OP time (min) | Hospital stay (days) | Success rate (%) |
|---|---|---|---|---|---|
| Atug et al. (2005) | 7 | 13.0 (6–15) | 184 | 1.2 | 100 |
| Kutikov et al. (2006) | 9 | 0.5 (0.3–0.7) | 123 | 1.4 | 100 |
| Olsen et al. (2007) | 67 | 7.9 (1.7–17.1) | 143 | 2.0 | 94 |
| | 5 | 9.5 (3.4–14.0) | 384 | 2.4 | 100 |
| Minnillo et al. (2011) | 155 | 10.5 ± 6.5 | 198.5 | 1.96 | 96 |
| Singh et al. (2012) | 34 | 12 (5–15) | 105 | 2.5 | 97 |
| Song et al. (2017) | 10 | 11.0 (4–18) | 254.1 | 3.2 | 100 |

time was 198.8 min. The mean hospital stay was 2.1 days, and success rate was 98.1% in the seven large series.

To compare the outcomes of robotic pyeloplasty to open and laparoscopic pyeloplasties in pediatric patients, Song et al. included 30 children who underwent open pyeloplasty, 30 who underwent laparoscopy, and 10 who underwent robot (Song et al. 2017). The mean age was 120.2 months, the Society for Fetal Urology grade was 3.6. The mean hospitalization period was significantly shorter in the robot group (3.2 days) than in the open (6.6 days) and laparoscopy (5.8 days) groups. The duration of analgesics use was shorter in the robot group (1.1 days) than in the other groups. Although there were no statistically significant differences, the success rate was 96.7%, 89.7%, and 100% in the open, laparoscopy, and robot groups, respectively. They found that the only factors to decrease the success rate was the presence of crossing vessels.

## 21.4 Robotic Single-Site Pyeloplasty

Laparoendoscopic single-site (LESS) surgery has been introduced in the urologic field with minimal invasive surgery (Georgiou et al. 2012). LESS surgery has advantages over conventional laparoscopic surgery in terms of pain relief, shorter hospital stay and higher patient satisfaction with cosmetic results (Autorino et al. 2011; Kaouk et al. 2011; Seo et al. 2011). However, potential disadvantages are the difficulty of surgery, which requires high technical demands with steep learning curve. There is also a need for the development of special instruments for this surgery. Overall, LESS surgery is considered an emerging trend in minimally invasive urological surgery in a relatively short period, and it has been widely applied with technical development. Although number of reconstructive surgeries have been performed via a LESS approach, until now, LESS is technically challenging due to issues with triangulation and instrument clashing. Intracorporeal suturing has been shown to be even more challenging than in standard laparoscopy (Kaouk et al. 2008).

However, it has been postulated that patients undergoing pyeloplasty might be ideal candidates for LESS as they are usually young with benign disease, and the procedure is not extensive or radical, thereby not requiring a larger incision for specimen extraction (Samarasekera and Stein 2014). To overcome the challenges associated with standard LESS, the robotic platform has been applied. Despite the fact that the current robotic system is not fully suitable for single site surgery, surgeons notice that dissection and suturing is easier. However, nevertheless instrument clashing remains an issue, and the specific instrumentation is under development for robot-assisted laparoendoscopic single site surgery (R-LESS).

Kaouk et al. described their early experience with robotic single-site pyeloplasty (or R-LESS pyeloplasty) (Kaouk et al. 2009; Seideman et al. 2012b; Stein et al. 2009; Cestari et al. 2012) and since then there have been a number of other series using various access ports (Seideman et al. 2012b; Stein et al. 2009; Cestari et al. 2012). The common conclusion from several papers have shown that use of the robotic system helps to reduce the technical difficulties of LESS pyeloplasty and shortens the learning curve associated with the procedure. Olweny et al. compared ten patients who underwent conventional LESS (C-LESS) pyeloplasty with ten patients who underwent robot-assisted laparoendoscopic single-site surgery (R-LESS) (Olweny et al. 2012). There was no significant difference between R-LESS and C-LESS except for operation time, which was significantly longer for R-LESS (226 vs. 188 min). Despite there being no clear advantage for R-LESS with regards to outcomes, the authors suggested the superior optics and endo-wrist technology of the robotic system beneficial. Cestari et al. tested the feasibility of the da Vinici single site surgery platform in nine patients with UPJO and showed short-term perioperative outcomes (Cestari et al. 2012). The system used a novel single port access device with curved cannulas and robotic instruments. Additionally, the instruments were crossed at the abdominal wall to minimize clashing and improved triangulation. All cases were completely successfully without complication or conversion. However, the main limitation of the system was the lack of articulation of the instruments.

Law et al. performed R-LESS pyeloplasty (16 cases) using the da Vinci SI system, and compared its result with multi-port robot pyeloplasty (14 cases) (Law et al. 2016). They used a SS access port, which has a five-lumen port that contains two curved cannulas that allow for the robotic instruments. It made an effective setup. The robotic arms were further separated intracorporeally, thus reducing instrument collision and allowing triangulation of the target tissue. The software of the Si system corrected for the right to left crossover of the arms, making for more natural hand-eye coordination. The mean operation time was similar between the single-port group and multi-port group (225.2 vs. 198.9 min). There was no significant difference in length of hospital stay (86.2 vs. 93.2 h), success rates (93.8% vs. 92.9%), and postoperative complications (31.3% vs. 35.7%) between two groups. According to the results reported so far, there is no difference in the results of the two surgeries, single-port and multi-port robotic pyeloplasties. Of course, these results may be due to the fact that this study is very early and there are not many cases. However, the wide adoption of robotic single-site pyeloplasty and its objective measurements of cosmesis and patient satisfaction requires the development of the instruments and techniques.

## 21.5 Conclusions

Robotic pyeloplasty with the da Vinci surgical robot system has advantages in regards to suturing and learning curve reduction. It has been proved that this surgery is safe and reproducible. And the operative outcomes also show comparable to open and laparoscopic pyeloplasty. However, the cost-effectiveness of robotic pyeloplasty is inferior to open and laparoscopic surgeries. Finally, to solve the cost problem and to facilitate the operation, development of the instruments and technique and accumulation of surgical experience are necessary. In addition, long-term follow-up studies are required for this surgery to become standard surgery for UPJO. If the number of the robotic surgeries increases, through long-term follow-up studies, robotic pyeloplasty may be the standard treatment for UPJO. Robotic surgery can be the standard treatment for UPJO if good results are obtained in long-term follow-up studies using sufficient number of operations.

## References


Atug F, Woods M, Burgess SV, et al. Robotic assisted laparoscopic pyeloplasty in children. J Urol. 2005;174:1440–2.

Autorino R, Cadeddu JA, Desai MM, et al. Laparoendoscopic single-site and natural orifice transluminal endoscopic surgery in urology: a critical analysis of the literature. Eur Urol. 2011;59:26–45.

Autorino R, Eden C, El-Ghoneimi A, et al. Robot-assisted and laparoscopic repair of ureteropelvic junction obstruction: a systematic review and meta-analysis. Eur Urol. 2014;65(2):430–52.

Babbar P, Hemal AK. Robot-assisted urologic surgery in 2010—advancements and future outlook. Urol Ann. 2011;3:1–7.

Bernardo N, Smith AD. Endopyelotomy review. Arch Esp Urol. 1999;52:541–8.

Bhayani SB, Link RE, Varkarakis JM, et al. Complete da Vinci versus laparoscopic pyeloplasty: cost analysis. J Endourol. 2005;19:327–32.

Bird VG, Leveillee RJ, Eldefrawy A, et al. Comparison of robot-assisted versus conventional laparoscopic transperitoneal pyeloplasty for patients with ureteropelvic junction obstruction: a single-center study. Urology. 2011;77:730–4.

Braga LHP, Pace K, DeMaria J, et al. Systematic review and meta-analysis of robotic-assisted versus conventional laparoscopic pyeloplasty for patients with ureteropelvic junction obstruction: effect on operative time, length of hospital stay, postoperative complications, and success rate. Eur Urol. 2009;56:848–558.

Brooks JD, Kavoussi LR, Preminger GM, et al. Comparison of open and endourologic approaches to the obstructed ureteropelvic junction. Urology. 1995;46:791–5.

Cassis AN, Brannen GE, Bush WH, et al. Endopyelotomy: review of results and complications. J Urol. 1991;146:1492–5.

Cestari A, Buffi NM, Lista G, et al. Feasibility and preliminary clinical outcomes of robotic laparoendoscopic single-site pyeloplasty using a new single-port platform. Eur Urol. 2012;62:175–9.

Chan KW, Lee KH, Tam YH, et al. Early experience of robotic-assisted reconstructive operations in pediatric urology. J Laparoendosc Adv Surg Tech A. 2010;20:379–82.

Davis DM. Intubated ureterotomy; result after four years. J Urol. 1947;57:233–7.

Erdeljan P, Caumartin Y, Warren J, et al. Robot-assisted pyeloplasty: follow-up of first Canadian experience with comparison of outcomes between experienced and trainee surgeons. J Endourol. 2010;24:1447–50.

Etafy M, Pick D, Said S, et al. Robotic pyeloplasty: the University of California-Irvine experience. J Urol. 2011;185:2196–200.

Georgiou AN, Rassweiler J, Herrmann TR, et al. Evolution and simplified terminology of natural orifice transluminal endoscopic surgery (NOTES), laparoendoscopic single-site surgery (LESS), and mini-laparoscopy (ML). World J Urol. 2012;30:573–90.

Gerber GS, Kim JC. Ureteroscopic endopyelotomy in the treatment of patients with ureteropelvic junction obstruction. Urology. 2000;55:198–202.

Gettman MT, Peschel R, Neururer R, et al. A comparison of laparoscopic pyeloplasty performed with the daVinci robotic system versus standard laparoscopic techniques: initial clinical results. Eur Urol. 2002a;42:453–8.

Gettman MT, Neururer R, Bartsch G, et al. Anderson-Hynes dismembered pyeloplasty performed using the da Vinci robotic system. Urology. 2002b;60(3):509–13.

Gupta NP, Mukherjee S, Nayyar R, et al. Transmesocolic robot-assisted pyeloplasty: single center experience. J Endourol. 2009;23:945–8.

Hollis MV, Cho PS, Yu RN. Pediatric robot-assisted laparoscopic pyeloplasty. Am J Robot Surg. 2015;2(1):1–8.

Hopf HL, Bahler CD, Sundaram CP. Long-term outcomes of robot-assisted laparoscopic pyeloplasty for ureteropelvic junction obstruction. Urology. 2016;90:106–10.

Inagaki T, Rha KH, Ong AM, et al. Laparoscopic pyeloplasty: current status. BJU Int. 2005;95(Suppl 2):102–5.

Jarrett TW, Chan DY, Charambura TC, et al. Laparoscopic pyeloplasty: the first 100 cases. J Urol. 2002;167:1253–6.

Kaouk JH, Goel RK, Haber GP, et al. Single-port laparoscopic radical prostatectomy. Urology. 2008;72:1190–3.

Kaouk JH, Goel RK, Haber GP, et al. Robotic single-port transumbilical surgery in humans: initial report. BJU Int. 2009;103:366–9.

Kaouk JH, Autorino R, Kim FJ, et al. Laparoendoscopic single-site surgery in urology: worldwide multi-institutional analysis of 1076 cases. Eur Urol. 2011;60:998–1005.

Kavoussi LR, Peters CA. Laparoscopic pyeloplasty. J Urol. 1993;150:1891–4.

Kim SC, Kang T, Park H. Experience with laparoscopic pyeloplasty, including robot-assisted laparoscopic surgery, for ureteropelvic junction obstruction. Korean J Urol. 2009;50:996–1002.

Kutikov A, Nguyen M, Guzzo T, et al. Robot assisted pyeloplasty in the infant-lessons learned. J Urol. 2006;176:2237–40.

Law J, Rowe N, Archambault J, et al. First Canadian experience with robotic single-incision pyeloplasty: comparison with multi-incision technique. Can Urol Assoc J. 2016;10(3–4):83–8.

Link RE, Bhayani SB, Kavoussi LR. A prospective comparison of robotic and laparoscopic pyeloplasty. Ann Surg. 2006;243:486–91.

Lucas SM, Sundaram CP, Wolf JS, et al. Factors that impact the outcome of minimally invasive pyeloplasty: results of the multi-institutional laparoscopic and robotic pyeloplasty collaborative group. J Urol. 2012;187:522–7.

McClinton S, Steyn JH, Hussey JK. Retrograde balloon dilatation for pelviureteric junction obstruction. Br J Urol. 1993;71:152–5.

Meretyk I, Meretyk S, Clayman RV. Endopyelotomy: comparison of ureteroscopic retrograde and antegrade percutaneous techniques. J Urol. 1992;148:775–82.

Minnillo BJ, Cruz JA, Sayao RH, et al. Long-term experience and outcomes of robotic assisted laparoscopic pyeloplasty in children and young adults. J Urol. 2011;185:1455–60.

Motola JA, Badlani GH, Smith AD. Results of 221 consecutive endopyelotomies: an 8-year follow-up. J Urol. 1993;149:453–6.

Mufarrij PW, Woods M, Shah OD, et al. Robotic dismembered pyeloplasty: a 6-year, multi-institutional experience. J Urol. 2008;180:1391–6.

Nakada SY, Johnson M. Ureteropelvic junction obstruction. Retrograde endopyelotomy. Urol Clin North Am. 2000;27:677–84.

Niver BE, Agalliu I, Bareket R, et al. Analysis of robotic-assisted laparoscopic pyleloplasty for primary versus secondary repair in 119 consecutive cases. Urology. 2012;79:689–94.

Notley RG, Beaugie JM. The long-term follow-up of Anderson-Hynes pyeloplasty for hydronephrosis. Br J Urol. 1973;45:464–7.

O'Reilly PH, Brooman PJ, Mak S, et al. The long-term results of Anderson-Hynes pyeloplasty. BJU Int. 2001;87:287–9.

Olsen LH, Jorgensen TM. Computer assisted pyeloplasty in children: the retroperitoneal approach. J Urol. 2004;171:2629–31.

Olsen LH, Rawashdeh YF, Jorgensen TM. Pediatric robot assisted retroperitoneoscopic pyeloplasty: a 5-year experience. J Urol. 2007;178:2137–41.

Olweny EO, Park SK, Tan YK, et al. Perioperative comparison of robotic assisted laparoendoscopic single-site pyeloplasty versus conventional less pyeloplasty. Eur Urol. 2012;61:410–4.

Palese MA, Munver R, Phillips CK, et al. Robot-assisted laparoscopic dismembered pyeloplasty. JSLS. 2005;9(3):252–7.

Passerotti CC, Passerotti AM, Dall'Oglio MF, et al. Comparing the quality of the suture anastomosis and the learning curves associated with performing open, freehand, and robotic-assisted laparoscopic pyeloplasty in a swine animal model. J Am Coll Surg. 2009;208:576–86.

Persky L, Krause JR, Boltuch RL. Initial complications and late results in dismembered pyeloplasty. J Urol. 1977;118:162–5.

Rassweiler JJ, Teber D, Frede T. Complications of laparoscopic pyeloplasty. World J Urol. 2008;26:539–47.

Samarasekera D, Stein RJ. Robotic-assisted laparoscopic approaches to the ureter: pyeloplasty and ureteral reimplantation. Indian J Urol. 2014;30(3):293–9.

Schuessler WW, Grune MT, Tecuanhuey LV, et al. Laparoscopic dismembered pyeloplasty. J Urol. 1993;150:1795–9.

Schwentner C, Pelzer A, Neururer R, et al. Robotic Anderson-Hynes pyeloplasty: 5-year experience of one centre. BJU Int. 2007;100:880–5.

Seideman CA, Sleeper JP, Lotan Y. Cost comparison of robot-assisted and laparoscopic pyeloplasty. J Endourol. 2012a;26:1044–8.

Seideman CA, Tan YK, Faddegon S, et al. Robot-assisted laparoendoscopic single-site pyeloplasty: technique using the da vinci si robotic platform. J Endourol. 2012b;26:971–4.

Seo IY, Lee JW, Rim JS. Laparoendoscopic single-site radical nephrectomy: a comparison with conventional laparoscopy. J Endourol. 2011;25(3):465–9.

Seo IY, Oh TH, Lee JW. Long-term follow-up results of laparoscopic pyeloplasty. Korean J Urol. 2014;55:656–9.

Singh P, Dogra PN, Kumar R, et al. Outcomes of robot-assisted laparoscopic pyeloplasty in children: a single center experience. J Endourol. 2012;26:249–53.

Siqueira TM Jr, Nadu A, Kuo RL, et al. Laparoscopic treatment for ureteropelvic junction obstruction. Urology. 2002;60:973–8.

Sivaraman A, Leveillee RJ, Patel MB, et al. Robot-assisted laparoscopic dismembered pyeloplasty for ureteropelvic junction obstruction: a multi-institutional experience. Urology. 2012;79(2):351–5.

Song SH, Lee C, Jung J, et al. A comparative study of pediatric open pyeloplasty, laparoscopy-assisted extracorporeal pyeloplasty, and robot-assisted laparoscopic pyeloplasty. PLoS One. 2017;12(4):e0175026.

Stein RJ, White WM, Goel RK, et al. Robotic laparoendoscopic single-site surgery using gelport as the access platform. Eur Urol. 2009;57:136–7.

Tobis S, Venigalla S, Balakumaran K, et al. Analysis of a large single-center experience with robot-assisted pyeloplasty. Int J Urol. 2013;20(2):230–4.

Tripp BM, Homsy YL. Neonatal hydronephrosis—the controversy and the management. Pediatr Nephrol. 1995;9:503–9.

Weise ES, Winfield HN. Robotic computer-assisted pyeloplasty versus conventional laparoscopic pyeloplasty. J Endourol. 2006;20:813–9.

Yanke BV, Lallas CD, Pagnani C, et al. The minimally invasive treatment of ureteropelvic junction obstruction: a review of our experience during the last decade. J Urol. 2008;180:1397–402.

# 22 LESS: Upper Tract, Lower Tract, and Robotic Surgery

Woong Kyu Han and Young Eun Yoon

**Abstract**

Since the beginning of the laparoscopic surgery in urologic field, many kinds of urological surgeries have been performed laparoscopically. A laparo-endoscopic single-site surgery (LESS) using only one access port was devised due to the desire of doctors and patients to leave less wound and postoperative pain than conventional laparoscopic surgery, which needed multi-ports. Almost all urological laparoscopic operations have been tried and reported with single port due to the development of surgical instruments and techniques. However, it is still not mainly performed in many hospitals because of the drawbacks of long operation time and relatively long learning curve compared to conventional laparoscopic surgery. Recently, the frequency of LESS has been more decreasing because robot surgery has replaced many laparoscopic procedures.

However, LESS is still one option of the most minimally invasive surgery for various urologic disease. In recent years, lots of robotic surgical systems are being developed based on single port, further development of LESS is expected. In this chapter, we will learn the history of urologic LESS and basic instruments. Further, most commonly performed urologic LESSs, such as radical nephrectomy, partial nephrectomy, pyeloplasty, and radical prostatectomy, would be described. We will also look into the recent status of robotic LESS and the robotic LESS systems to be developed in the future.

**Keywords**

Laparoendoscopic single-site surgery · Single-port surgery · NOTES · Minimal invasive surgery · Robot-assisted surgery

## 22.1 Introduction of LESS

### 22.1.1 History of NOTES and LESS

It has been over 25 years since Dr. Clayman performed the first laparoscopic nephrectomy (Clayman et al. 1991). Laparoscopic surgery was sufficient to change the paradigm of surgery due to small wounds and excellent outcomes compared to conventional open surgery. The scar was small, the postoperative pain was low, the operation time was short, and the amount of blood loss during the operation was small. However, with the development of laparoscopic instruments and skills, minimally invasive surgeons tried to perform much less invasive surgeries. In particular, laparoscopic surgery required 3–6 ports, there were lots of efforts to reduce or even eliminate these skin scars. These attempts were first introduced in the form of natural orifice transluminal endoscopic surgery (NOTES). In the dictionary meaning of NOTES, the operative method was very limited. Since most urinary organs are in the retroperitoneal space and so the operative methods are more complex, the pure NOTES surgical series which have been reported are extremely limited. First, transvaginal extraction of resected kidney was reported by Gill et al. (2002). This was not NOTES in the correct sense, but suggested that NOTES in the urology area might be possible; in fact this method is later even tried in donor nephrectomy (Pietrabissa et al. 2010). Then Gettman et al. reported their first six transvaginal nephrectomies in porcine model, although additional 5-mm abdominal trocar was inserted for visualization. Since then, a number of NOTES have been reported by urological surgeons. Transgastric, transvaginal, transvesical, and transrectal NOTES had been tried (Swain 2008). However, NOTES has

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**Table 22.1** Various names of surgery reported before the name LESS was established

| Acronyms | Full names |
|---|---|
| E-NOTES | Embryonic natural orifice transluminal endoscopic surgery (Gill et al. 2008) |
| | Single keyhole surgery (Zeltser et al. 2007) |
| LESS | Laparoendoscopic single-site surgery (Tracy et al. 2008) |
| NOTUS | Natural orifice transumbilical surgery (Nguyen et al. 2009) |
| OPUS | One port umbilical surgery (Rane et al. 2008) |
| R-NOTES | Robot-assisted natural orifice transumbilical endoscopic surgery (Haber et al. 2008) |
| SAS | Single-access site (Ponsky et al. 2008) |
| SIL | Single incision laparoscopy (Rieger and Lam 2010) |
| SILS | Single incision laparoscopic surgery (Raman et al. 2008) |
| SIMPLE | Single incision multiport laparoendoscopic surgery (Petrotos and Molinelli 2009) |
| SITUS | Single-incision triangulated umbilical surgery (Nagele et al. 2012) |
| SLAPP | Single laparoscopic port procedure (Rao et al. 2008) |
| SLIT | Single laparoscopic incision transabdominal surgery (Nguyen et al. 2008) |
| SPA | Single port access (Rane et al. 2008) |
| SPILS | Single port/incision laparoscopic surgery (Rehman and Ahmed 2011) |
| SPL | Single port laparoscopy (Kaouk and Goel 2009) |
| SPS | Single port surgery (Rao et al. 2010) |
| SSA | Single-site access (Cox et al. 2011) |
| TUES | Transumbilical endoscopic surgery (Zhu et al. 2009) |
| TULA | Transumbilical laparoscopic assisted surgery (Cobellis et al. 2011) |
| U-LESS | Transumbilical laparoendoscopic single-site surgery (Rane et al. 2009) |
| U-NOTES | Umbilical natural orifice transluminal endoscopic surgery (Box et al. 2008) |
| VSUS | Visibly scarless urologic surgery (Box et al. 2008) |

not been widespread due to long operating time, lack of specialized equipment, difficulty of suturing, surgeon's fatigue, and ethical problems due to risks of unproven surgical methods.

Instead, single incision surgery through umbilicus, which is more familiar than NOTES, was widely performed (Canes et al. 2008). When these surgical methods first started, their names were inconsistent and very diverse (Zhu 2009; Tracy et al. 2008; Rao and Rao 2012). Table 22.1 summarized these initial nomenclatures, named by each operator. Over time, there was a movement to unify the name over these indiscriminate nomenclatures; eventually a consortium named LESSCAR (laparo-endoscopic single site surgery consortium for assessment and research) promulgated "LESS (laparo-endoscopic single-site surgery)" for these single access and single incision surgeries.

### 22.1.2 Access, Ports and Instruments of LESS

In urologic field, as with previous conventional laparoscopy, transperitoneal approach is more commonly performed. There are, of course, surgeons who prefer the retroperitoneal approach in adrenal or kidney surgery (Micali et al. 2011; Chung et al. 2011). The transperitoneal approach is usually done through the umbilical incision, which also has been reported to have been performed through paramedian or Pfannenstiel incision (Ponsky et al. 2009, 2008). However, umbilical incision was most preferred for the intention to leave the least surgical scars.

A number of multichannel ports have been developed and marketed to insert multiple instruments into the abdominal cavity through one incision. One of the easiest of these is the use of conventional laparoscopic ports in the fingers of surgical gloves. This is called home-made single-port (Choi et al. 2011; Han et al. 2010). The Alexis wound retractor (Applied Medical, Rancho Santa Margarita, CA) is inserted at the umbilicus through a 2–7 cm incision, and over the outer ring of the retractor, a surgical glove might be installed. About three or four fingers of the glove are cut, and then conventional 5–12 mm trocars could be placed in each finger of glove (Fig. 22.1). Commercially available ports, such as R-port, TriPort, Quadport (Advanced Surgical Concepts, Wicklow, Ireland), SILS port (Covidien, Dublin, Ireland), GelPoint (Applied Medical, Rancho Santa Margarita, CA, USA), and Octo-Port (Dalim SurgNET, Seoul, South Korea) have its own advantages and disadvantages, so the operator can choose the preferred product.

Conventional laparoscopic instruments may be used, but some devices have been developed that allow for bending due to space limitations. Initially, a prebent instruments were devised, but flexible instruments such as Autonomy Laparo-Angle (Cambridge Endo, Framingham, MA, USA), Real Hand (Novare Surgical Systems, Cupertino, CA, USA), and Roticulator (Covidien, Dublin, Ireland) were developed due to the development of technology, which could make surgical triangle. However, when using these flexible instruments, the left hand and right hand are changed (mirror imaging), so surgery could be difficult for beginners.

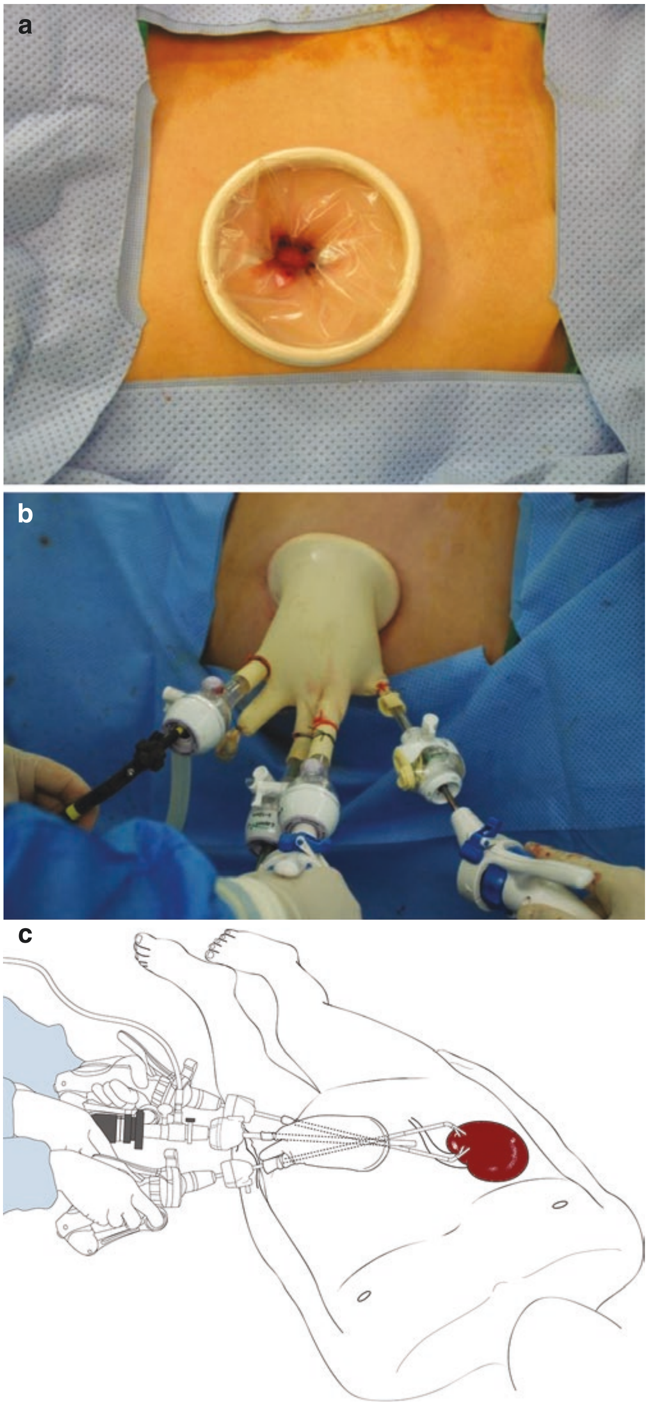


**Fig. 22.1** Making home-made single-port. (**a**) Placement of Alexis wound retractor in umbilical incision, (**b**) placement of a surgical glove over outer ring and insertion of ports through each finger, and (**c**) scheme of surgical field in renal surgery

## 22.2 LESS for Upper Tract and Lower Tract

### 22.2.1 LESS Nephrectomy

LESS simple and radical nephrectomy has been performed for benign and malignant renal disease, respectively. The procedure of LESS nephrectomy is similar to conventional laparoscopic nephrectomy. However, each surgeon has a modified his/her own specific technique to overcome the limitation of LESS technique. Many LESS surgeons prefer to small kidney mass in low BMI patient. The first case of LESS nephrectomy was reported in 2007 (Rane et al. 2007). The morcellation of the benign pathologic kidney could be performed in the end. It does not need to extend the access incision in umbilicus. It helps to maximize the cosmetic outcomes (Rane et al. 2009). To obey the oncologic efficacy of the malignant pathological renal disease, extension of the incision is sometimes necessary in the case of radical nephrectomy and nephroureterectomy to remove the intact specimen (Park et al. 2016; Jeon et al. 2010a). Since the first report of LESS nephrectomy, other groups have reported LESS radical nephrectomy with excellent oncologic outcomes (Jeon et al. 2010a; Stolzenburg et al. 2009; Raman et al. 2009). LESS radical nephrectomy has been performed through umbilical incision as well as a lower abdominal incision (Pfannenstiel incision). The range of reported incision is 4–8 cm in malignant renal disease. In order to minimize the incision, LESS surgeons have made an attempt to remove the specimen through vagina (Gill et al. 2002).

In the series of LESS nephrectomy, operative time, postoperative analgesics use, rate of complication, length of hospital stay and estimated blood loss are equivalent to conventional laparoscopic nephrectomy (Raman et al. 2008; Park et al. 2015). A randomized controlled trial (LESS versus conventional laparoscopic nephrectomy) has shown lower visual analog pain scores and decreased analgesic requirements in LESS nephrectomy group (Tugcu et al. 2010). Oncologic outcome of LESS radical nephrectomy is also acceptable at intermediate follow-up interval (Cheng et al. 2015).

### 22.2.2 LESS Partial Nephrectomy

LESS partial nephrectomy is the most challenging operation among LESS for upper urinary tract. So far, LESS partial nephrectomy has been reported in selected cases, and it has been demonstrated the feasibility and safety of their series. LESS partial nephrectomy was performed in an extremely selected patient with favorable tumor location and size, low body mass index, limited prior abdominal surgical history (Aron et al. 2009; Jeon et al. 2010b).

LESS partial nephrectomy has similar principles and procedure to conventional laparoscopic partial nephrectomy, with more careful hilar dissection and the robust renorrhaphy. LESS surgeon usually perform a surgeon-specific modification to overcome the hurdles such as warm ischemic time and a robust renorrhaphy during LESS partial nephrectomy. A 2-mm needlescopic accessory port can be utilized for intracorporeal suturing in challenging cases (Aron et al. 2009). In a recent series, a new robotic platform of LESS has been developed and can apply to partial nephrectomy even in large renal mass (Tiu et al. 2013). However, long term oncologic follow up data of LESS partial nephrectomy has been rarely reported.

### 22.2.3 LESS Pyeloplasty

Pyeloplasty is the most common reconstructive surgery in upper urinary tract. Patients who need to undergo pyeloplasty are usually young and healthy men and women, therefore cosmetics may greater concerns for them. The group of LESS pyeloplasty demonstrated a younger age compared to other LESS group in a single institution. LESS pyeloplasty can be performed with or without the use of additional trocars (Rais-Bahrami et al. 2009; Ju et al. 2011). The technical maneuver of LESS pyeloplasty is quite similar to conventional laparoscopic pyeloplasty (Fig. 22.2) (Tracy et al. 2009).

Postoperative outcomes of LESS pyeloplasty have been reported and compared to conventional laparoscopic pyeloplasty. Tracy et al. reported that LESS pyeloplasty revealed comparable perioperative and functional outcomes (Tracy et al. 2009).

A multi-institutional investigation demonstrated that LESS pyeloplasty was a safe option with equivalent success rates to conventional laparoscopic pyeloplasty (Brandao et al. 2015; Rais-Bahrami et al. 2013). Although there was no mention about postoperative pain and analgesic requirements, the biggest benefit was the minimized incision size and postoperative scar formation (Rais-Bahrami et al. 2013).

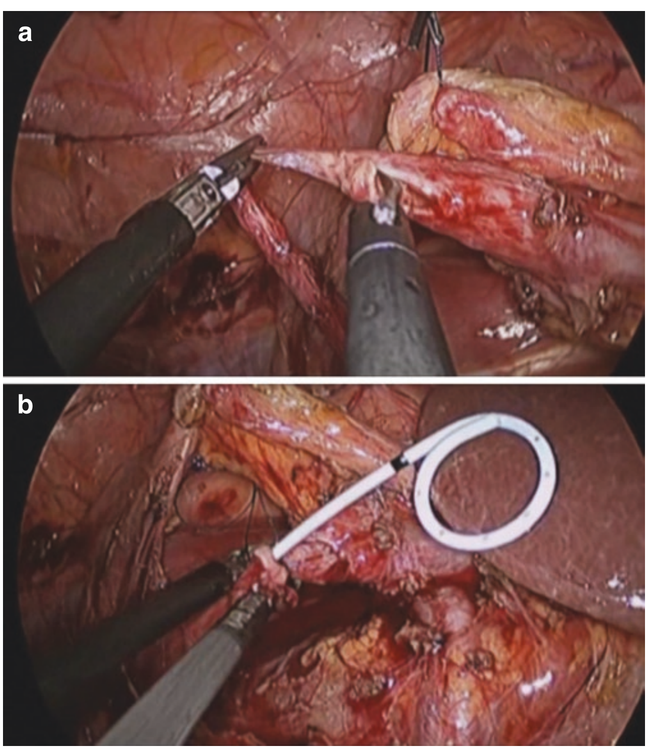

**Fig. 22.2** LESS pyeloplasty. (**a**) Incising stricted UPJ. (**b**) Insertion of double J catheter

### 22.2.4 LESS Prostatectomy

The first case of LESS radical prostatectomy was reported in 2008 in four patients with prostate cancer (Kaouk et al. 2008). Criteria of selected patients were strict and included low stage (T1c) cancer, less than body mass index(BMI) 35, and no prior pelvic surgery. The LESS radical prostatectomy was performed using a multichannel single-port device (Uni-X single access port, Pnavel System, Morganville, NJ) inserted through umbilicus without additional ports. The mean operative time for prostate excision and urethrovesical anastomosis were 3.25 h and 1.1 h, respectively. One patient developed a rectourethral fistula and two had positive surgical margins. The first clinical case of LESS extraperitoneal radical prostatectomy was reported in 2010 (Rabenalt et al. 2010). The extraperitoneal space was created using a balloon trocar. The Triport™ (Olympus Medical, Tokyo, Japan) was inserted through a 2-cm midline subumbilical incision without additional ports. The overall operative time was 290 min and estimated blood loss (EBL) was 100 mL. Gao et al. reported single-port transvesical laparoscopic radical prostatectomy (STLRP) in 2013 (Gao et al. 2013). The procedure was performed in 16 consecutive patients with clinical stage T1-2aN0M0. The mean operative time was 105 min, and the mean EBL was 130 mL. Three patients developed a urinary infection and two patients had hematoma in perioperative period.

LESS simple prostatectomy or enucleation of large volume prostatic adenoma have been successfully performed in the patients with symptomatic BPH. The initial clinical experience was reported in 2009 (Sotelo et al. 2009). LESS enucleation of prostatic adenoma was performed using a transperitoneal or transvesical approach with a single-port device inserted through the umbilicus. Desai et al. reported initial experiences in the consecutive 34 cases with large and symptomatic BPH (Desai et al. 2010). The mean operative duration was 116 min and the EBL was 460 mL. The authors concluded that LESS transvesical enucleation of the prostate is an effective treatment option for selected patients with large-volume obstructive BPH, although one patient who refused a transfusion (Jehovah's Witness) died because of uncontrolled bleeding.

## 22.3 Robotic LESS

### 22.3.1 Robotic LESS with Conventional Ports

Although new equipment has been developed for LESS, there are several limitations in LESS such as a limited range of motion, clashing of instruments both inside and outside of operative space. Therefore, to overcome these difficulties, the da Vinci surgical robotic system has been used in the field of LESS. Robotic LESS has been applied in various urological surgeries including radical/simple/partial nephrectomy, pyeloplasty, nephroureterectomy, prostatectomy, and sacrocolpopexy (Lim et al. 2014; Kaouk et al. 2009; Han et al. 2011; White et al. 2010). The first three cases of robotic LESS was reported in 2009 (Kaouk et al. 2009). They used the da Vinci S robot to perform radical prostatectomy, dismembered pyeloplasty and radical nephrectomy through an R-port (Advanced Surgical Concepts, Dublin, Ireland) with additional robotic port alongside the main port. In prospective setting, the feasibility of robotic LESS for partial nephrectomy was reported in 2011 (Han et al. 2011). Fourteen cases of robotic LESS partial nephrectomy for renal cell carcinoma were performed using hybrid glove homemade port. However, the first generation of da Vinci platform for LESS with conventional port had been faced with the lack of adequate triangulation, robotic arm clashing, decreased access for the bedside assistant and lack of wrist articulation. The lack of triangulation was demonstrated as "chopstick" resulted from the lack of wrist movement (Joseph et al. 2010).

### 22.3.2 Robotic LESS with da Vinci Single-Site Platform

In an effort to improve on the problems associated with standard robotic LESS, a novel set of robotic instruments named the da Vinci Single-Site instruments (Intuitive Surgical, Sunnyvale, CA, USA) had been developed specifically for single-site laparoscopy, and Kroh et al. reported first human surgery (cholecystectomy) with this platform in 2011 (Kroh et al. 2011). The da Vinci Single-Site robotic surgery platform is a semirigid robotic operative system designed to work with the Intuitive da Vinci Si or Xi Surgical System (Cestari et al. 2012). The system requires an incision of at least 2 cm and can be used with a newly designed rubber port with five channels; one is for camera, one is for $CO_2$ gas inflation, one is for bedside assistant, and other two are for both arms. By inserting a semirigid instrument on the bowed arched port, both arms can be crossed, and the left and right arms are programmatically changed so that the operator in the console can manipulate with left and right reversed. This is a breakthrough system that can solve mirror imaging which is considered as the biggest disadvantage of LESS (Fig. 22.3).

Surgeries using da Vinci Single-Site surgical platform in the surgical and obstetric area have been reported (Corcione et al. 2014; Sendag et al. 2014; Morelli et al. 2013), and in urologic field, there are not many reports yet. Cestari et al. reported pyeloplasty using this new platform for the first time in 2012 (Cestari et al. 2012). Through nine cases of dismembered pyeloplasty, their mean operation time was 166 min and there was no perioperative complication. In a multi-institutional 2a study, 30 pyeloplasties were performed and the perioperative outcome was promising (Buffi et al. 2015). In

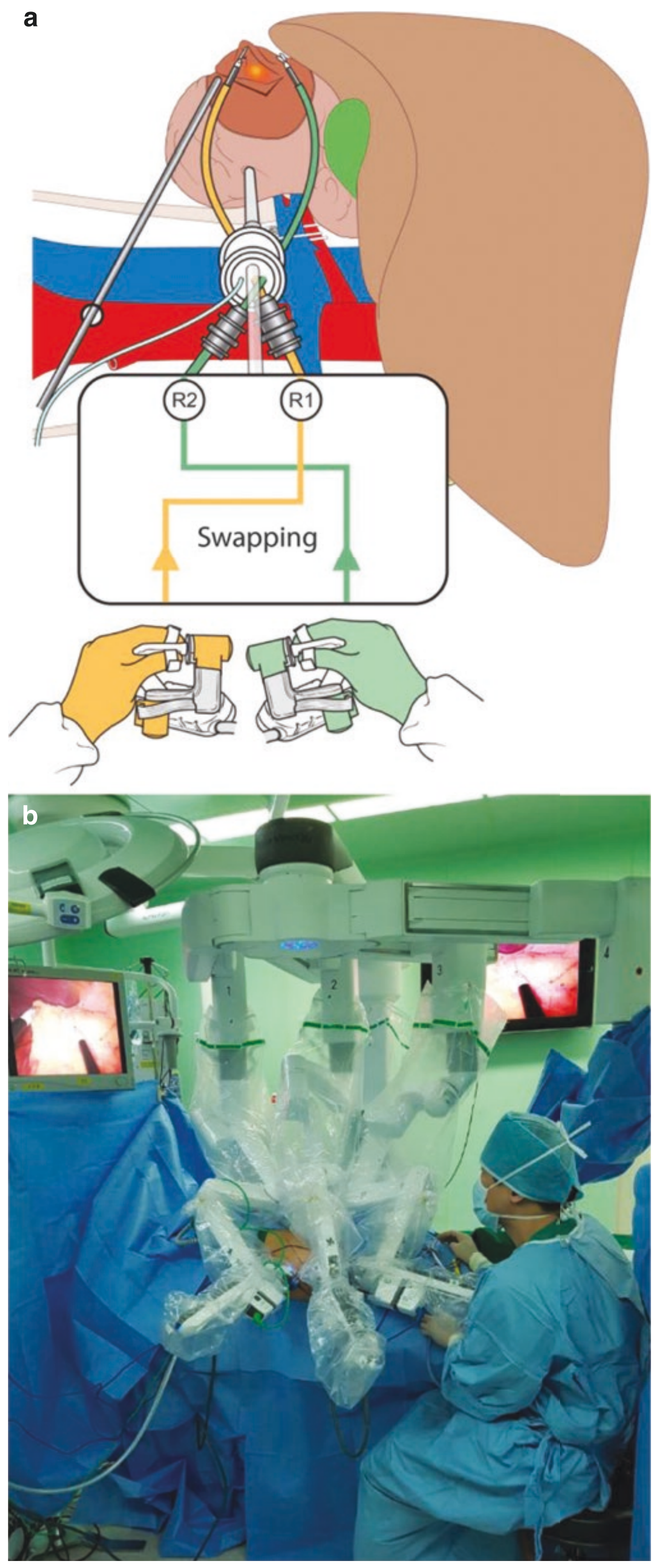


**Fig. 22.3** (**a**) Scheme and (**b**) configuration of da Vinci single-site surgical system

particular, even when this article was written, the authors described difficulty in suturing because there was no wrist joint of the needle driver. However, now a needle driver with a

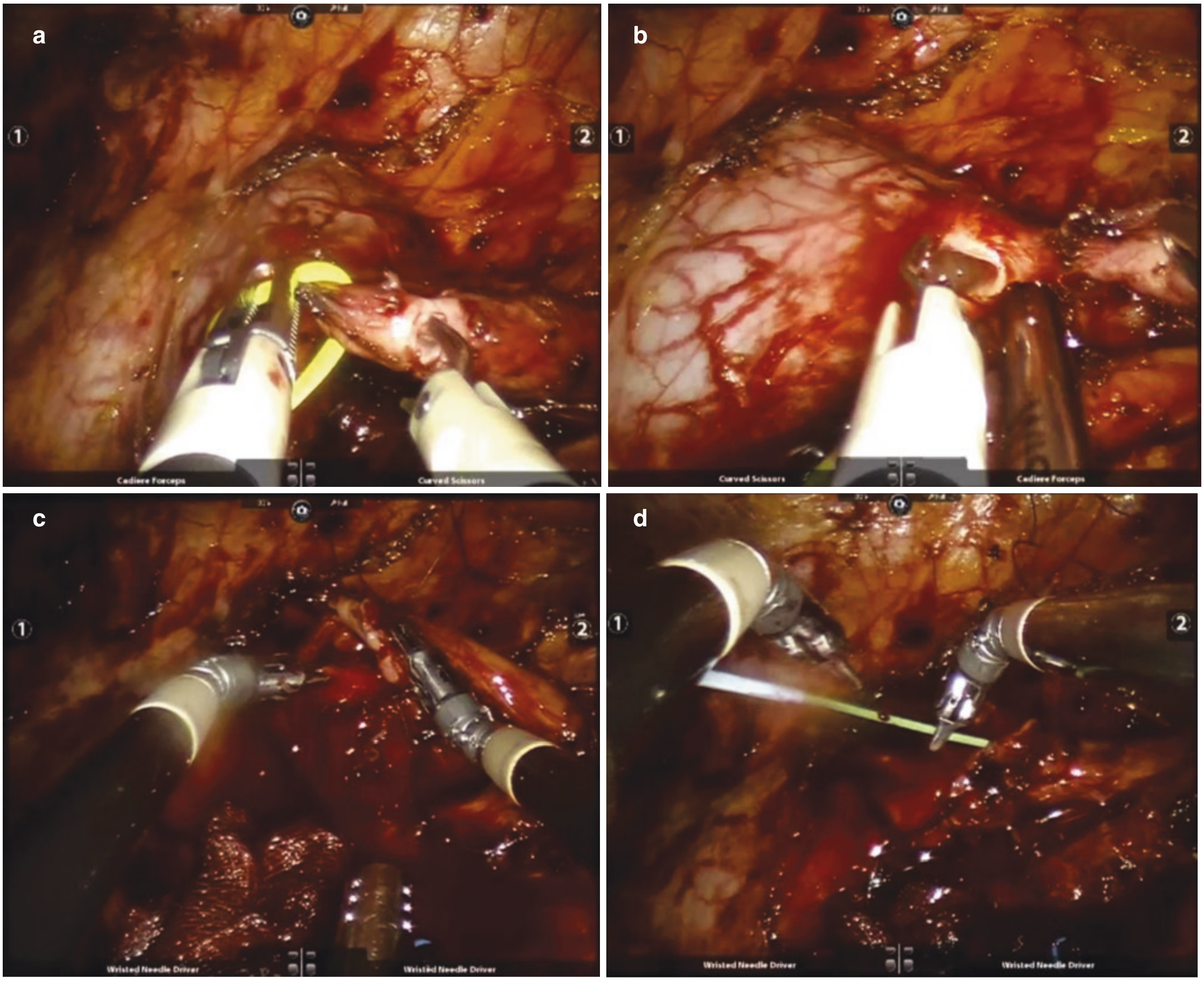


**Fig. 22.4** Robotic LESS dismembered pyeloplasty using da Vinci Si Single-Site platform. (**a**, **b**) incising stricture segment of UPJ, (**c**) suturing using wristed needle driver, and (**d**) insertion of D-J catheter

wrist joint has been developed and it seems to be easier to perform pyeloplasty (Fig. 22.4). Radical nephrectomy was reported (Mathieu et al. 2014) and partial nephrectomy was also tried (Fig. 22.5) (Komninos et al. 2014). Through their initial three partial nephrectomies, Komninos et al. reported that all cases were completed with the off-clamp technique, whereas one case required conversion to the multiport approach because of difficulty in creating the appropriate scope for safe tumor resection (Komninos et al. 2014). Scissors without wrist joints are considered to be the biggest barrier to complicated operations such as partial nephrectomy.

After introduction of wristed needle driver for Single-Site platform, sacrocolpopexy was reported (Lee 2016). The most lately, Mattevi et al. reported their first experience of robotic LESS radical prostatectomy with da Vinci Single-Site platform (Mattevi et al. 2018). The authors inserted just one more additional 12 mm port in order to facilitate table assistance during surgery. The operation time was 300 min and EBL was 400 mL. They introduced a tip using internal retraction sutures in a marionette fashion to replace the fourth robotic arm in order to pull the catheter and the seminal vesicles up. Although much clinical experience is not existing, radical prostatectomy using da Vinci Single-Site platform also seems to be feasible in selected patients. However, there has been no report of pelvic lymph node dissection and long-term oncological result, so careful consideration is needed before surgical plan.

### 22.3.3 Future of Robotic LESS

The da Vinci single-site platform has many disadvantages because it uses the arms developed for the multiports system. The movement of the instrument was limited and the port

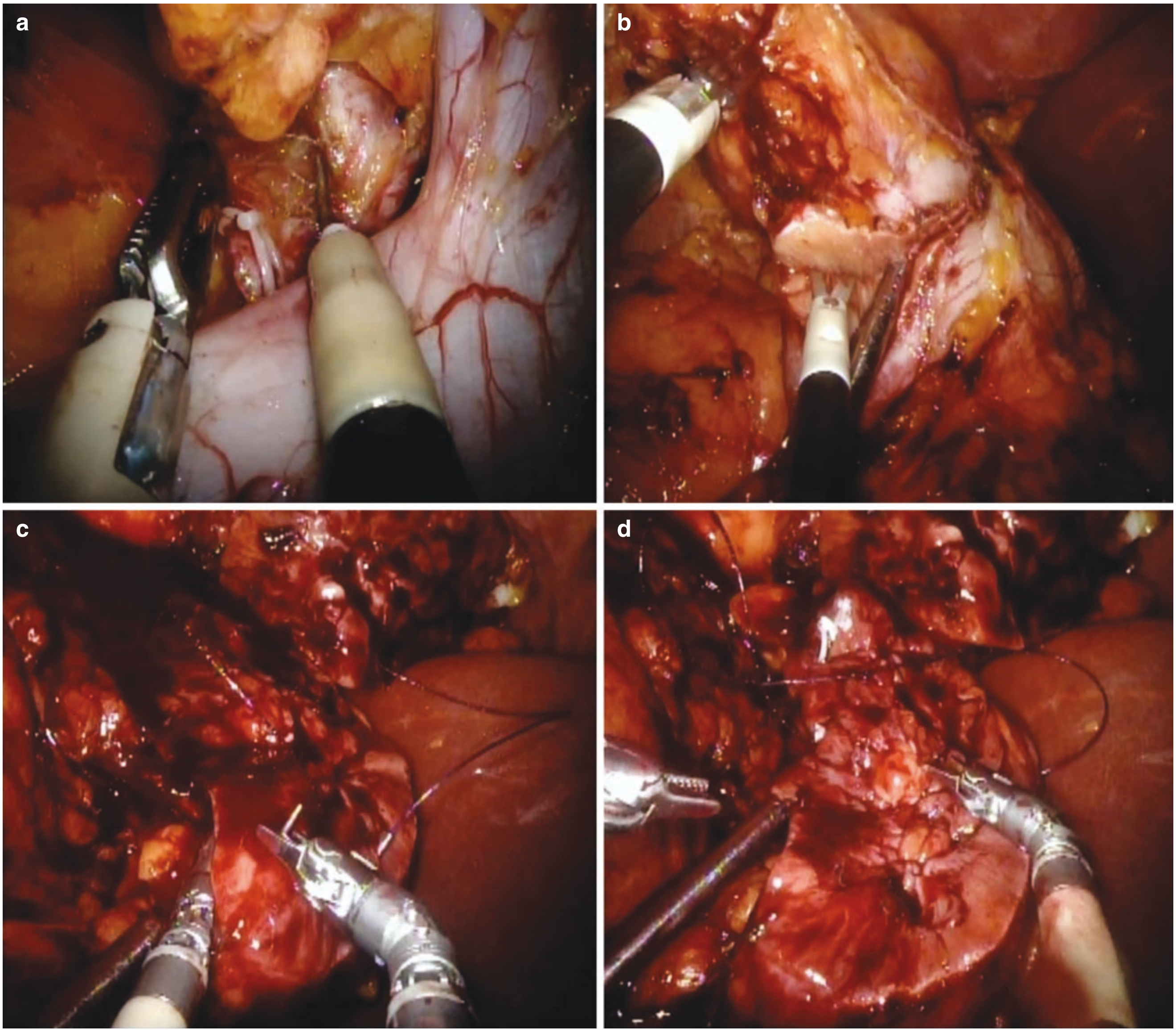

**Fig. 22.5** Robotic LESS partial nephrectomy using da Vinci Xi Single-Site platform. (**a**) Dissecting the renal vessels with hook device. (**b**) Resection of tumor (**c**) and (**d**)

was bent, which limits the operating range. Especially, it is difficult to do elaborate surgery because there is no wrist joint of instruments such as scissors. Furthermore, the incision was still large because it needs more than 2.5 cm.

In fact, various "true" single port robot systems are under development or have already been developed around the world. Among them, The da Vinci SP Surgical System (Intuitive Surgical Inc., Sunnyvale, CA, USA) is the most pioneering. In 2014, the Innovation, Development, Exploration, Assessment, Long-term Study (IDEAL) phase 1 study was reported, which is a prospective multicenter research performing urological surgery using da Vinci SP Surgical System (Kaouk et al. 2014). The authors performed 19 major surgeries (11 radical prostatectomies and 8 nephrectomies), with the perioperative results, 3-year of follow up result was also provided. Although the operation time was a little bit long (radical prostatectomy, median 239 min; partial nephrectomy, median 232 min) and warm ischemia time was elongated [median 38 (range; 26–46)], complication rates and oncological outcomes were acceptable. Most importantly, there was no conversion.

Recently, Maurice et al. reported a preclinical study using three male cadavers to assess the feasibility of the da Vinci SP surgical system (model SP1098; Intuitive Surgical, Sunnyvale, CA, USA) which is modified specifically for extraperitoneal single-site surgery (Maurice et al. 2017). The authors performed four partial nephrectomy with this brand new surgical system, and the mean warm ischemia time was 21.3 min, which is more acceptable and shorter than previous study (Kaouk et al. 2014). And same group also tried to perform radical prostatectomy and pelvic lymph node dissection (Ramirez et al. 2016). After three cases of cadaveric surgeries, the authors insisted that this single port robot system would facilitate single-port applications and allow surgeons to perform major urological operations via a small, single incision while preserving triangulation and optics, and eliminating clashing between instruments.

Many other robotic systems are being developed for true single incision surgery. Desire for less invasive surgery has continued to evolve. Robot LESS is expected to be implemented in the near future. Then again, a major innovation is expected to change the paradigm of surgery.

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## References

Aron M, Canes D, Desai MM, Haber GP, Kaouk JH, Gill IS. Transumbilical single-port laparoscopic partial nephrectomy. BJU Int. 2009;103(4):516–21.

Box G, Averch T, Cadeddu J, Cherullo E, Clayman R, Desai M, Frank I, Gettman M, Gill I, Gupta M, Haber GP, Kaouk J, Landman J, Lima E, Ponsky L, Rane A, Sawyer M, Humphreys M. Nomenclature of natural orifice translumenal endoscopic surgery (NOTES) and laparoendoscopic single-site surgery (LESS) procedures in urology. J Endourol. 2008;22(11):2575–81.

Brandao LF, Laydner H, Zargar H, Torricelli F, Andreoni C, Kaouk J, Autorino R. Laparoendoscopic single site surgery versus conventional laparoscopy for transperitoneal pyeloplasty: a systematic review and meta-analysis. Urol Ann. 2015;7(3):289–96.

Buffi NM, Lughezzani G, Fossati N, Lazzeri M, Guazzoni G, Lista G, Larcher A, Abrate A, Fiori C, Cestari A, Porpiglia F. Robot-assisted, single-site, dismembered pyeloplasty for ureteropelvic junction obstruction with the new da Vinci platform: a stage 2a study. Eur Urol. 2015;67(1):151–6.

Canes D, Desai MM, Aron M, Haber GP, Goel RK, Stein RJ, Kaouk JH, Gill IS. Transumbilical single-port surgery: evolution and current status. Eur Urol. 2008;54(5):1020–9.

Cestari A, Buffi NM, Lista G, Lughezzani G, Larcher A, Lazzeri M, Sangalli M, Rigatti P, Guazzoni G. Feasibility and preliminary clinical outcomes of robotic laparoendoscopic single-site (R-LESS) pyeloplasty using a new single-port platform. Eur Urol. 2012;62(1):175–9.

Cheng J, Chen J, Sheng X, Xu Y, Bao Y, Xiao L, Liu B, Wu Z, Wang L, Sun Y. Oncologic and functional outcomes of laparoendoscopic single-site radical nephrectomy for localized kidney cancer: a single surgeon's series with a minimum of 3-year follow-up. J Endourol. 2015;29(11):1242–7.

Choi KH, Ham WS, Rha KH, Lee JW, Jeon HG, Arkoncel FR, Yang SC, Han WK. Laparoendoscopic single-site surgeries: a single-center experience of 171 consecutive cases. Korean J Urol. 2011;52(1):31–8.

Chung SD, Huang CY, Wang SM, Tai HC, Tsai YC, Chueh SC. Laparoendoscopic single-site (LESS) retroperitoneal adrenalectomy using a homemade single-access platform and standard laparoscopic instruments. Surg Endosc. 2011;25(4):1251–6.

Clayman RV, Kavoussi LR, Soper NJ, Dierks SM, Meretyk S, Darcy MD, Roemer FD, Pingleton ED, Thomson PG, Long SR. Laparoscopic nephrectomy: initial case report. J Urol. 1991;146(2):278–82.

Cobellis G, Torino G, Noviello C, Cruccetti A, Mastroianni L, Amici G, Martino A. Versatility of one-trocar surgery in children. J Laparoendosc Adv Surg Tech A. 2011;21(6):549–54.

Corcione F, Bracale U, Pirozzi F, Cuccurullo D, Angelini PL. Robotic single-access splenectomy using the Da Vinci Single-Site(R) platform: a case report. Int J Med Robot. 2014;10(1):103–6.

Cox DR, Zeng W, Frisella MM, Brunt LM. Analysis of standard multiport versus single-site access for laparoscopic skills training. Surg Endosc. 2011;25(4):1238–44.

Desai MM, Fareed K, Berger AK, Astigueta JC, Irwin BH, Aron M, Ulchaker J, Sotelo R. Single-port transvesical enucleation of the prostate: a clinical report of 34 cases. BJU Int. 2010;105(9):1296–300.

Gao X, Pang J, Si-tu J, Luo Y, Zhang H, Li LY, Zhang Y. Single-port transvesical laparoscopic radical prostatectomy for organ-confined prostate cancer: technique and outcomes. BJU Int. 2013;112(7):944–52.

Gill IS, Cherullo EE, Meraney AM, Borsuk F, Murphy DP, Falcone T. Vaginal extraction of the intact specimen following laparoscopic radical nephrectomy. J Urol. 2002;167(1):238–41.

Gill IS, Canes D, Aron M, Haber GP, Goldfarb DA, Flechner S, Desai MR, Kaouk JH, Desai MM. Single port transumbilical (E-NOTES) donor nephrectomy. J Urol. 2008;180(2):637–41; discussion 41.

Haber GP, Crouzet S, Kamoi K, Berger A, Aron M, Goel R, Canes D, Desai M, Gill IS, Kaouk JH. Robotic NOTES (Natural Orifice Translumenal Endoscopic Surgery) in reconstructive urology: initial laboratory experience. Urology. 2008;71(6):996–1000.

Han WK, Park YH, Jeon HG, Jeong W, Rha KH, Choi H, Kim HH. The feasibility of laparoendoscopic single-site nephrectomy: initial experience using home-made single-port device. Urology. 2010;76(4):862–5.

Han WK, Kim DS, Jeon HG, Jeong W, Oh CK, Choi KH, Lorenzo EI, Rha KH. Robot-assisted laparoendoscopic single-site surgery: partial nephrectomy for renal malignancy. Urology. 2011;77(3):612–6.

Jeon HG, Jeong W, Oh CK, Lorenzo EI, Ham WS, Rha KH, Han WK. Initial experience with 50 laparoendoscopic single site surgeries using a homemade, single port device at a single center. J Urol. 2010a;183(5):1866–71.

Jeon HG, Kim DS, Jeoung HB, Han SW, Hong CH, Im YJ, Oh YT, Kim MJ, Han WK. Pediatric laparoendoscopic single-site partial nephrectomy: initial report. Urology. 2010b;76(1):138–41.

Joseph RA, Goh AC, Cuevas SP, Donovan MA, Kauffman MG, Salas NA, Miles B, Bass BL, Dunkin BJ. "Chopstick" surgery: a novel technique improves surgeon performance and eliminates arm collision in robotic single-incision laparoscopic surgery. Surg Endosc. 2010;24(6):1331–5.

Ju SH, Lee DG, Lee JH, Baek MK, Jeong BC, Jeon SS, Lee KS, Han DH. Laparoendoscopic single-site pyeloplasty using additional 2 mm instruments: a comparison with conventional laparoscopic pyeloplasty. Korean J Urol. 2011;52(9):616–21.

Kaouk JH, Goel RK. Single-port laparoscopic and robotic partial nephrectomy. Eur Urol. 2009;55(5):1163–9.

Kaouk JH, Goel RK, Haber GP, Crouzet S, Desai MM, Gill IS. Single-port laparoscopic radical prostatectomy. Urology. 2008;72(6):1190–3.

Kaouk JH, Goel RK, Haber GP, Crouzet S, Stein RJ. Robotic single-port transumbilical surgery in humans: initial report. BJU Int. 2009;103(3):366–9.

Kaouk JH, Haber GP, Autorino R, Crouzet S, Ouzzane A, Flamand V, Villers A. A novel robotic system for single-port urologic surgery: first clinical investigation. Eur Urol. 2014;66(6):1033–43.

Komninos C, Tuliao P, Kim DK, Choi YD, Chung BH, Rha KH. Robot-assisted laparoendoscopic single-site partial nephrectomy with the

novel da vinci single-site platform: initial experience. Korean J Urol. 2014;55(6):380–4.
Kroh M, El-Hayek K, Rosenblatt S, Chand B, Escobar P, Kaouk J, Chalikonda S. First human surgery with a novel single-port robotic system: cholecystectomy using the da Vinci Single-Site platform. Surg Endosc. 2011;25(11):3566–73.
Lee SR. Robotic Single-Site(R) sacrocolpopexy: first report and technique using the Single-Site(R) wristed needle driver. Yonsei Med J. 2016;57(4):1029–33.
Lim SK, Shin TY, Kim KH, Han WK, Chung BH, Hong SJ, Choi YD, Rha KH. Laparoendoscopic single-site (LESS) robot-assisted nephroureterectomy: comparison with conventional multiport technique in the management of upper urinary tract urothelial carcinoma. BJU Int. 2014;114(1):90–7.
Mathieu R, Verhoest G, Vincendeau S, Manunta A, Bensalah K. Robotic-assisted laparoendoscopic single-site radical nephrectomy: first experience with the novel Da Vinci single-site platform. World J Urol. 2014;32(1):273–6.
Mattevi D, Luciani LG, Vattovani V, Chiodini S, Puglisi M, Malossini G. First case of robotic laparoendoscopic single-site radical prostatectomy with single-site VesPa platform. J Robot Surg. 2018;12(2):381–5.
Maurice MJ, Ramirez D, Kaouk JH. Robotic laparoendoscopic single-site retroperitioneal renal surgery: initial investigation of a purpose-built single-port surgical system. Eur Urol. 2017;71(4):643–7.
Micali S, Isgro G, De Stefani S, Pini G, Sighinolfi MC, Bianchi G. Retroperitoneal laparoendoscopic single-site surgery: preliminary experience in kidney and ureteral indications. Eur Urol. 2011;59(1):164–7.
Morelli L, Guadagni S, Caprili G, Di Candio G, Boggi U, Mosca F. Robotic right colectomy using the Da Vinci Single-Site(R) platform: case report. Int J Med Robot. 2013;9(3):258–61.
Nagele U, Walcher U, Herrmann TR. Initial experience with laparoscopic single-incision triangulated umbilical surgery (SITUS) in simple and radical nephrectomy. World J Urol. 2012;30(5):613–8.
Nguyen NT, Hinojosa MW, Smith BR, Reavis KM. Single laparoscopic incision transabdominal (SLIT) surgery-adjustable gastric banding: a novel minimally invasive surgical approach. Obes Surg. 2008;18(12):1628–31.
Nguyen NT, Reavis KM, Hinojosa MW, Smith BR, Wilson SE. Laparoscopic transumbilical cholecystectomy without visible abdominal scars. J Gastrointest Surg. 2009;13(6):1125–8.
Park YH, Kim KT, Ko K, Kim HH. Prospective randomized controlled trial of conventional laparoscopic versus laparoendoscopic single-site radical nephrectomy for localized renal cell carcinoma: a preliminary report regarding quality of life. World J Urol. 2015;33(3):367–72.
Park J, Lee SB, Cho SY, Jeong CW, Son H, Park YH, Kim HH, Rashid IA, Jeong H. Comparison of the efficacy and safety of laparoendoscopic single-site surgery with conventional laparoscopic surgery for upper ureter or renal pelvis stones in a single institution: a randomized controlled study. Urol J. 2016;13(4):2759–64.
Petrotos AC, Molinelli BM. Single-incision multiport laparoendoscopic (SIMPLE) surgery: early evaluation of SIMPLE cholecystectomy in a community setting. Surg Endosc. 2009;23(11):2631–4.
Pietrabissa A, Abelli M, Spinillo A, Alessiani M, Zonta S, Ticozzelli E, Peri A, Dal Canton A, Dionigi P. Robotic-assisted laparoscopic donor nephrectomy with transvaginal extraction of the kidney. Am J Transplant. 2010;10(12):2708–11.
Ponsky LE, Cherullo EE, Sawyer M, Hartke D. Single access site laparoscopic radical nephrectomy: initial clinical experience. J Endourol. 2008;22(4):663–6.
Ponsky LE, Steinway ML, Lengu IJ, Hartke DM, Vourganti S, Cherullo EE. A Pfannenstiel single-site nephrectomy and nephroureterectomy: a practical application of laparoendoscopic single-site surgery. Urology. 2009;74(3):482–5.
Rabenalt R, Arsov C, Giessing M, Winter C, Albers P. Extraperitoneal laparo-endoscopic single-site radical prostatectomy: first experience. World J Urol. 2010;28(6):705–8.
Rais-Bahrami S, Montag S, Atalla MA, Andonian S, Kavoussi LR, Richstone L. Laparoendoscopic single-site surgery of the kidney with no accessory trocars: an initial experience. J Endourol. 2009;23(8):1319–24.
Rais-Bahrami S, Rizkala ER, Cadeddu JA, Tugcu V, Derweesh IH, Abdel-Karim AM, Kawauchi A, George AK, Autorino R, Bagrodia A, Sonmezay E, Elsalmy S, Liss MA, Harrow BM, Kaouk JH, Richstone L, Stein RJ. Laparoendoscopic single-site pyeloplasty: outcomes of an international multi-institutional study of 140 patients. Urology. 2013;82(2):366–72.
Raman JD, Cadeddu JA, Rao P, Rane A. Single-incision laparoscopic surgery: initial urological experience and comparison with natural-orifice transluminal endoscopic surgery. BJU Int. 2008;101(12):1493–6.
Raman JD, Bagrodia A, Cadeddu JA. Single-incision, umbilical laparoscopic versus conventional laparoscopic nephrectomy: a comparison of perioperative outcomes and short-term measures of convalescence. Eur Urol. 2009;55(5):1198–204.
Ramirez D, Maurice MJ, Kaouk JH. Robotic perineal radical prostatectomy and pelvic lymph node dissection using a purpose-built single-port robotic platform. BJU Int. 2016;118(5):829–33.
Rane A, Rao P, Bonadio F, Rao P. Single port laparoscopic nephrectomy using a novel laparoscopic port (R-port) and evolution of single laparoscopic port procedure (SLIPP). J Endourol. 2007;21. (Suppl. 1:A287.
Rane A, Rao P, Rao P. Single-port-access nephrectomy and other laparoscopic urologic procedures using a novel laparoscopic port (R-port). Urology. 2008;72(2):260–3; discussion 3–4.
Rane A, Ahmed S, Kommu SS, Anderson CJ, Rimington PD. Single-port 'scarless' laparoscopic nephrectomies: the United Kingdom experience. BJU Int. 2009;104(2):230–3.
Rao PP, Rao PP. LESS and NOTES: history and introduction. In: Smith AD, Badlani G, Preminger GM, Kavoussi LR, editors. Smith's textbook of endourology. 3rd ed. Hoboken: Wiley-Blackwell; 2012. p. 1241–7.
Rao P, Rao S, Rane A, Bonadio F, Rao P. Evaluation of the R port for single laparoscopic port procedures (SLAPP): a study of 20 cases. Surg Endosc. 2008;22(1):S279.
Rao A, Kynaston J, MacDonald ER, Ahmed I. Patient preferences for surgical techniques: should we invest in new approaches? Surg Endosc. 2010;24(12):3016–25.
Rehman H, Ahmed I. Technical approaches to single port/incision laparoscopic appendicectomy: a literature review. Ann R Coll Surg Engl. 2011;93(7):508–13.
Rieger NA, Lam FF. Single-incision laparoscopically assisted colectomy using standard laparoscopic instrumentation. Surg Endosc. 2010;24(4):888–90.
Sendag F, Akdemir A, Oztekin MK. Robotic single-incision transumbilical total hysterectomy using a single-site robotic platform: initial report and technique. J Minim Invasive Gynecol. 2014;21(1):147–51.
Sotelo RJ, Astigueta JC, Desai MM, Canes D, Carmona O, De Andrade RJ, Moreira O, Lopez R, Velasquez A, Gill IS. Laparoendoscopic single-site surgery simple prostatectomy: initial report. Urology. 2009;74(3):626–30.
Stolzenburg JU, Hellawell G, Kallidonis P, Do M, Haefner T, Dietel A, Liatsikos EN. Laparoendoscopic single-site surgery: early experience with tumor nephrectomy. J Endourol. 2009;23(8):1287–92.
Swain P. Nephrectomy and natural orifice translumenal endoscopy (NOTES): transvaginal, transgastric, transrectal, and transvesical approaches. J Endourol. 2008;22(4):811–8.
Tiu A, Kim KH, Shin TY, Han WK, Han SW, Rha KH. Feasibility of robotic laparoendoscopic single-site partial nephrectomy for renal tumors >4 cm. Eur Urol. 2013;63(5):941–6.

Tracy CR, Raman JD, Cadeddu JA, Rane A. Laparoendoscopic single-site surgery in urology: where have we been and where are we heading? Nat Clin Pract Urol. 2008;5(10):561–8.

Tracy CR, Raman JD, Bagrodia A, Cadeddu JA. Perioperative outcomes in patients undergoing conventional laparoscopic versus laparoendoscopic single-site pyeloplasty. Urology. 2009;74(5):1029–34.

Tugcu V, Ilbey YO, Mutlu B, Tasci AI. Laparoendoscopic single-site surgery versus standard laparoscopic simple nephrectomy: a prospective randomized study. J Endourol. 2010;24(8):1315–20.

White MA, Haber GP, Autorino R, Khanna R, Forest S, Yang B, Altunrende F, Stein RJ, Kaouk JH. Robotic laparoendoscopic single-site radical prostatectomy: technique and early outcomes. Eur Urol. 2010;58(4):544–50.

Zeltser IS, Bergs R, Fernandez R, Baker L, Eberhart R, Cadeddu JA. Single trocar laparoscopic nephrectomy using magnetic anchoring and guidance system in the porcine model. J Urol. 2007;178(1):288–91.

Zhu JF. Which term is better: SILS, SPA, LESS, E-NOTES, or TUES? Surg Endosc. 2009;23(5):1164–5.

Zhu JF, Hu H, Ma YZ, Xu MZ, Li F. Transumbilical endoscopic surgery: a preliminary clinical report. Surg Endosc. 2009;23(4):813–7.

# 23 Minimally Invasive LESS for Urachal Remnant

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**Abstract**

Urachal remnant is the persistence of an embryonic tubular structure that connects the urinary bladder to the allantois. Recent reports suggest that an asymptomatic urachal remnant in children does not require surgical treatment. Children with repeated infection of the urachal remnant, as well as adults with symptomatic urachal abnormalities, should undergo surgical resection. For resecting an urachal remnant, laparoendoscopic single-site surgery via single umbilical incision can provide a better cosmetic outcome compared with conventional multiport laparoscopy. Similar to conventional laparoscopy or open surgery, the umbilical laparoendoscopic single-site surgery should be planned after sufficient management of any preceding infection. Both para- and intraumbilical 2-cm incisions are used for commencing the dissection of the urachal remnant. The proximal part of the urachal remnant should be dissected as far distally as possible with an open surgical procedure, because this part is too close to dissect via the umbilical access site with laparoscopic technique. Using a small single-site platform with three 5-mm ports, an effective counter traction and sharp dissection of the urachal remnant can be performed. To close the bladder wall, horizontal stitching with 2-0 absorbable sutures is recommended. The incised anterior peritoneum is closed with a 3-0 running suture. The umbilical laparoendoscopic single-site surgery is a simple and efficient minimally invasive technique and appears to be ideal for patients with symptomatic urachal remnant.

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**Keywords**

Laparoendoscopic single site surgery · Urachal remnant
Laparoscopy

## 23.1 Urachal Remnant

### 23.1.1 Etiology and Anatomy

The urachus is an embryonic tubular structure that connects the urinary bladder to the allantois. In the early embryonic life, the urachus contains three different components, including the internal epithelial canal, surrounding connective tissue, and muscularis propria (Blichert-Toft and Nielsen 1971). The urachus is generally obliterated after birth, and complete regression results in a solid fibrous remnant. The urachal remnant results from incomplete obliteration or possibly the reopening of the urachal tubular structure.

The urachal remnant anatomically lies between the transverse fascia and peritoneum; thus, it is recognized as the peri-peritoneal structure (Yu et al. 2001). The structure provides pyramid-shaped ligamentous support, called umbilicovesical fascia, from the dome of the bladder to the umbilicus, and the urachus is located in the center of the pyramid-shaped space. The medial umbilical ligaments, including the obliterated umbilical artery, are lined along both sides of the pyramid. On the laparoscopic view, the median umbilical ligament, which includes the urachal remnant, is recognized as a midline fold of the anterior peritoneum (Fig. 23.1). Nevertheless, surgeons may encounter difficulties while identifying the urachus owing to a possible different anatomic variant (Patrzyk et al. 2013). There are some important anatomical urachal variants, including urachus with direct connection to the umbilicus, urachus fused with one umbilical artery, urachus fused with both umbilical arteries, and formation of a so-called "Luschka Plexus" (Blichert-Toft et al. 1973). Understanding these anatomic variants is essential to correctly identify the urachal remnant and to avoid unnecessary wide dissection of the peritoneum intraoperatively.


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### 23.1.2 Classification

In 1971, the urachal remnant was originally classified into five types by Blichert-Toft and Nelson (1971); however, four different anomalies have been recently described and widely used (Fig. 23.2). Patent urachus shows completely open lumen between the umbilicus and urinary bladder. Urachal cyst shows cystic structure between the umbilicus and urinary bladder but no connection to the intravesical space and umbilicus. Urachal sinus is the pouch opening for the umbilicus. Vesicourachal diverticulum is the pouch connecting to the bladder lumen.

### 23.1.3 Incidence

Although a previous report suggested that the urachal remnant can be observed in up to 30% of adult bladder autopsies (Schubert et al. 1982), the true incidence of each type of urachal abnormality remains unclear. Robert et al. (1996) evaluated the incidence of urachal remnant using ultrasound, and the remnant was found in 36% of 150 patients. The urachal remnant was more frequently observed in patients aged <16 years (61.7%), compared with those aged 16–35 years old (20.4%) or 36–55 years (3.7%). They suggested that the urachal remnants in young patients should be considered a normal variant unless there is an increase in size or the patients is symptomatic. Cacciarelli et al. (1990) reported that ultrasonography revealed that >60% of every 100 children had urachal remnant. Another report suggested that the urachal remnants were present in 99% of children who underwent ultrasonography (Ozbek et al. 2001). They also concluded that urachal remnants should be considered a normal variant if they are asymptomatic. In contrast, on the basis of the large number of clinical records (n = 64,803), Gleason et al. (2015) recently reported that urachal anomalies in children are relatively uncommon and are incidentally detected in approximately 1% of children who underwent any diagnostic imaging. Gleason et al. (2015) also revealed that there were urachal remnants in 89% of cases, urachal cysts in 9%, and patent urachus in 1.5%. These reported incidences of urachal remnants widely varied, and this heterogeneity may be because of the differences in patient age distribution, patient selection, or lack of an objective standard to diagnose urachal remnants. The diagnostic criteria for urachal remnants appears to be indispensable for revealing the true incidence of this abnormality, and thus, further investigations are required to settle this matter.

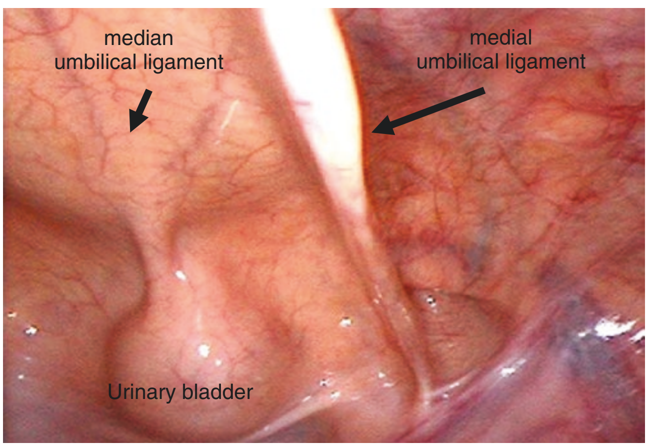


**Fig. 23.1** Laparoscopic view of the anterior pelvis. The median umbilical ligament, including the urachal remnant tissue, is recognized as a midline fold (median umbilical fold). In this view, the right medial umbilical fold (ligament), including the occluded umbilical artery, is more clearly identified

### 23.1.4 Symptoms and Treatment Policy

It is currently common belief that asymptomatic urachal remnants in children do not require surgical resection (Ueno et al. 2003; Galati et al. 2008; Sato et al. 2015; Gleason et al. 2015). Some previous reports recommended the surgical resection of apparent urachal remnants, even if they are

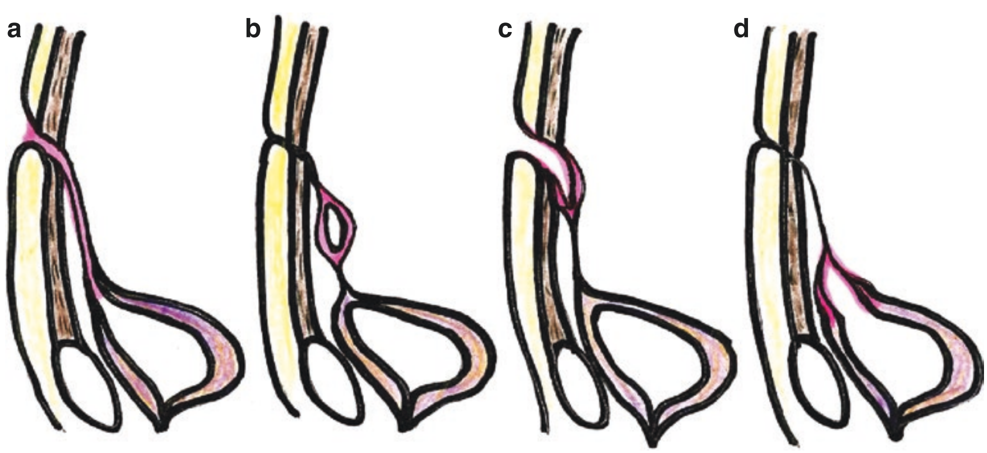


**Fig. 23.2** Urachal anomalies. (**a**) Patent urachus. (**b**) Urachal cyst. (**c**) Urachal sinus. (**d**) Vesicourachal diverticulum

asymptomatic, to preclude possible malignant transformation (Blichert-Toft and Nelson 1971; Minevich et al. 1997; Ashley et al. 2007). Nevertheless, there is no reported evidence that a persistent urachal remnant is the cause of later malignancy. In addition, Gleason et al. (2015) suggest that >5000 urachal anomalies would need to be excised to prevent a single case of urachal adenocarcinoma. Moreover, asymptomatic urachal remnants in young patients likely resolve with nonoperative management (Ueno et al. 2003; Galati et al. 2008; Naiditch et al. 2013). Thus, the prophylactic resection of asymptomatic urachal remnant is no longer recommended, and a non-surgical policy for incidental urachal remnants is reasonable, particularly for young patients.

Regardless of the type of urachal abnormalities, once urachal remnants are infected, they show some clinical symptoms. The urachal sinus with an infection can present as an umbilical abscess, and the infected vesicourachal diverticulum presents acute or chronic cystitis symptoms. Additional symptoms include localized lower abdominal pain, voiding symptoms, or even a painful and palpable mass in patients with infected urachal remnants.

As a rule, appropriate drainage under antibiotic coverage is the initial treatment of an infected urachal remnant. The primary resection of an infected urachal anomaly can cause perioperative complications and extension of hospital stay (Minevich et al. 1997). McCollum et al. (2003) recommended a two-stage procedure because they found a 40% complication rate in five patients who underwent a primary excision versus no complications in six patients who underwent a two-stage procedure. To avoid unnecessary complications, McCollum et al. (2003) recommended an initial incision and drainage of abscess with delayed excision of the urachus in case of acute infection. Moreover, spontaneous resolutions were frequently observed after initial conservative treatment in young patients (Sato et al. 2015; Nogueras-Ocaña et al. 2014; Lipskar et al. 2010). From previous reports, the spontaneous remissions of pediatric urachal remnants including both symptomatic and asymptomatic diseases reached from 50% to 79% (Galati et al. 2008; Naiditch et al. 2013; Nogueras-Ocaña et al. 2014). Therefore, non-operative management is recommended as the initial treatment for urachal remnants in patients aged <1 year (Ueno et al. 2003; Sato et al. 2015), particularly those <6 months (Galati et al. 2008; Stopak et al. 2015). However, if urachal remnants fail to resolve by conservative therapy or show recurrent infection, they should be surgically treated after the focal infection subsides.

Once a surgical treatment is planned, the tissue of the urachal remnant, including a bladder cuff, is recommended to be completely excised to avoid the recurrence of an infectious condition or stone formation and to preclude possible malignant transformation (Blichert-Toft and Nelson 1971; Minevich et al. 1997; Ashley et al. 2007). Nevertheless, as mentioned above, the evidence of later malignancy that originates from a persistent urachal remnant has not been previously reported. Thus, at least the infected focus should be completely excised, and the necessary extent of surgical resection depends on the type of urachal remnants and the localization of subsided infection. The final decision may be left to the surgical policy of each institution or each surgeon.

## 23.2 Laparoscopic and Robot-Assisted Surgery for Urachal Remnants

Traditionally, the standard surgical management involved the total excision of the umbilicus along with the urachal remnant and anterior bladder dome using a transverse or midline infraumbilical incision, for which considerably large incisions are required. The urachal remnant has been recently recognized as a good candidate for laparoscopic surgery. In 1992, Neufang et al. (1992) initially reported a laparoscopic resection of a symptomatic urachal remnant. A 28-year-old woman with complaints of recurrent discharge from her umbilicus originally underwent the laparoscopic procedure to confirm the diagnosis. They used three 5-mm trocars, including a camera port placed left lateral to the umbilicus, and two working ports placed in the right and left lower quadrants. The infected urachal fistula was diagnosed, the urachus was mobilized from its origin on the bladder roof, and both the distal and proximal ends of the urachus were ligated with endoloop (Ethicon, Germany). They described that the cosmetic result was excellent as the incisions for trocar insertion keeled practically without scaring. In the next year, Trondsen et al. (1993) presented the case of a patient undergoing laparoscopic resection of symptomatic urachal sinus. The surgeons used four ports, and the bladder roof was transected with a surgical stapler through a 12-mm umbilical port. Then, the proximal urachal tissue was dissected free of the umbilical incision. After these initial descriptions of laparoscopic resections of the urachal remnant, several reports of this laparoscopic technique have been published (Cadeddu et al. 2000; Cutting et al. 2005; Okegawa et al. 2006; Turian et al. 2007; Li Destri et al. 2011; Araki et al. 2012). Although each study is a case report or a relatively small case series and some technical variations exist, all suggest that the laparoscopic technique for urachal remnant is safe and technically feasible and that this procedure can reduce the morbidity compare with open surgery. Some authors suggested that the laparoscopic technique is more suitable for completely excising the distal involvement because of better visualization and recognition of the distal urachal structure (Li Destri et al. 2011; Nozaki et al. 2010; Kojima et al. 2007).

Although a relatively wide variety of port arrangements have been described, Cutting et al. (2005) mentioned that all ports would be placed in the rectus muscle. They initially reproduced the port placement described by Cadeddu et al. (2000) with the camera port placed in the midline above the umbilicus. However, they later used a different port placement, with all of the ports placed lateral to the rectus muscle on the left side. They suggested that the lateral view appears to give a better perspective on the complete extent of the urachal remnant, allowing a more complete resection.

Several reports of robot-assisted laparoscopic surgery for urachal remnant have been recently published (Yamzon et al. 2008; Kim et al. 2010; Kilday and Finley 2016). In general, compared with the laparoscopic procedure, the robot-assisted laparoscopic procedure has some advantages, such as good three-dimensional visualization, better articulation, and dexterity. For patients with a benign urachal abnormality, the best point of robotic surgery may be realized in the setting of bladder reconstruction. The robotic surgery can lead to fine resection and steady intracorporeal suturing to close the bladder dome; therefore, symptomatic vesicourachal diverticulum appears be a good candidate of this procedure. Because of the high cost, accepting the use of a robotic system may be difficult unless the suturing of a bladder is necessary.

Compared with conventional open surgery, laparoscopic or robotic-assisted surgeries can cure symptomatic urachal remnants, reduce morbidity, and provide better cosmesis. Nevertheless, various multiport laparoscopic techniques are reported to still leave scars outside the umbilicus.

## 23.3 Laparoendoscopic Single-Site (LESS) Surgery in Urology

Laparoendoscopic single-site (LESS) surgery has been developed to further improve cosmetic results and possibly reduce invasiveness associated with surgical intervention (Ahmed et al. 2011). In urology, Hirano et al. (2005) reported regarding initial single-site laparoscopic surgery. In their report, gasless retroperitoneal adrenalectomies were successfully performed in 53 cases using a single multichannel device. Thereafter, LESS nephrectomy via the umbilicus was reported by Raman et al. (2007) and Rane et al. (2008), and LESS living donor nephrectomy was reported by Gill et al. (2008). To date, a relatively large number of reports about urological LESS surgeries have been accumulated (Humphrey and Cane 2012; Matsuda 2013). Among them, there are several randomized control studies (RCTs) of urological LESS surgeries compared with conventional laparoscopic procedures. Reported RCTs on varicocelectomy (Lee et al. 2012; Wang et al. 2014), pyeloplasty (Tugcu et al. 2013), simple nephrectomy (Tugcu et al. 2010), and living donor nephrectomy (Kurien et al. 2011; Richstone et al. 2013; Aull et al. 2014), suggested that the postoperative use of analgesics (Lee et al. 2012; Tugcu et al. 2010, 2013) and the postoperative pain (Lee et al. 2012; Wang et al. 2014; Tugcu et al. 2010, 2013; Kurien et al. 2011; Richstone et al. 2013) were lower, and the time to return to normal activities was shorter (Lee et al. 2012; Wang et al. 2014; Tugcu et al. 2010, 2013; Aull et al. 2014) in the LESS group. In addition, three reports of meta-analysis about urological LESS surgery are available (Fan et al. 2012; Autorino et al. 2015; Hu et al. 2013). Fan et al. (2012) reported about LESS nephrectomy and compared it with conventional laparoscopic nephrectomy. Compared with conventional laparoscopic surgery, LESS surgery is associated with less postoperative pain, lower analgesic requirement, shorter hospital stay, shorter recovery time and better cosmetic outcome, although LESS surgery showed a longer operative time and a higher conversion rate. Autorino et al. (2015) reported another meta-analysis. Compared with conventional laparoscopic living donor nephrectomy, LESS living donor nephrectomy had lower blood loss and lower analgesic requirement, albeit longer operation time. In addition, Hu et al. (2013) reported a meta-analysis of LESS adrenalectomy compared with conventional laparoscopic adrenalectomy, and the LESS surgery had a longer operative time, shorter postoperative hospital stay, and lower visual analog pain scale scores.

According to these reports, LESS surgery may reduce the morbidity and scarring associated with surgical interventions. Nevertheless, the LESS surgical technique is obviously more complex and challenging than the standard laparoscopic technique. Hence, experienced surgeons can properly perform LESS surgery in selected patients; however whether we should maintain the LESS surgical technique in the future remains unknown. Based on our multiinstitutional experiences (Sato et al. 2017), the LESS technique is available for many urological diseases; however, claiming that this technique is a standard technique for patients undergoing a complex surgery is uncertain. Obviously, the LESS technique is not suitable for complex surgeries such as radical cystectomy, radical prostatectomy, or nephroureterectomy with extended reteroperitoneal lymph node dissection. In addition, because the biggest advantage of LESS surgery is its better cosmesis, surgical procedures that require large umbilical incisions such as radical nephrectomy, nephroureterectomy, or cystectomy cannot achieve the intended goal. Therefore, the LESS surgery can be recommended when a relatively simple and reproducible procedure is required, and in addition, the surgical specimen should be sufficiently small to pass through a small umbilical incision that will be invisible after healing.

In terms of treatment strategy for urachal remnants, the cosmetic outcome is quite important for patients because it is basically congenital, and a benign inflammatory disease in relatively young patients. Furthermore, in urology, urachal remnant is a unique disease in terms of requiring a umbilical incision, which is inevitable to completely remove the remnant tissue. Considering the various factors, urachal remnant is one of the most suitable candidates for umbilical LESS surgery.

## 23.4 LESS Surgery for Urachal Remnant

### 23.4.1 Indications

Most principles for the LESS surgery in patients with symptomatic urachal remnant is similar to those for conventional laparoscopic surgery, and its surgical indication is approximately identical to that of conventional laparoscopy. Suspected intraabdominal adhesion is a relative contraindication, and bowel adhesion just beneath the umbilicus is the absolute contraindication to the umbilical LESS surgery. In addition to surgical safety, the expected cosmetic outcome should be considered. In this sense, a patient with a conspicuous para-umbilical or lower abdominal scar would be considered for open surgery or multiport laparoscopic surgery rather than umbilical LESS surgery. In patients without any history of lower abdominal surgery, the umbilical LESS surgery for urachal remnants should be considered. Young patients or patients with concern about their cosmetic outcome are particularly good candidates for LESS surgery. LESS surgery for urachal remnants, as well as conventional laparoscopy or open surgery, should be planned after preceding infections subside.

### 23.4.2 Review of Reported LESS Techniques

Patrzyk et al. (2010) derived the first case report of a urachal remnant treated with LESS surgery. They chose a supraumbilical mid-abdominal part the single incision site, and directly inserted three trocars via a 2.5-cm skin incision without any single-site access platforms. They successfully excised the urachal remnant with a urachal fistula, and closed the bladder wall with absorbable clips. Next, we (Sato et al. 2012) and then, Iida et al. (2012) reported regarding umbilical LESS surgery for urachal remnants. Iida et al. made a semicircumferential subumbilical incision, and the SILS prot (Covidien, Norwalk, USA) was used in two cases with vesicourachal diverticulum. Iida et al. used cystoscope guidance to incise the urinary bladder wall, and a 3-mm trocar was added to the right lower quadrant to close the bladder wall with a 3-0 absorbable suture. In our cases with infected urachal sinus, the SILS™ port was also inserted via umbilical incision. We initially excised the tissue of the urachal fistula at the umbilicus dome, and bladder cuff resection was performed. Intracorporeal suturing was also performed without any extra port or needlescopic instrument. Nakamura et al. (2016) recently reported umbilical LESS surgery for urachal sinus, wherein they incised the umbilical site, and used a home-made glove device. An absorbable loop device (ENDOLOOP ligature, Ethicon) and an ultrasonic device were used to transect the distal end of the urachus. Garisto et al. (2017) more recently reported another case in which they conducted a curvilinear incision surrounding the umbilical fold, and the SILS™ port was used. Without an additional trocar, the opened bladder wall was closed with a 3-0 V-Lock suture.

Although these previous studies were single case reports or small case series, the objective benefit of LESS surgery for urachal remnants was improved cosmetic outcome. We believe that a direct incision on the umbilical site, as previously reported (Iida et al. 2012; Sato et al. 2012; Nakamura et al. 2016; Garisto et al. 2017), is quite reasonable to excise the entire urachal remnant and leads to a better cosmetic outcome.

### 23.4.3 Umbilical LESS Surgery: Our Transperitoneal Technique

Here, we discuss our current technique of umbilical LESS surgery for urachal remnants. Under general anesthesia, a patient is placed in the supine position. If a rigid resectoscope is required for assistance to incise the bladder, the lithotomy position is favorable. A transurethral Foley catheter is placed in the urinary bladder to distend the bladder. To secure the proximal urachal remnant, both para- and intraumbilical incisions are available. In patients with an urachal fistula, an intraumbilical, elliptical incision at the umbilical base is preferable to completely resect the fistula tissue. The extent of resection should be limited in the umbilical ring so as not to destroy the original shape of the umbilicus. The intraumbilical incision can be extended up and down, reaching the total incisional length of 2-cm (Fig. 23.3a). In patients without history of umbilical discharge, a communicating fis-

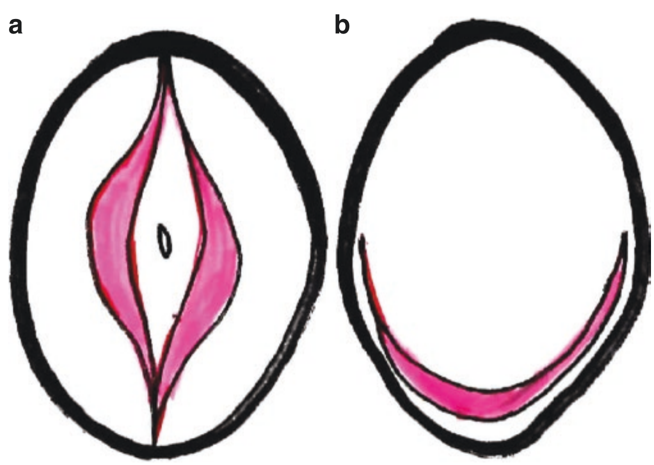


**Fig. 23.3** Umbilical incisions for LESS. (**a**) Intraumbilical elliptical incision. (**b**) Subumbilical arcuate incision

tula does not exist, and the umbilicus can be preserved without the resection of the umbilical base. Because the proximal urachal tissue occasionally fuses to the inferior pole of the urachal ring, if the paraumbilical incision is planned, the subumbilical arcuate incision is preferable (Fig. 23.3b) (Iida et al. 2012; Garisto et al. 2017).

Via a 2-cm umbilical skin incision, the subcutaneous tissue is dissected, and the proximal urachal remnant is identified just caudal to the umbilical ring. The resection of urachal remnants is usually intraperitoneally performed, and the rectus fascia and peritoneum are incised, reaching the peritoneal cavity. The umbilical edge of the urachal remnant is completely transected away from the umbilical base.

In an attempt to succeed in this umbilical LESS surgery, it should be emphasized that the proximal part of urachal remnant is continuously dissected as far distally as possible with an open surgical procedure. Because the proximal umbilical part of the urachal remnant is too close to start dissection via the umbilical access site with LESS technique, a 3- to 4-cm dissection of the urachal remnant via a 2 cm incision is more reasonable with the open technique. After making proximal dissection in reaching approximately 3- to 4-cm further, an effective counter traction and sharp dissection of the urachal remnant can be performed with umbilical LESS surgery. After the open technique, the dissected part is dropped into the abdominal cavity, hanging down from the anterior abdominal wall (Fig. 23.4). Then, a single port device, such as SILS™ port (Fig. 23.5) (Covidien, Mansfield, MA, USA), GelPoint® Mini (Applied Medical, Rancho Santa Margarita, CA, USA), EZ-Access mini (Hakko, Nagano, Japan), or homemade globe device is attached. Each device can assure three ports. A 5-mm flexible laparoscope (EndoEye™, Olympus, Tokyo, Japan) is used; furthermore, 5-mm conventional laparoscopic devices can be mainly used. An articulating or a pre-bent instrument is also useful to maintain better triangulation. With an electrocautery, the dissection of the urachal remnant with umbilical ligament continues toward the bladder dome. To minimize the defect of bladder wall, 200–300 ml of air or sterile saline is filled in the bladder, and a bladder cuff including the urachal insertion is marked and circumferentially excised using an electrocautery (Fig. 23.6a, b). At this stage, transurethral cystoscopy for light guidance or resectoscope for transurethral bladder incision can assist with LESS surgery. The entire urachal remnant from the umbilicus to the anterior bladder dome is freed, and the resected specimen is placed in a specimen bag. To close the bladder wall, we used an articulating needle holder (Autonomy™ Laparo-Angle™ Needle Holder, Cambridge Endoscopic Devices, Framingham, MA, USA), but a conventional laparoscopic needle holder is also useful. Suturing is a critical step for obtaining the expected result and for early recovery; the bladder should be tightly closed in two layers with 2-0 absorbable running sutures (Fig. 23.7). We note that horizontal suturing is more comfortable than vertical suturing with this LESS technique. An additional 2- to 3-mm trocar or a needlescopic instrument to the lower abdomen is useful for closing the bladder in difficult cases (Iida et al. 2012). The incised anterior peritoneum is closed from the distal end to the proximal end with a 3-0 running suture. The specimen bag is

**Fig. 23.5** Intraoperative view. The single port platform with three trocars is attached via an umbilical incision

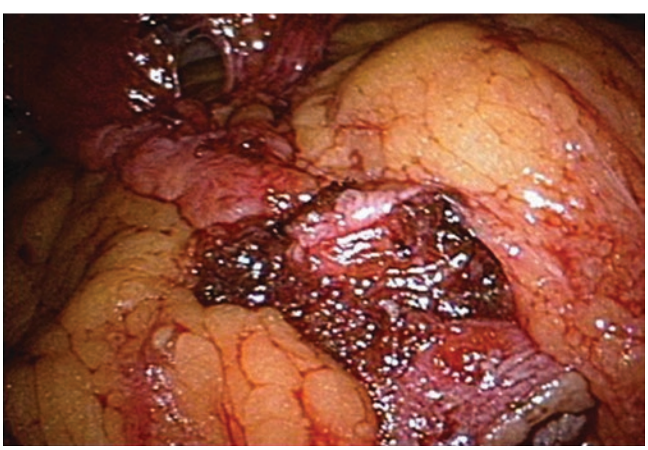

**Fig. 23.4** Intraoperative laparoscopic view. The proximal part of urachal remnant is dissected and dropped into the abdominal cavity

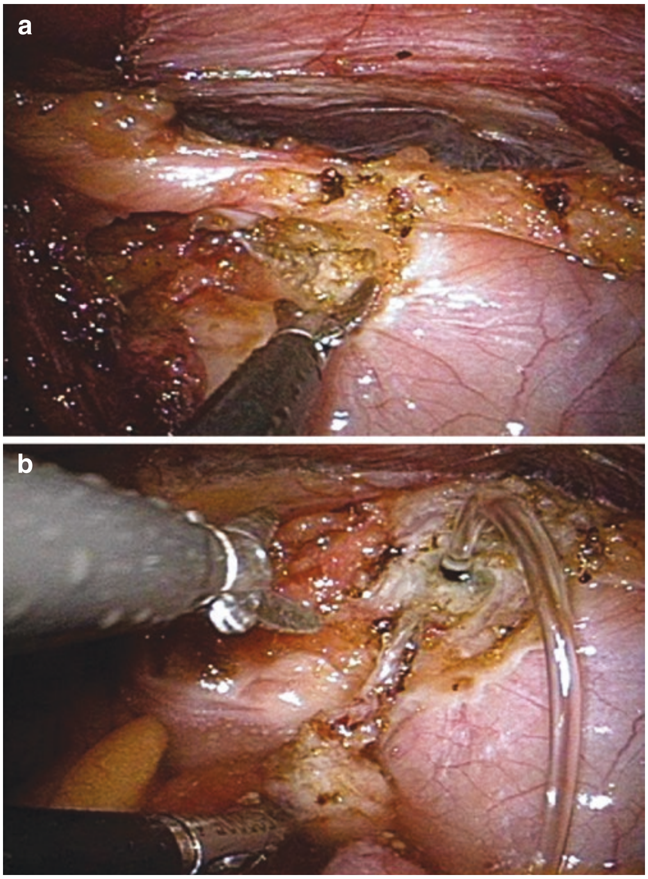

**Fig. 23.6** Intraoperative laparoscopic views. The distal part of urachal remnant is sharply dissected (**a**) and transected (**b**)

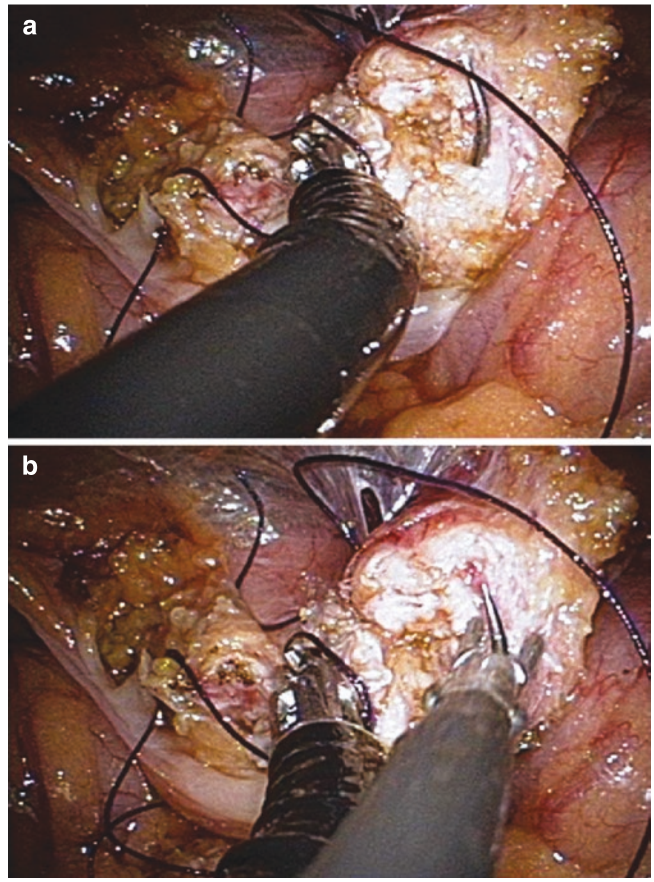

**Fig. 23.7** Intraoperative laparoscopic views. To bladder is closed with an absorbable running suture (**a**, **b**)

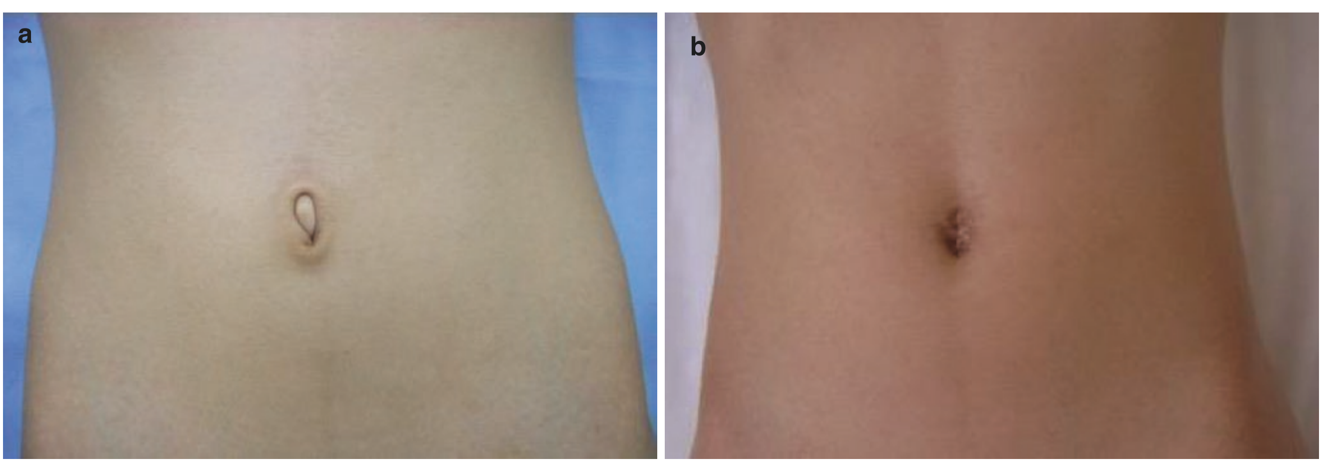

**Fig. 23.8** Patient's abdominal views. Preoperative (**a**) and postoperative (**b**) views of the patient's abdomen. The umbilical scar is almost invisible after surgery (**b**)

retrieved via the umbilical incision, and the single port is detached. To prevent umbilical hernia, the rectus fascia with peritoneum should be properly closed with several interrupted sutures. The umbilical base is sutured with the rectus fascia, and the incised skin is closed with an absorbable buried suture. A drain tube is usually not required. The indwelling urethral catheter is commonly removed approximately 1 week after surgery. The wound healing is completed within a few weeks, and the umbilical scar is almost invisible (Fig. 23.8a, b).

## 23.5 Conclusion

Umbilical LESS surgery for urachal remnant is an uncomplicated and efficient procedure for curing the disease, and this technique can provide satisfactory cosmetic results. In conclusion, LESS surgery for urachal remnants is an ideal minimally invasive technique.

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## References

Ahmed K, Wang TT, Patel VM, Nagpal K, Clark J, Ali M, Deeba S, Ashrafian H, Darzi A, Athanasiou T, Paraskeva P. The role of single-incision laparoscopic surgery in abdominal and pelvic surgery: a systematic review. Surg Endosc. 2011;25:378–96.

Araki M, Saika T, Araki D, Kobayashi Y, Uehara S, Watanabe T, Yamada K, Nasu Y, Kumon H. Laparoscopic management of complicated urachal remnants in adults. World J Urol. 2012;30:647–50.

Ashley RA, Inman BA, Routh JC, Rohlinger AL, Husmann DA, Kramer SA. Urachal anomalies: a longitudinal study of urachal remnants in children and adults. J Urol. 2007;178:1615–8.

Aull MJ, Afaneh C, Charlton M, Serur D, Douglas M, Christos PJ, Kapur S, Del Pizzo JJ. A randomized, prospective, parallel group study of laparoscopic versus laparoendoscopic single site donor nephrectomy for kidney donation. Am J Transplant. 2014;14:1630–7.

Autorino R, Brandao LF, Sankari B, Zargar H, Laydner H, Akça O, De Sio M, Mirone V, Chueh SC, Kaouk JH. Laparoendoscopic single-site (LESS) vs laparoscopic living-donor nephrectomy: a systematic review and meta-analysis. BJU Int. 2015;115:206–15.

Blichert-Toft M, Nielsen OV. Diseases of the urachus simulating intra-abdominal disorders. Am J Surg. 1971;122:123–8.

Blichert-Toft M, Koch F, Nielsen OV. Anatomic variants of the urachus related to clinical appearance and surgical treatment of urachal lesions. Surg Gynecol Obstet. 1973;137:51–4.

Cacciarelli AA, Kass EJ, Yang SS. Urachal remnants: sonographic demonstration in children. Radiology. 1990;174:473–5.

Cadeddu JA, Boyle KE, Fabrizio MD, Schulam PG, Kavoussi LR. Laparoscopic management of urachal cysts in adulthood. J Urol. 2000;164:1526–8.

Cutting CW, Hindley RG, Poulsen J. Laparoscopic management of complicated urachal remnants. BJU Int. 2005;96:1417–21.

Fan X, Lin T, Xu K, Yin Z, Huang H, Dong W, Huang J. Laparoendoscopic single-site nephrectomy compared with conventional laparoscopic nephrectomy: a systematic review and meta-analysis of comparative studies. Eur Urol. 2012;62:601–12.

Galati V, Donovan B, Ramji F, Campbell J, Kropp BP, Frimberger D. Management of urachal remnants in early childhood. J Urol. 2008;180:1824–6.

Garisto JD, Henriquez K, Pimentel MEE. Single-incision laparoscopy surgery excision of an infected urachal cyst: description of the technique. J Endourol Case Rep. 2017;3:7–9.

Gill IS, Canes D, Aron M, Haber GP, Goldfarb DA, Flechner S, Desai MR, Kaouk JH, Desai MM. Single port transumbilical (E-NOTES) donor nephrectomy. J Urol. 2008;180:637–41.

Gleason JM, Bowlin PR, Bagli DJ, Lorenzo AJ, Hassouna T, Koyle MA, Farhat WA. A comprehensive review of pediatric urachal anomalies and predictive analysis for adulturachal adenocarcinoma. J Urol. 2015;193:632–6.

Hirano D, Minei S, Yamaguchi K, Yoshikawa T, Hachiya T, Yoshida T, Ishida H, Takimoto Y, Saitoh T, Kiyotaki S, Okada K. Retroperitoneoscopic adrenalectomy for adrenal tumors via a single large port. J Endourol. 2005;19:788–92.

Hu Q, Gou Y, Sun C, Xu K, Xia G, Ding Q. A systematic review and meta- analysis of current evidence comparing laparoendoscopic single-site adrenalectomy and conventional laparoscopic adrenalectomy. J Endourol. 2013;27:676–83.

Humphrey JE, Canes D. Transumbilical laparoendoscopic single-site surgery in urology. Int J Urol. 2012;19:416–28.

Iida T, Kawa G, Takizawa N, Kawabata T, Komai Y, Kinoshita H, Matsuda T. Laparoendoscopic single-site surgery for urachal remnants. Asian J Endosc Surg. 2012;5:100–2.

Kilday PS, Finley DS. Robot-assisted excision of a urachal cyst causing dyspareunia and dysorgasmia: report of a case. J Endourol Case Rep. 2016;2:3–5.

Kim DK, Lee JW, Park SY, Kim YT, Park HY, Lee TY. Initial experience with robotic-assisted laparoscopic partial cystectomy in urachaldiseases. Korean J Urol. 2010;51:318–22.

Kojima Y, Hayashi Y, Yasui T, Itoh Y, Maruyama T, Kohri K. Laparoscopic management for urachal cyst in a 9-year-old boy. Int Urol Nephrol. 2007;39:771–4.

Kurien A, Rajapurkar S, Sinha L, Mishra S, Ganpule A, Muthu V, Sabnis R, Desai M. First prize: standard laparoscopic donor nephrectomy versus laparoendoscopic single-site donor nephrectomy: a randomized comparative study. J Endourol. 2011;25:365–70.

Lee SW, Lee JY, Kim KH, Ha US. Laparoendoscopic single-site surgery versus conventional laparoscopic varicocele ligation in men with palpable varicocele: a randomized, clinical study. Surg Endosc. 2012;26:1056–62.

Li Destri G, Schillaci D, Latino R, Castaing M, Scilletta B, Cataldo AD. The urachal pathology with umbilical manifestation: overview of laparoscopic technique. J Laparoendosc Adv Surg Tech A. 2011;21:809–14.

Lipskar AM, Glick RD, Rosen NG, Layliev J, Hong AR, Dolgin SE, Soffer SZ. Nonoperative management of symptomatic urachal anomalies. J Pediatr Surg. 2010;45:1016–9.

Matsuda T. Recent advances in urologic laparoscopic surgeries: laparoendoscopic single-site surgery, natural orifice transluminal endoscopic surgery, robotics and navigation. Asian J Endosc Surg. 2013;6:68–77.

McCollum MO, Macneily AE, Blair GK. Surgical implications of urachal remnants: presentation and management. J Pediatr Surg. 2003;38:798–803.

Minevich E, Wacksman J, Lewis AG, Bukowski TP, Sheldon CA. The infected urachal cyst: primary excision versus a staged approach. J Urol. 1997;157:1869–72.

Naiditch JA, Radhakrishnan J, Chin AC. Current diagnosis and management of urachal remnants. J Pediatr Surg. 2013;48:2148–52.

Nakamura H, Oshita A, Imamura Y, Sasaki M, Kohyama M, Tazaki T, Sugiyama Y, Daimaru Y, Nakamitsu A. Successful treatment of a patient with an infected urachal remnant via single-incisionlaparoscopic surgery: report of a case. Asian J Endosc Surg. 2016;9:86–8.

Neufang T, Ludtke FE, Lepsien G. Laparoscopic excision of an urachal fistula—a new therapy for a rare disorder. Min Invasive Ther. 1992;1:245–9.

Nogueras-Ocaña M, Rodríguez-Belmonte R, Uberos-Fernández J, Jiménez-Pacheco A, Merino-Salas S, Zuluaga-Gómez A. Urachal anomalies in children: surgical or conservative treatment? J Pediatr Urol. 2014;10:522–6.

Nozaki T, Ichimatsu K, Ito T, Yasuda K, Watanabe A, Fuse H. Laparoscopic excision of symptomatic urachal anomalies: a technique to restore the natural appearance of the umbilicus. J Laparoendosc Adv Surg Tech A. 2010;20:821–4.

Okegawa T, Odagane A, Nutahara K, Higashihara E. Laparoscopic management of urachal remnants in adulthood. Int J Urol. 2006;13:1466–9.

Ozbek SS, Pourbagher MA, Pourbagher A. Urachal remnants in asymptomatic children: gray-scale and color Doppler sonographic findings. J Clin Ultrasound. 2001;29:218–22.

Patrzyk M, Glitsch A, Schreiber A, von Bernstorff W, Hei- decke CD. Single-incision laparoscopic surgery as an option for the laparoscopic resection of an urachal fistula: First description of the surgical technique. Surg Endosc. 2010;24:2339–42.

Patrzyk M, Wilhelm L, Ludwig K, Heidecke CD, von Bernstorff W. Improved laparoscopic treatment of symptomatic urachal anomalies. World J Urol. 2013;31:1475–81.

Raman JD, Bensalah K, Bagrodia A, Stern JM, Cadeddu JA. Laboratory and clinical development of single keyhole umbilical nephrectomy. Urology. 2007;70:1039–42.

Rane A, Rao P, Rao P. Single-port-access nephrectomy and other laparoscopic urologic procedures using a novel laparoscopic port (R-port). Urology. 2008;72:260–3.

Richstone L, Rais-Bahrami S, Waingankar N, Hillelsohn JH, Andonian S, Schwartz MJ, Kavoussi LR. Pfannenstiel laparoendoscopic single-site (LESS) vs conventional multiport laparoscopic live donor nephrecomy: a prospective randomized controlled trial. BJU Int. 2013;112:616–22.

Robert Y, Hennequin-Delerue C, Chaillet D, Dubrulle F, Biserte J, Lemaitre L. Urachal remnants: sonographic assessment. J Clin Ultrasound. 1996;24:339–44.

Sato F, Shin T, Yuki H, Liang M, Ando T, Mori K, Nomura T, Mimata H. Umbilical laparoendoscopic single-site technique for complete excision of urachal remnant. J Laparoendosc Adv Surg Tech A. 2012;22:899–903.

Sato H, Furuta S, Tsuji S, Kawase H, Kitagawa H. The current strategy for urachal remnants. Pediatr Surg Int. 2015;31:581–7.

Sato F, Nakagawa K, Kawauchi A, Matsubara A, Okegawa T, Habuchi T, Yoshimura K, Hoshi A, Kinoshita H, Miyajima A, Naitoh Y, Inoue S, Itaya N, Narita S, Hanai K, Okubo K, Yanishi M, Matsuda T, Terachi T, Mimata H. Laparoendoscopic single-site surgeries: a multicenter experience of 469 cases in Japan. Int J Urol. 2017;24:69–74.

Schubert GE, Pavkovic MB, Bethke-Bedürftig BA. Tubular urachal remnants in adult bladders. J Urol. 1982;127:40–2.

Stopak JK, Azarow KS, Abdessalam SF, Raynor SC, Perry DA, Cusick RA. Trends in surgical management of urachal anomalies. J Pediatr Surg. 2015;50:1334–7.

Trondsen E, Reiertsen O, Rosseland AR. Laparoscopic excision of urachal sinus. Eur J Surg. 1993;159:127–8.

Tugcu V, Ilbey YO, Mutlu B, Tasci AI. Laparoendoscopic single-site surgery versus standard laparoscopic simple nephrectomy: a prospective randomized study. J Endourol. 2010;24:1315–20.

Tugcu V, Ilbey YO, Sonmezay E, Aras B, Tasci AI. Laparoendoscopic single-site versus conventional transperitoneal laparoscopic pyeloplasty: a prospective randomized study. Int J Urol. 2013;20:1112–7.

Turial S, Hueckstaedt T, Schier F, Fahlenkamp D. Laparoscopic treatment of urachal remnants in children. J Urol. 2007;177:1864–6.

Ueno T, Hashimoto H, Yokoyama H, Ito M, Kouda K, Kanamaru H. Urachal anomalies: ultrasonography and management. J Pediatr Surg. 2003;38:1203–7.

Wang J, Xue B, Shan YX, Cui Y, Tao W, Zhu J, Liu X, Yao Q. Laparoendoscopic single-site surgery with a single channel versus conventional laparoscopic varicocele ligation: a prospective randomized study. J Endourol. 2014;28:159–64.

Yamzon J, Kokorowski P, De Filippo RE, Chang AY, Hardy BE, Koh CJ. Pediatric robot-assisted laparoscopic excision of urachal cyst and bladder cuff. J Endourol. 2008;22:2385–8.

Yu JS, Kim KW, Lee HJ, Lee YJ, Yoon CS, Kim MJ. Urachal remnant diseases: spectrum of CT and US findings. Radiographics. 2001;21:451–61.

# 24 Laparoendoscopic Single-Site Pyeloplasty for Children

Akihiro Kawauchi, Kazuyoshi Johnin, Kenichi Kobayashi, Tetsuya Yoshida, and Susumu Kageyama

**Abstract**

Laparoendoscopic single-site (LESS) pyeloplasty is an attractive alternative procedure for uretero-pelvic junction (UPJ) obstruction. This procedure offers excellent cosmesis and similar surgical outcomes to conventional laparoscopic pyeloplasty. Pediatric patients are reported to be particularly suitable for LESS, because the size of the surgical incision in pediatric patients increases with growth. There are increasing numbers of reports of LESS being tried in pediatric cases. In this chapter, we describe our recent operative methods and important technical points for LESS pyeloplasty in children.

**Keywords**

Laparoendoscopic single-site surgery (LESS) · Pyeloplasty Pediatrics

## 24.1 Introduction

Laparoscopic surgery is a standard procedure as a minimally invasive treatment modality for many urological diseases even in children. Recently, laparoendoscopic single-site surgery (LESS) is attracting attention as a new technique with even lower minimal invasiveness, and its efficacy has been reported (Kaouk et al. 2011; Sato et al. 2017). Low body mass index and young female patients are thought to be good indications for LESS. Additionally, pediatric patients are reported to be particularly suitable for LESS, because the size of the surgical incision in pediatric patients increases with growth. Consequently, reports of LESS being tried in pediatric cases are increasing (Kawauchi et al. 2011; Marietti et al. 2010).

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LESS pyeloplasty was first reported by Desai et al. (2008), and in 2013, a worldwide multi-institutional analysis of 140 adult cases was published (Rais-Bahrami et al. 2013). In this multi-institutional study, the authors concluded that surgical outcomes were parallel to those of large published series of conventional laparoscopic pyeloplasty. In the field of pediatric urology, the number of the reports of LESS pyeloplasty is increasing, since this procedure provides excellent cosmetic result (Tugcu et al. 2011; Naitoh et al. 2014; Zhou et al. 2012; Yamada et al. 2016). A comparison between LESS and conventional laparoscopic procedures in adults and pediatric patients was also reported (Naitoh et al. 2014). The operative results were similar between the adults and pediatric groups both in the LESS and the conventional laparoscopic groups, while the faces pain scale showed less pain in the LESS group compared to that in the conventional laparoscopic group.

In this chapter, we describe our recent operative methods and important technical points for LESS pyeloplasty.

## 24.2 Indications

The indications for pyeloplasty were more than 5% decreased split renal function or a subjective symptom of back pain or urinary tract infection. LESS pyeloplasty is the first-choice procedure for patients with uretero-pelvic junction (UPJ) obstruction in our institute, except for those with a solitary kidney or a similar condition, and patients less than 1 year old. Conventional laparoscopic methods will be used in patients with solitary kidney and the open procedure is chosen for the patient <1 year old.

## 24.3 Patient Position

Patients are placed in the lateral position under general anesthesia. It is very important to place patients towards the operator side of the operating table, in order to avoid the obstruction of movement of the laparoscope by the table edge (Fig. 24.1).


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## 24.4 Incision and Port Placement

A 2–2.5 cm incision is made in the umbilicus, and an OctoPort® (DalimSurgNet, Korea) or a Gelpoint® (Applied Medical, USA) was inserted. An additional 2 mm needlescopic port was used for the operator's left hand (Fig. 24.2).

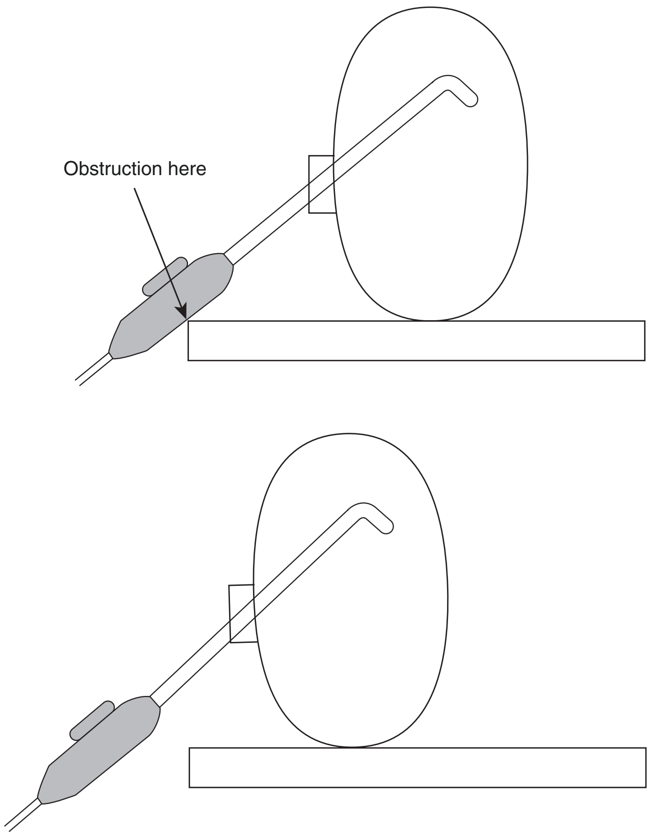



**Fig. 24.1** Patients should be placed on the operator side of the operating table, in order to avoid the obstruction of movement of the laparoscope by the table edge. (Reproduced with permission from the Japanese Journal of Pediatric Surgery, 2014, Tokyo Igakusha)

## 24.5 Instruments

A 5 mm flexible scope (Olympus Surgical, Japan), a 5 mm curved forceps and regular 5, 3 and 2 mm laparoscopic devices were used. The 5 mm curved forceps is mainly used by an assistant and the 2 mm devices are for the left hand of the operator.

## 24.6 Surgical Procedure

We use the transperitoneal approach. On observation of the intraabdominal cavity, the dilated renal pelvis can usually be visualized easily. For the right side, the peritoneum on or near the renal pelvis is cut and the retroperitoneal cavity is dissected. For the left side, the descending colon is mobilized, and the retroperitoneal cavity is dissected. As an option, the transmesenteric approach can be used. In this approach, a small incision is made in the mesenterium on the renal pelvis.

The UPJ is exposed, and the renal pelvis and the ureter are dissected sufficiently for anastomosis. The renal pelvis is pulled up by a traction suture from outside the body (Fig. 24.3). The renal pelvis is incised for dismembering. Just before completion of dismemberment, the ureter was spatulated for 2–3 mm as a landmark of the exact side of the spatulation (Fig. 24.4). After dismembering the UPJ, the ureteral spatulation is completed without excising the redundant portion of UPJ. The posterior anastomosis is started intermittently using a 5-0 monofilament suture. For this suture, traction of the unresected PUJ by the assistant's curved grasper is useful for the accurate approximation of the pelvis and ureter (Fig. 24.5). After one more interrupted suture, the posterior anastomosis is completed by a continuous suture with a 5-0 monofilament suture. A stent catheter is placed in an anterior manner through the single port, after

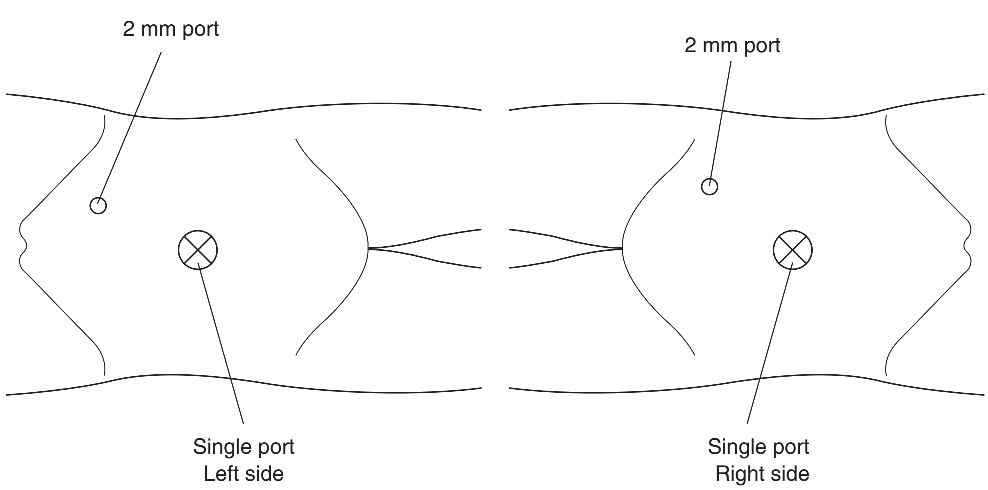



**Fig. 24.2** Port placement. (Reproduced with permission from the Japanese Journal of Pediatric Surgery, 2014, Tokyo Igakusha)

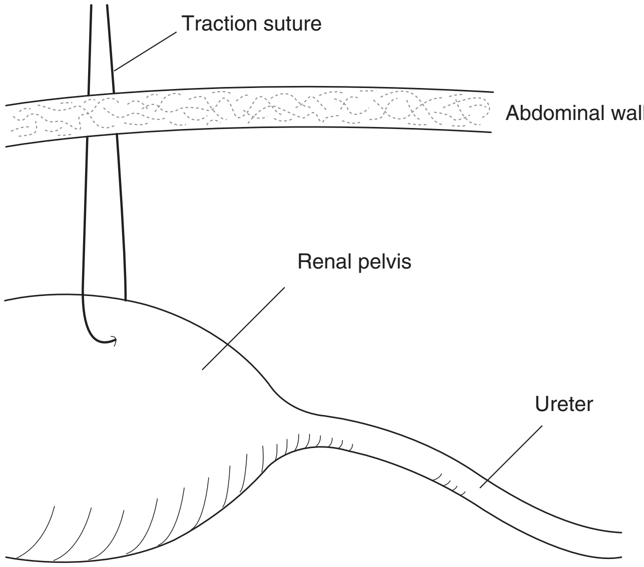



**Fig. 24.3** The renal pelvis is pulled up by a traction suture from outside the body. (Reproduced with permission from the Japanese Journal of Pediatric Surgery, 2014, Tokyo Igakusha)

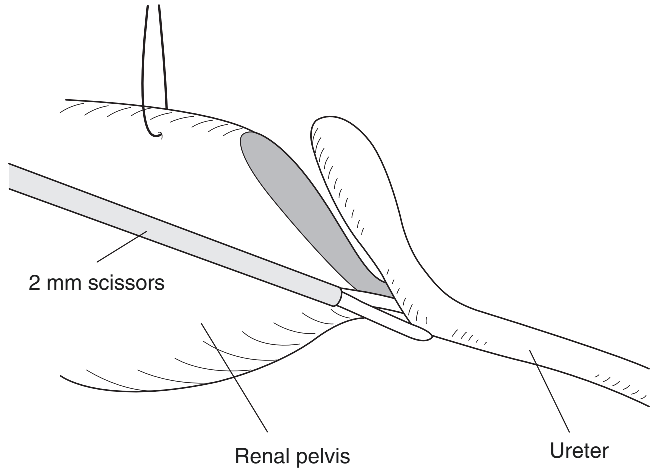
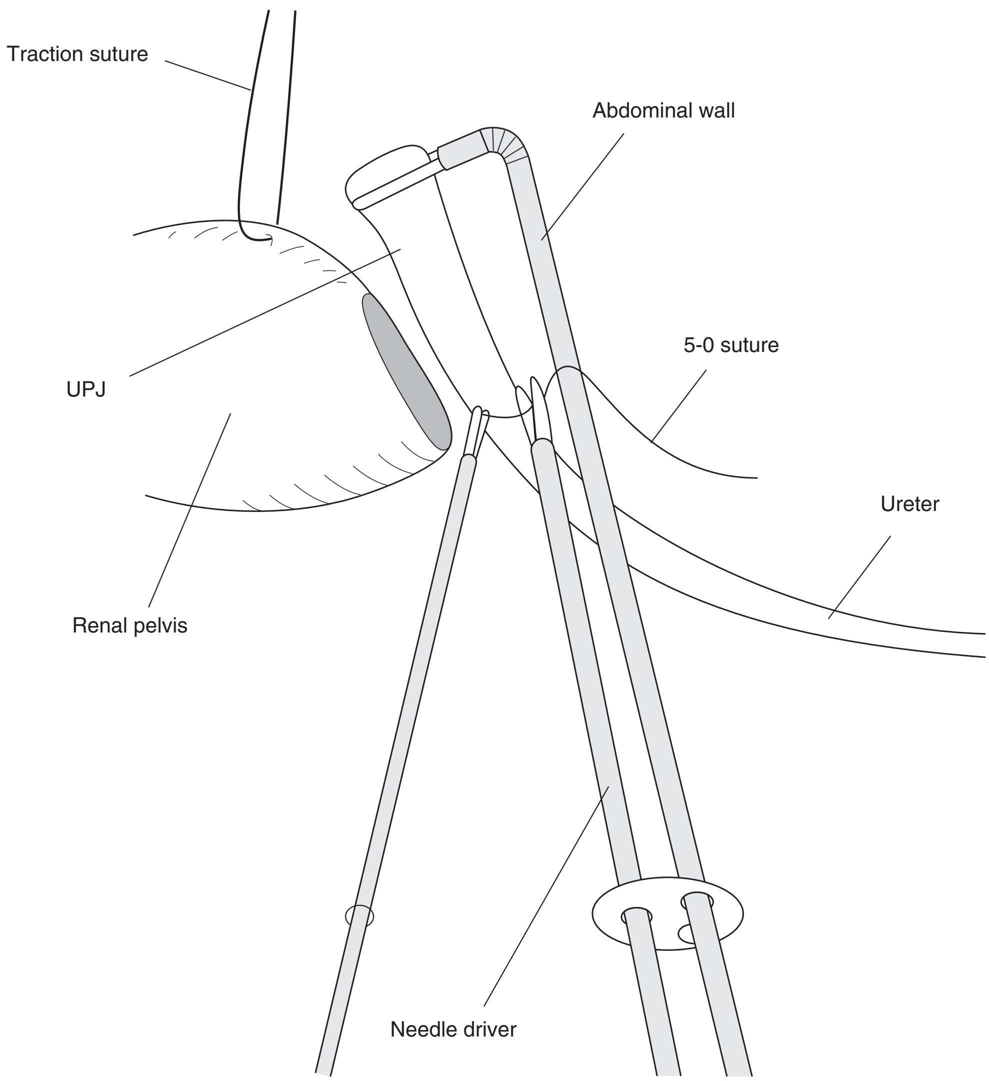



**Fig. 24.4** The renal pelvis is cut for dismembering. Just before completion of the dismemberment, the ureter was spatulated in a 2–3 mm as a landmark of the exact side of spatulation. (Reproduced with permission from the Japanese Journal of Pediatric Surgery, 2014, Tokyo Igakusha)

**Fig. 24.5** For this suture, traction of the unresected UPJ by the assistant's curved grasper is useful for the accurate attachment of the pelvis and ureter. (Reproduced with permission from the Japanese Journal of Pediatric Surgery, 2014, Tokyo Igakusha)



saline with indigo carmine has been filled in the bladder to avoid misallocation of the catheter. Then the UPJ is transected and removed. After loosening the traction suture, the anterior anastomosis is made with one interrupted and one continuous suture. A 6 Fr drain is placed through the 2 mm port. The peritoneum and rectus fascia are closed with absorbable sutures and the skin is closed with a subcuticular suture. The stent catheter is removed 4 weeks after the operation. The postoperative scars at 6 months after operation are shown in Fig. 24.6.

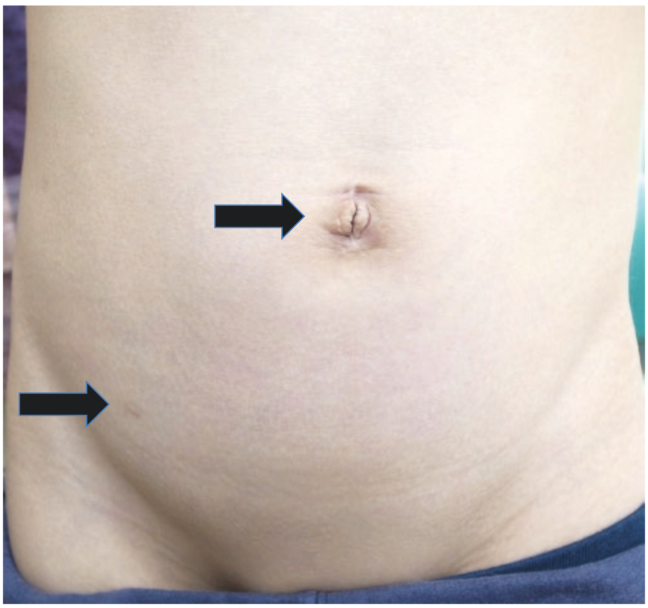


**Fig. 24.6** Operation scars 6 months after LESS Pyeloplasty (arrows)

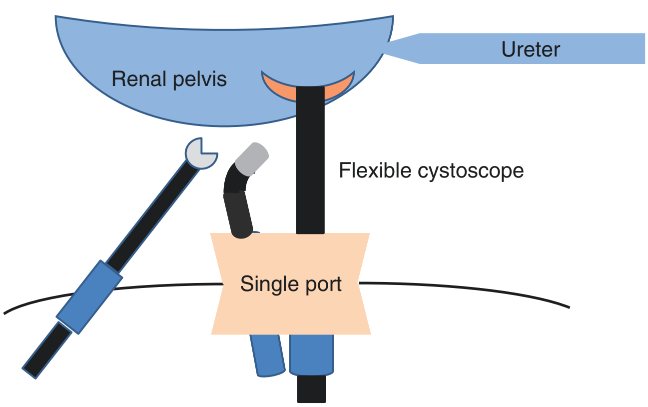



**Fig. 24.7** Nephrolithotomy performed concurrently with LESS pyeloplasty. Similar to the cases of standard laparscopic pyeloplasty, surgery was performed in the lateral position. After making a 15-mm-long umbilical incision, a LESS specific port, was indwelled

## 24.7 Nephrolithotomy Performed Concurrently with LESS Pyeloplasty

In patients with UPJ stenosis and renal stones, we reported nephrolithotomy performed concurrently with LESS pyeloplasty (Naitoh et al. 2014). An incision of approximately 1 cm was made along the presumed transection line of the renal pelvis. Through one of the channel ports a 16.5F flexible cystoscope (Olympus Surgical, Japan) was inserted. Under the direct vision of the nephroscope and outside vision of the laparoscope, the nephroscope was inserted into the renal pelvis through the 1 cm incision (Fig. 24.7). The stones were removed using basket forceps and stone grasping forceps. After the completion of pyelolithotomy, dismembered pyeloplasty was performed.

## 24.8 Discussion

We reported 21 pediatric LESS pyeloplasty cases (Yamada et al. 2016) in which the mean age was 6.5 (1–14) years. The mean operation time was 240 (178–363) min. In all cases, there were no intraoperative or postoperative complications and blood loss was minimal. The mean follow-up period was 35.1 (12–78) months. Postoperative renal pelvis dilatation was relieved in all patients, and the renal function was unchanged or improved in all patients compared with their condition before surgery. In comparison of the faces pain scale between LESS pyeloplasty and conventional laparoscopic pyeloplasty, the scale reached a peak on day 1 and gradually decreased in both LESS and conventional cases. The score on day 4 in the LESS group was significant lower than that in the conventional group. Postoperative photographs showed excellent cosmesis (Fig. 24.6).

In the report on four patients who underwent nephrolitotomy concurrently with LESS pyeloplasty (Naitoh et al. 2014), one was a child. The mean lithotomy time was 31 (20–50) min. No intraoperative or postoperative complications were observed. All patients became stone free. Postoperative ultrasound revealed that hydronephrosis improved in all patients. In all patients, resolution of the symptoms was confirmed after surgery.

Tugcu et al. reported 11 pediatric cases of LESS pyeloplasty (Tugcu et al. 2011). The mean age of the patients was 10 (2–17) years. The mean operation time was 182.5 (160–300) min, and the mean estimated blood loss including urine, was 97.3 (80–160) ml. Wound infection at the port site and urinary infection occurred in one case each. All parents seemed extremely satisfied with the postoperative cosmetic outcomes. The success rate was 100%.

Zhou et al. reported 24 pediatric patients with UPJO treated by transumbilical LESS pyeloplasty (Zhou et al. 2012).

The average age was 14 (2–62) months: 16 were males, and 18 had obstruction on the left side. The mean operative time was 145 min, and the average blood loss about 10 ml. No intraoperative complications occurred. The mean hospital time was 7 days. Two patients had postoperative urinary fistula, which naturally disappeared at the fourth and seventh days of post-operation, respectively. All patients showed clinical improvement in ultrasound examination and/or diuretic renal scintigraphy.

In EAU guidelines, pyeloplasty is mentioned to be an excellent indication for single-site surgery because of the tendency of LESS to minimize postoperative scars (Merseburger et al. 2013). The vast majority of complications have been reported during the initial ten cases. After this learning curve threshold, the complication rate appears to be similar to that of standard laparoscopic pyeloplasty. Actually, in a meta-analysis on LESS versus conventional laparoscopic pyeloplasty including adult cases by Brandao et al. (2015), LESS pyeloplasty is reported to offer comparable surgical and functional outcomes to conventional laparoscopic pyeloplasty while providing the potential advantages of less blood loss and lower analgesic requirements. In conclusion, despite being more technically challenging, LESS pyeloplasty can be regarded as a minimally invasive approach for patients seeking fewer incisional scars.

Taken together, LESS pyeloplasty offers similar surgical outcomes to conventional laparoscopic pyeloplasty, even in children. It is considered an excellent indication for pediatric patients whose surgery scars are in any case expected to expand with growth.

## References

Brandao LF, Laydner H, Zargar H, et al. Laparoendoscopic single site surgery versus conventional laparoscopy for transperitoneal pyeloplasty: a systematic review and meta-analysis. Urol Ann. 2015;7:289–96.

Desai MM, Rao PP, Aron M, et al. Scarless single port transumbilical nephrectomy and pyeloplasty: first clinical report. BJU Int. 2008;101(1):83–8.

Kaouk JH, Autorino R, Kim FJ, et al. Laparoendoscopic single-site surgery in urology : worldwide multi-institutional analysis of 1076 cases. Eur Urol. 2011;60:998–1005.

Kawauchi A, Naitoh Y, Miki T. Laparoendoscopic single-site surgery for pediatric patients in urology. Curr Opin Urol. 2011;21:303–8.

Marietti S, DeCambre M, Fairbanks T, et al. Early experience with laparoendoscopic single-site surgery in the pediatric urology patient population. J Endourol. 2010;24:1321–4.

Merseburger AS, Herrmann TRW, Shariat SF, et al. EAU guidelines on robotic and single-site surgery in urology. Eur Urol. 2013;64:277–91.

Naitoh Y, Kawauchi A, Kamoi K, et al. Nephrolithotomy performed concurrently with laparoendoscopic single-site pyeloplasty. Urology. 2014;83:243–6.

Naitoh Y, Kawauchi A, Yamada Y, et al. Laparoendoscopic single-site versus conventional laparoscopic pyeloplasty: a matched pair analysis. Int J Urol. 2014;21:793–6.

Rais-Bahrami S, Rizkala ER, Cadeddu JA, et al. Laparoendoscopic single-site pyeloplasty: outcomes of an international multi-institutional study of 140 patients. Urology. 2013;82:366–72.

Sato F, Nakagawa K, Kawauchi A, et al. Laparoendoscopic single-site surgeries: a multicenter experience of 469 cases in Japan. Int J Urol. 2017;24:69–74.

Tugcu V, Ilbey TO, Polat H, et al. Early experience with laparoendoscopic single-site pyeloplasty in children. J Pediatr Urol. 2011;7:187–91.

Yamada Y, Naitoh Y, Kobayashi K, et al. Laparoendoscopic single-site surgery for pediatric urologic disease. J Endourol. 2016;30:24–7.

Zhou H, Sun N, Zhang X, et al. Transumbilical laparoendoscopic single-site pyeloplasty in infants and children: initial experience and short-term outcome. Pediatr Surg Int. 2012;28:321–5.

# 25 ERAS Protocol in Minimal Invasive Urological Surgery

Ho-Yin Ngai, Chi-Man Ng, and Eddie Chan

**Abstract**

Radical cystectomy is the standard treatment for muscle-invasive bladder cancer. However, the procedure is associated with high complication rate up to 60%. Most of the patients have high surgical risk with advanced age and multiple comorbidities. Operation procedure is technically demanding. Hemorrhage, infection, bowel-related complications are common after radical cystectomy. Enhanced recovery after surgery (ERAS) protocol has been used in colorectal surgery and has been proven to reduce complication rates and shorten hospital stay. In recent years, many centres has implemented ERAS on patients undergoing radical cystectomy with good results. This chapter will review the current evidence and different aspects of ERAS.

**Keywords**

ERAS · Fast-track · Cystectomy · Bladder cancer

## 25.1 Introduction of Enhanced Recovery After Surgery (ERAS)

The concept of Enhanced Recovery After Surgery (ERAS) is to improve the quality of patients who undergoing surgery. In the literature, there are different terminologies, such as Enhanced Recovery Programme (ERP) and Fast Track Surgery, which describe the same concept. ERAS encompasses the patient's journey from prior to operation to discharge from hospital (Koo et al. 2013). The aim of ERAS pathway is to minimize the physiologic and psychological stress from surgery. The goal of making a positive impact on patient care from diagnosis, through surgery, to return of normal function can be achieved from ERAS (Collins et al. 2016). Evidence based medicine, multi-disciplinary team approach, standardized clinical protocol and continuous quality improvement through auditing serve as the necessary foundation for the success.

The idea of ERAS was first described in colorectal surgery, as a multi-modal programme involving the use of laparoscopic mini-invasive approach, optimized pain treatment, early oral intake and active mobilization, which successfully reduced the in-patient stay of patients by 2 days (Kehlet 1997). Since then, there are increasing evidences that ERAS reduces complication rates, shortens the length of hospital stay and the time to resume normal activities following major pelvic (Pedziwiatr et al. 2015). In United Kingdom, Enhanced Recovery Partnership Programme (ERPP) was introduced since April 2009 (Simpson et al. 2015). In 2009, Royal College of Surgeons issued guideline on enhanced recovery programme (Khan et al. 2009). Meta-analyses confirmed level 1 evidence that ERAS is associated with reduced of complication rate (50%) and shorter of hospital stay (2.5 days) (Varadhan et al. 2010).

The success of ERAS program sets the benchmark for different specialties, including urology. The experience of implementing ERAS protocol or pathway was reported on different urological procedures, including radical nephrectomy (Firoozfard et al. 2003; Recart et al. 2005), partial nephrectomy (Chughtai et al. 2008), radical cystectomy (Arumainayagam et al. 2008) and laparoscopic radical prostatectomy (Magheli et al. 2011). International associations and governing bodies publish their own ERAS guidelines and recommendations in recent years (Collins et al. 2016; Cerantola et al. 2013; The BAUS ERP Group 2015).

## 25.2 Spectrum of ERAS Application in Minimal Invasive Urological Surgery

Since the initial introduction for open colonic surgery in 1990s by Kehlet (1997), ERAS has been adopted by

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various specialties including gynecology, thoracic, vascular, pediatric and orthopedic surgery. In a recent meta-analysis involving 5099 patients from 38 studies across different specialties, enhanced recovery program reduces length of stay (LOS) and risk of all complications within 30 days. There was no difference in mortality rate, major complications rate or readmission rates (Nicholson et al. 2014).

Guidelines for perioperative management pathway for patients undergoing urologic procedure, including radical prostatectomy, radical cystectomy, radical nephrectomy, partial nephrectomy, pyeloplasty and nephroureterectomy has been developed (The BAUS ERP Group 2015). Radical Cystectomy is regarded as ultra-major surgery, which is technically demanding and associated with high perioperative morbidity rate (Chang et al. 2002; Shabsigh et al. 2009; Yuh et al. 2012; Musch et al. 2014) and a prolonged LOS (Kim et al. 2012). Patients with bladder cancer are generally advanced age with smoking habit, impaired kidney function and multiple comorbidities. This group of patient is particularly benefited from good perioperative management. However, ERAS protocol specific for radical cystectomy is lacking until recently. Practical guidelines have been published to describe in details on different elements of measures at different stages of patients' journey (Collins et al. 2016; Cerantola et al. 2013; The BAUS ERP Group 2015).

## 25.3 Defining Elements of ERAS and Existing ERAS Protocol

The principle of ERAS is to maintain homeostasis of patients' physiology during different challenges of treatment journey. Stress triggers inflammatory and endocrine responses, promotes the catabolism, leads to hyperglycemia and increases the insulin resistance, which prolongs patient's recovery (Ljungqvist and Jonathan 2012). Therefore, the ideal ERAS protocol should include every element to minimize the physical and psychological stress. It should involve multiple facets covering the pre-operative, during operation and post-operative periods. These measures are crucial in dampening the inflammatory response, maintenance of muscle strength and help in retaining adequate cellular functions. The role of endocrine and metabolic consideration in ERAS protocol would be important in this regard to ascertain body homeostasis, different measures are proposed such as shortening of fasting time, preoperative nutritional assessment and optimization, use of carbohydrate rich oral drink pre-operatively (Balteskard et al. 1998). The ultimate goal will be shortened the recovery journey.

## 25.4 ERAS Protocol

### 25.4.1 Pre-admission

#### 25.4.1.1 Pre-operative Counselling

Preoperative counseling is of utmost important for any operation. Comprehensive patient information such as the indications, nature and magnitude of the surgical procedures should be explained by surgeons and health care professionals. Treatment options, and potential complications, expected outcomes and anticipated recovery, by means of leaflet or video, are essential to empower the patients and their families to make informed decision and eventually enhance post-operative recovery (Gustafsson et al. 2013).

#### 25.4.1.2 Pre-operative Medical Optimization

**Smoking Cessation**

Cigarette smoking is a risk factor of different urological malignancy, including urothelial cancer and renal cell carcinoma. It is associated with impaired cardio-pulmonary function, impaired wound healing, coagulopathy, muscle dysfunction and immuno-suppression (Furlong 2005), in turns, increases the risk of perioperative complications. Smoking cessation before surgery is highly recommended (Cerantola et al. 2013; Furlong 2005).

Individual counselling and nicotine substitutions should be provided when patient agreed with smoking cessation, it should be started 4 weeks before surgery and continued 4 weeks postoperatively. With the abstinence from smoking, the incidence of post-operative infective complications, wound complications and cardiopulmonary complications will be significantly reduced (Tonnesen et al. 2009; Lindström et al. 2008). Cardiopulmonary exercise testing should be performed if indicated.

**Physical Conditioning and Muscle Training**

Optimization of underlying medical conditions and maintenance of good physical status would be vital for one to overcome the stress of surgery. Appropriate physical conditioning and muscle training are recommended from guideline (Nygren et al. 2012; Azhar et al. 2016).

#### 25.4.1.3 Nutritional Support

Patients with advanced bladder cancer usually presented with weight loss and cachexia. They are in particular prone to develop peri-operative complications and death after radical cystectomy (Karl et al. 2009; Gregg et al. 2011). The aim of nutritional support is to optimize the nutritional status before operation and maintain good nutrition throughout the pathway, eventually reduce the complications associated with malnutrition (The BAUS ERP Group 2015).

Apart from the general assessment such as body anthropometric measurements and basic biochemical evaluation (e.g. albumin levels), nutritional risk scores stratifications such as Nutritional Risks Scores Screening (Kondrup et al. 2003) and Malnutrition Universal Screening Tool (MUST) should be used to evaluate patient's nutritional conditions. Individualized assessment and advice from dietitian in the ERAS multi-disciplinary team would be invaluable in identifying malnourished patients for necessary pre-operative action. It is suggested that perioperative nutritional support is useful in reducing complications and improving patient's recovery following radical cystectomy (Bertrand et al. 2014).

Depending on patient's nutritional status, dietary supplement and use of immuno-enhanced nutrients including use of fish oils, nucleotides, arginine, glutamine, and structured lipid should also be considered if necessary (Hamilton-Reeves et al. 2016). Use of immunonutrition was shown from RCTs for the positive modulating effect on post-operative inflammatory responses and host defense mechanism after major operation including radical cystectomy, thus reducing the post-operative infection risks.

#### 25.4.1.4 Conduit and Neobladder Care by Urology Nurse

Pre-operative education should be provided to patients who will receive urinary diversion. Clean intermittent self-catheterization (CISC) technique should be taught before neobladder or orthotopic bladder reconstruction. If ileal conduit is planned, patient should have stoma care training including daily routines and stoma emergency handling before operation.

#### 25.4.1.5 Addressing Social Issues and Discharge Planning

Family and social supports for patients undergoing major operations are important. It should be well addressed prior to the surgery and involve different disciplines of ERAS team such as social workers and case nurses or manager to facilitate the discharge plan.

### 25.4.2 Day of Surgery

#### 25.4.2.1 Mechanical Bowel Preparation

Traditionally, mechanical bowel preparation is administered while preparing patients for colorectal surgery. It is based on the belief that mechanical bowel preparation may avoid massive contamination, so as to minimize anastomotic complications and infective soiling concern. However, meta-analysis from elective colorectal surgery literatures clearly showed that there is no advantage of using mechanical bowel preparation in minimizing anastomotic complications but imposing risks of electrolytes disturbance and rendering patient dehydrated starting pre-operatively (Güenaga et al. 2011). In radical cystectomy with urinary diversion, ileal or colonic segments are harvested for creation of conduits or neobladder. From the available prospective and retrospective studies, mechanical bowel preparation can be safely omitted before radical cystectomy (Hashad et al. 2012; Large et al. 2012; Xu et al. 2010).

#### 25.4.2.2 Pre-operative Alvimopan

Alvimopan is a peripherally active μ-opioid receptor antagonist. It is shown to enhance recovery of bowel and decrease the LOS in studies after surgery and radical cystectomy (Kauf et al. 2014; Lee et al. 2014; Tobis et al. 2014). Single dose Alvimopan is started 30 min to 5 h pre-operatively, and then continued as post-operative twice daily regimen till discharge or a maximum of 7 days. Lee et al. reported that Alvimopan has positive impact on first bowel movement, post-operative ileus-related complications and mean LOS (Lee et al. 2014).

#### 25.4.2.3 Pre-operative Fasting and Carbohydrate Loading

Prolonged fasting should be avoided before surgery. According to the Cochrane review of 22 randomized controlled trials (Brady et al. 2003), prolonged fasting did not reduce gastric content nor rise in pH of gastric acid. Instead, it leads to thirsty and hungry sensation, which triggers the inflammatory responses and increases the perioperative insulin resistance.

European Society of Anesthesiology recommends that patients are allowed to drink clear fluid including water, pulp free juice and tea or coffee without milk up to 2 h before elective surgery. Solid food should be withheld 6 h before the operations (Smith et al. 2011; Adding et al. 2015; Lambert and Carey 2016). The protocol can also be safely applied to patients with delayed gastric emptying, diabetics, gastroesophageal reflux, and in pregnant women (Smith et al. 2011).

#### 25.4.2.4 Carbohydrate Loading

The practice of fasting patients from midnight is used to avoid pulmonary aspiration; however, there is no evidence to support this. Preoperative fasting actually increases the metabolic stress, hyperglycemia and insulin resistance (Soop et al. 2004). It is recommended that oral clear fluid containing high content of complex carbohydrate should be consumed 2 h before induction of anaesthesia (Bilku et al. 2014; Hausel et al. 2001; Awad et al. 2013).

Carbohydrate loading increases peripheral glucose uptake, decreases the hunger, thirsty sensation and anxiety, and importantly, reduces insulin resistance significantly, which helps in improving post-operative muscle function and decreases lean body mass loss (Svanfeldt et al. 2007). Insulin resistance correlates with the magnitude of surgery, use of carbohydrate loading have been shown in meta-analysis to reduce the length of stay after open abdominal surgery (Awad et al. 2013).

#### 25.4.2.5 Pre-anaesthetic Medications

Beneficial effects of pre-anaesthetic medication on anxiety have not been established and pre-anaesthetic provision of anxiolytics increases postoperative sedation (Caumo et al. 2002). No sedative medication before operation is needed in particular use of long acting benzodiazepines, as their pharmacological properties may impair cognitive function and thus ability to resume eating, drinking and mobilizing in early post-operative period (Cerantola et al. 2013; Nygren et al. 2012; Smith et al. 2011; Walker and Smith 2009).

#### 25.4.2.6 Prophylaxis Against Deep Vein Thrombosis (DVT)

Thromboembolism is one of the common causes of 30 days mortality of surgery with oncological intent (Kakkar et al. 2005). DVT is one of the common complications after pelvic and cancer surgeries. The reported incidence of DVT, irrespective to surgical approaches, is 4–8% (Alberts et al. 2014; Kauffman et al. 2010).

Mechanical measures include use of compressive stocking and intermittent pneumatic compressive devices should be used. They are both non-invasive and effective in preventing DVT (Sachdeva et al. 2010). The benefit of perioperative prophylactic low-molecular-weight heparin (LMWH) is also established among abdominal and pelvic oncological surgery (Bergqvist et al. 2002). Although there is no available randomized controlled trials and prospective studies in bladder cancer patients, perioperative use of LMWH is also recommended from the latest consensus in the ERAS protocol of radical cystectomy (Khan et al. 2009).

#### 25.4.2.7 Antibiotic Prophylaxis

Use of prophylactic antibiotic for patients undergoing radical cystectomy is recommended according to EAU guideline (European Association of Urology 2015). Single dose administration, within 60 min before the surgical incision, should be adequate to achieve the purpose. Broad-spectrum antibiotics, like cephalosporin, are the agents of choice (Richards and Steinberg 2013). For certain antimicrobial agents, such as vancomycin and fluoroquinolones, they should be administered early and within 120 min before surgical incision as prolonged infusion time is required. When there is anticipated higher infection risk such as prolonged operation or massive blood loss, extended use of antibiotics may be required up to 72 h. Apart from antimicrobial agent, appropriate skin preparation with chlorhexidine-alcohol scrub is also recommended to prevent surgical site infection in patients undergoing radical cystectomy (Collins et al. 2016).

### 25.4.3 Peri- and Intra-operative

#### 25.4.3.1 Standard Anesthetic Protocol

Every team members have to pay attention to every detail to ascertain surgical safety of the patients. A standard anaesthetic protocol does help in minimizing the risks of patients and lead to smoother recovery. In the protocol, attentions have to be drawn on patient positioning, including the degree of Trendelenburg position, proper padding of pressure points, and pressure insufflation of pneumoperitoneum. If robot-assisted approach is used, the limited access from anaesthetists to the patients will be a concern and the need of intravenous extension lines will be necessary.

#### 25.4.3.2 Fluid Management

Goal-directed fluid therapy has been advocated in ERAS pathway. It involves the close peri-operative monitoring and manipulation of hemodynamic variables to adjust the fluid given to the patient. Stroke volume, cardiac output and oxygen delivery measurement can be monitored from esophageal Doppler monitoring, non-invasive hemodynamic monitoring or pulmonary artery catheter, therefore the fluid management can be titrated according to such hemodynamic parameters, thus maintaining a physiological fluid balance and achieve homeostasis by optimizing the oxygen delivery and tissue perfusion (Giglio et al. 2009; Pillai et al. 2011). Goal-directed fluid therapy has been applied in patients undergoing colorectal surgery. It is shown that it decreased post-operative nausea and vomiting and led to lower complication rate and shorter LOS (Giglio et al. 2009).

Fluid management is obviously more difficult and challenging in patients undergoing urological surgery, typically in procedures such as radical prostatectomy and radical cystectomy. Since the urine output cannot be easily and accurately measured intra-operatively, injudicious replacement may lead to excessive fluid overload and hypervolaemia, which may trigger splanchnic hypoperfusion resulting in post-operative ileus (Giglio et al. 2009). Restrictive deferred hydration with norepinephrine infusion during radical cystectomy has been shown in a randomized controlled trial that it significantly reduced the post-operative complication rate and shortened the LOS by 2 days (Wuethrich et al. 2014).

#### 25.4.3.3 Prevention of Hypothermia

Hypothermia leads to increased tissue oxygen consumptions and related risks of cardiac events, wound infection, post-operative ileus, peripheral coagulopathy and eventually causing longer LOS (Gustafsson et al. 2013; Kurz et al. 1996). Warmed intravenous fluid and forced air warming blanket are recommended to keep patients in normothermic state during operation (Collins et al. 2016).

#### 25.4.3.4 Management of Post-operative Nausea and Vomiting (PONV)

PONV is commonly reported adverse effect after anaesthesia. It increased risks of aspiration and even the risks of bleeding as a result of straining. Individuals having higher risks of developing PONV should be identified, in particular patients who are non-smoker, female patients, patients with motion sickness and patients using opioid.

Multi-modal anti-emesis prophylaxis should be considered. There are different anti-emetic agents available such as nitrous oxide plus propofol, ondansetron, metoclopramide and dexamethasone. In addition to the medical therapy, meta-analysis by Giglio et al. also showed that the use of goal-directed fluid therapy is effective in reducing PONV in patients undergoing colorectal surgery (Giglio et al. 2009). The practice of stenting across ureteroileal anastomosis was reported to minimize the PONV experienced by the patients (Mattei et al. 2008).

#### 25.4.3.5 Post-operative Pain Management

Poly-pharmacologic opioid sparing analgesia is the essence of pain control for patients undergoing surgery. Satisfactory pain control counteracts against insulin resistance and enhances muscle strength, thus facilitate early mobilization of patients. It is known that the use of opiates leads to PONV and might impair cognitive function, therefore hinders the progress of recovery. Use of opiate-based Patient-Controlled Analgesia (PCA) should be avoided as it is shown to delay early discharge. Regular uses of oral or intravenous paracetamol with or without using non-steroidal anti-inflammatory drugs are now integrated in ERAS protocol to achieve adequate pain control (The BAUS ERP Group 2015).

#### 25.4.3.6 Surgical Approach

The beauty of minimal invasive surgery means more than better cosmetic results with the smaller incision, it is associated with less analgesic requirement, less bowel handling and less blood loss (Nix et al. 2010), hence better recovery and shorter LOS.

However, it is still too early to conclude whether the available minimal invasive surgery do better compared with the open counterpart performed in ERAS program. There are scanty evidence to demonstrate the long term oncological outcome and complications profile of robotic assisted radical cystectomy. At the moment, the recommendation from ERAS society and ERUS scientific working group on radical cystectomy is that robotic assisted radical cystectomy is not recommended outside a trial setting until long term results are available (Collins et al. 2016; Cerantola et al. 2013).

#### 25.4.3.7 Ureteroileal Anastomosis Drainage

Although stenting across ureteroileal anastomosis helps in minimizing the PONV experienced by the patients (Mattei et al. 2008), there is no optimal timing reported regarding the removal of such stents in ileal conduit or orthotopic neobladder urinary diversion. For ileal conduit, majority (64%) would like to have stents removal in 8–14 days, while minority preferred stent removal in 5–7 days. For orthotopic bladder reconstruction, 32%, 36% and 32% of expert would prefer stent removal in 5–7 days, 8–14 days and more than 14 days respectively (Collins et al. 2016).

#### 25.4.3.8 Resection Site Drainage

There is no clear evidence from randomized studies to assess the role of resection site drainage after radical cystectomy. It is advised that a passive drainage tube should be placed and can be removed in early post-operative day if there is no suspicion of urinary leakage. In general, surgical drain should be removed when it completed its purpose. ERAS pathway aims to minimize the use of drain, so as to reduce the analgesic requirement and the limitation on mobilization of patients (The BAUS ERP Group 2015). Practically drain fluid can be obtained and routinely sent for creatinine level in second post-operative day, and the drain can then be removed if result is not indicative of urine leakage (Collins et al. 2016).

### 25.4.4 Post-operative

#### 25.4.4.1 Naso-Gastric Tube

Early removal and avoidance of naso-gastric tube is recommended. This reduces post-operative complications and allows early return of normal bowel function after surgery according to the recent meta-analysis. Early removal of nasogastric tube shortened the duration of post-operative ileus, decreased the risk of pulmonary complication, increased patient's quality of life, without increasing the anastomotic leakage risk (Rao et al. 2011). The safety of this practice is also demonstrated in radical cystectomy series with less pharyngolaryngitis, respiratory infection and vomiting (Donat et al. 1999; Nelson et al. 2007).

#### 25.4.4.2 Early Feeding

There are traditional worries that oral feeding might jeopardize healing of bowel anastomosis and thus hindering the practice of early resumption of diet to post-operative patients. A meta-analysis including thirteen randomized controlled trials reviewed the result of early commencement of diet (within 24 h) in patients undergoing gastrointestinal surgery, there was a significant reduction of incidence of anastomotic dehiscence, fewer post-operative complications (paralytic ileus, pneumonia, infectious complications) and lower mortality in early feeding group. This meta-analysis also included patients undergoing radical cystectomy and urinary diversion (Lewis et al. 2009). In addition, early feeding triggers the brain-gut axis to positively affect higher cognitive function such as feeling and decision making (Al Omran and Aziz 2014).

Current guideline recommended the early resumption of normal oral food intake after operation, there is no evidence to support prolonged fasting after radical cystectomy (Collins et al. 2016). Total parental nutrition should never be a routine for those patients unless there is an anticipated prolonged delay in enteral nutrition following surgery.

#### 25.4.4.3 Early Mobilization

The aim of early mobilization is to promote return to normal activity as soon as possible after surgery. Prolonged bed rest may cause deep vein thrombosis and associated pulmonary embolism, decrease muscle strength, atelectasis, respiratory function compromise, ileus and increase insulin resistance. Therefore it is advised in ERAS pathway to have early mobilization. Practically, some may advocate out of bed 2 h in post-operative on day 1 and 6 h in post-operative on day 2.

There is one RCT evaluating the impact of pre- and post-operative rehabilitation compared with standard mobilization in patients undergoing RC. No significant difference in LOS, complications, readmissions, and mortality is shown in patients in exercise programme, yet they were significantly more mobile in the first 7 days with improved ability to perform personal activities (Jensen et al. 2015).

#### 25.4.4.4 Ileus Prophylaxis

Multi-modal preventive approach is recommended to prevent post-operative ileus. Avoidance of opiate, early enteral nutrition, minimizing intravenous fluid, use of anti-emetics and early mobilization would contribute. Pruthi et al. found a beneficial effect of empiric metoclopramide use, avoidance of nonnarcotic analgesics, post-operative chewing gum use and early institution of an oral diet in bowel function recovery (Pruthi et al. 2010).

Gum chewing was shown in meta-analysis to be effective in decreasing the time to the first flatus and the time to first bowel movement, yet no shortening of LOS (Fitzgerald and Ahmed 2009). The postulation of its effect in reducing ileus is related to the cephalo-vagal stimulation which promotes the gastric motility and stimulates saliva production and pancreatic juice secretion leading to the early recovery of bowel function (Asao et al. 2002). Cochrane review also showed that the use of gum chewing after colorectal surgery reduced the time to first flatus by 12.5 h and reduced the time to bowel movement by 12.7 h. And importantly, gum chewing is well tolerated to most patients and at minimal cost difference (Short et al. 2015).

Gum chewing three times a day starting from post-operative day 1 shortened the time to return to normal bowel function in patients undergoing radical cystectomy (Kouba et al. 2007). Similar effect has also been reported in robotic assisted radical cystectomy series from a prospective randomized trial (Choi et al. 2011). Koupparis et al. studied 56 radical cystectomy patients before and 56 patients after implementation of chewing gum into their enhanced recovery protocol for radical cystectomy, found a significant reduction in the time to return of bowel function was observed in patients using chewing gum post-operatively (4 vs 6 days, $p < 0.0001$) (Koupparis et al. 2010).

## 25.5 Clinical Outcome and Impact of ERAS Protocol

### 25.5.1 LOS

Djaladat and Daneshmand reported a study of 124 patients underwent radical cystectomy with ERAS and 81 historical cohort, revealing a significant shortening of hospital length of stay (4 vs 8 days, $p < 0.001$) (Djaladat and Daneshmand 2014).

Another study from Southmead Hospital in Bristol showed a reduction of LOS from 15 days to 12 days ($p < 0.01$) after ERAS implementation in 56 radical cystectomy patients compared with a cohort of 56 without ERAS, without significant difference in readmission rate, morbidities and mortality (Arumainayagam et al. 2008).

There is a recent report on the results of a non-randomized quasi-experimental study, Quality Improvement in Cystectomy Care with Enhanced Recovery (QUICCER) Study, a significantly shorter median LOS was shown in group of patients undergoing enhanced recovery pathway (5 days vs 8 days, $p < 0.001$) (Baack Kukreja et al. 2017).

### 25.5.2 Re-admission Rate

There is a retrospective study evaluated the outcome of 207 radical cystectomy patients on ERAS protocol at the Stanford University Hospital and 177 counterpart historical cohort. ERAS protocol was shown to have a decrease of median LOS for 2 days, without increasing the re-admission rates since its introduction. The 30-days and 90-days readmission rates in the post- and pre-ERAS groups are 20% versus 27% and 27% versus 30% respectively (Altobelli et al. 2017).

### 25.5.3 Mortality

There is no available evidence of ERAS showing either positive or negative impact on post-operative mortality on radical cystectomy patients.

### 25.5.4 Cost

The evidence on cost-effectiveness of ERAS on urological surgery is scanty. One study estimated the practice of using chewing gum following colectomy to be cost effective as it could reduce the hospital stay and the associated costs (Schuster et al. 2006).

A cost effectiveness study on colonic surgery patients from New Zealand found a significant reduction in total hospital stay, intravenous fluid use, and duration of epidural use in the ERAS group, as well as significantly fewer complications, resulting in a cost-saving of approximately NZ$6900 per patient after subtracting the implementation cost (Sammour et al. 2010).

One recent retrospective study from US showed no increase in median total charge from implementing ERAS on radical cystectomy (US$60,055 in ERAS vs US$59,539 in control, $p = 0.175$). Although a higher medication cost was noted from implementing ERAS, there were more savings from laboratory, radiology, supplies, physiotherapy & miscellaneous charges (Chipollini et al. 2017).

## 25.6 Limitations and Future Development of ERAS

From the limited available evidence on ERAS in urological surgery, recovery of bowel function and shorter hospital stay appear to be more evident. There is no strong evidence of reduction of complications or mortality. Impact of patient satisfaction assessment is not well studied. Cost effectiveness analysis evaluating the cost saving effect of ERAS in urological surgery is scarce as well.

ERAS is not widely practiced in every part of the world in field of Urology yet. Even though RC is the most widely studied procedure regarding ERAS implementation, the experience is still limited to certain Urology centers. There are foreseeable potential barriers for widespread application of ERAS such as insufficient data to support ERAS use due to heterogeneous study design, and the difficulty in identifying which elements in ERAS protocol are really determining to positive outcome of ERAS. Moreover, different centers have different degree of administrative concern, and there are resistances from traditional and conventional practices during introduction of ERAS.

Nevertheless, we observed the expansion of ERAS in field of Urological procedures in the past decade. Apart from radical cystectomy, there are different successful experience in applying concept of ERAS or fast tract surgery, including transperitoneal nephrectomy (Firoozfard et al. 2003), laparoscopic nephrectomy (Recart et al. 2005), open partial nephrectomy (Chughtai et al. 2008), laparoscopic radical prostatectomy (Magheli et al. 2011). Although the current evidence in minimal invasive urologic surgery are still limited, we believe the concept of ERAS is going to improve the quality of care, more data will soon be available to justify and establish the role of ERAS in minimal invasive urologic surgery.

ERAS should not be merely regarded as a tool of reduction in LOS and saver of health care cost. Instead, ERAS is facilitating holistic care during the treatment journey, before and after our surgical treatment. The implementation of ERAS can ensure good communication is present among the anaesthetists, surgeons and the whole ERAS team. On the other hand, ERAS contributes mutual benefit to patients and their families, surgical quality, clinical managing teams and the hospitals.

## References


Adding C, Collins JW, Laurin O, Hosseini A, Wiklund NP. Enhanced recovery protocols (ERP) in robotic cystectomy surgery. Review of current status and trends. Curr Urol Rep. 2015;16(5):32.

Al Omran Y, Aziz Q. The brain-gut axis in health and disease. Adv Exper Med Biol. 2014;817:135–53.

Alberts BD, Woldu SL, Weinberg AC, Danzig MR, Korets R, Badani KK. Venous thromboembolism after major urologic oncology surgery: a focus on the incidence and timing of thromboembolic events after 27,455 operations. Urology. 2014;84:799–806.

Altobelli E, Buscarini M, Gill HS, Skinner EC. Readmission rate and causes at 90-day after radical cystectomy in patients on early recovery after surgery protocol. Bladder Cancer. 2017;3(1):51–6.

Arumainayagam N, McGrath J, Jefferson KP, Gillatt DA. Introduction of an enhanced recovery protocol for radical cystectomy. BJU Int. 2008;101(6):698–701.

Asao T, Kuwano H, Nakamura J, Morinaga N, Hirayama I, Ide M. Gum chewing enhances early recovery from postoperative ileus after laparoscopic colectomy. J Am Coll Surg. 2002;195(1):30–2.

Awad S, Varadhan KK, Ljungqvist O, Lobo DN. A meta-analysis of randomised controlled trials on preoperative oral carbohydrate treatment in elective surgery. Clin Nutr. 2013;32:34–44.

Azhar RA, Bochner B, Catto J, Goh AC, Kelly J, Patel HD, et al. Enhanced recovery after urological surgery: a contemporary systermatic review of outcomes, key elements, and research needs. Eur Urol. 2016;70:176–87.

Baack Kukreja JE, Kiernan M, Schempp B, Siebert A, Hontar A, Nelson B, et al. Quality Improvement in Cystectomy Care with Enhanced Recovery (QUICCER) study. BJU Int. 2017;119:38–49.

Balteskard L, Unneberg K, Mjaaland M, Jenssen TG, Revhaug A. Growth hormone and insulin like growth factor 1 promote intestinal uptake and hepatic release of glutamine in sepsis. Ann Surg. 1998;228(1):131–9.

Bergqvist D, Agnelli G, Cohen AT, Eldor A, Nilsson PE, Le Moigne-Amrani A, et al. Duration of prophylaxis against venous thromboembolism with enoxaparin after surgery for cancer. N Engl J Med. 2002;346:975–80.

Bertrand J, Siegler N, Murez T, Poinas G, Segui B, Ayuso D, et al. Impact of preoperative immunonutrition on morbidity following cystectomy for bladder cancer: a case-control pilot study. World J Urol. 2014;32:233–7.

Bilku DK, Dennison AR, Hall TC, Metcalfe MS, Garcea G. Role of preoperative carbohydrate loading: a systematic review. Ann R Coll Surg Engl. 2014;96:15–22.

Brady M, Kinn S, Stuart P. Preoperative fasting for adults to prevent perioperative complications. Cochrane Database Syst Rev. 2003;(4):CD004423.

Caumo W, Hidalgo MP, Schmidt AP, Iwamoto CW, Adamatti LC, Bergmann J, et al. Effect of pre-operative anxiolysis on postoperative pain response in patients undergoing total abdominal hysterectomy. Anaesthesia. 2002;57(8):740–6.

Cerantola Y, Valerio M, Persson B, Jichlinski P, Ljungqvist O, Hubner M, et al. Guidelines for perioperative care after radical cystectomy for bladder cancer: Enhanced Recovery After Surgery (ERAS) Society recommendations. Clin Nutr. 2013;32:879–87.

Chang SS, Cookson MS, Baumgartner RG, Wells N, Smith JA Jr. Analysis of early complications after radical cystectomy: results of collaborative care pathway. J Urol. 2002;167(5):2012–6.

Chipollini J, Tang DH, Hussein K, Patel SY, Garcia-Getting RE, Pow-Sang JM, et al. Does implementing an enhanced recovery after surgery protocol increase hospital charges? Comparisons from a radical cystectomy program at a specialty cancer center. Urology. 2017;105:108–12.

Choi H, Kang SH, Yoon DK, Kang SG, Ko HY, du Moon G, et al. Chewing gum has a stimulatory effect on bowel motility in patients after open or robotic radical cystectomy for bladder cancer: a prospective randomized comparative study. Urology. 2011;77(4):884–90.

Chughtai B, Abraham C, Finn D, Rosenberg S, Yarlagadda B, Perrotti M. Fast track open partial nephrectomy: reduced postoperative length of stay with a goal-directed pathway does not compromise outcome. Adv Urol. 2008:507543.

Collins JW, Patel H, Adding C, Annerstedt M, Dasgupta P, Khan SM, et al. Enhanced recovery after robot-assisted radical cystectomy: EAU robotic urology section scientific working group consensus view. Eur Urol. 2016;70(4):649–60.

Djaladat H, Daneshmand S. Enhanced recovery pathway following radical cystectomy. Curr Opin Urol. 2014;24(2):135–9.

Donat SM, Slaton JW, Pisters LL, Swanson DA. Early nasogastric tube removal combined with metoclopramide after radical cystectomy and urinary diversion. J Urol. 1999;162:1599–602.

European Association of Urology. Guideline on urological infection. 2015. https://uroweb.org/wp-content/uploads/19-Urological-infections_LR2.pdf

Firoozfard B, Christensen T, Kristensen JK, Mogensen S, Kehlet H. Fast-track open transperitoneal nephrectomy. Scand J Urol Nephrol. 2003;37(4):305–8.

Fitzgerald JE, Ahmed I. Systematic review and meta-analysis of chewing-gum therapy in the reduction of postoperative paralytic ileus following gastrointestinal surgery. World J Surg. 2009;33:2557–66.

Furlong C. Smoking cessation and its effects on outcomes of surgical interventions. 2005. http://www.thehealthwell.info/node/27981. Accessed 30 Oct 2017.

Giglio MT, Marucci M, Testini M, Brienza N. Goal-directed hemodynamic therapy and gastrointestinal complications in major surgery: a meta-analysis of randomized controlled trials. Br J Anaesth. 2009;103:637–46.

Gregg JR, Cookson MS, Phillips S, Salem S, Chang SS, Clark PE, et al. Effect of preoperative nutritional deficiency on mortality after radical cystectomy for bladder cancer. J Urol. 2011;185(1):90–6.

Güenaga KF, Matos D, Wille-Jørgensen P. Mechanical bowel preparation for elective colorectal surgery. Cochrane Database Syst Rev. 2011;(9):CD001544.

Gustafsson UO, Scott MJ, Schwenk W, Demartines N, Roulin D, Francis N, McNaught CE, et al. Guidelines for perioperative care in elective colonic surgery: Enhanced Recovery After Surgery (ERAS) Society recommendations. World J Surg. 2013;37:259–84.

Hamilton-Reeves JM, Bechtel MD, Hand LK, Schleper A, Yankee TM, Chalise P, et al. Effects of immunonutrition for cystectomy on immune response and infection rates: a pilot randomized controlled clinical trial. Eur Urol. 2016;69:389–92.

Hashad MM, Atta M, Elabbady A, Elfiky S, Khattab A, Kotb A. Safety of no bowel preparation before ileal urinary diversion. BJU Int. 2012;110:E1109–13.

Hausel J, Nygren J, Lagerkranser M, Hellström PM, Hammarqvist F, Almström C, Lindh A, Thorell A, Ljungqvist O. A carbohydrate-rich drink reduces preoperative discomfort in elective surgery patients. Anesth Analg. 2001;93(5):1344–50.

Jensen BT, Petersen AK, Jensen JB, Laustsen S, Borre M. Efficacy of a multiprofessional rehabilitation programme in radical cystectomy pathways: a prospective randomized controlled trial. Scand J Urol. 2015;49:133–41.

Kakkar AK, Haas S, Wolf H, Encke A. Evaluation of perioperative fatal pulmonary embolism and death in cancer surgical patients: the MC-4 cancer substudy. Thromb Haemost. 2005;94:867–71.

Karl A, Rittler P, Buchner A, Fradet V, Speer R, Walther S, et al. Prospective assessment of malnutrition in urologic patients. Urology. 2009;73:1072–6.

Kauf TL, Svatek RS, Amiel G, Beard TL, Chang SS, Fergany A, et al. Alvimopan, a peripherally acting μ-opioid receptor antagonist, is associated with reduced costs after radical cystectomy: economic analysis of a phase 4 randomized, controlled trial. J Urol. 2014;s191:1721–7.

Kauffman EC, Ng CK, Lee MM, Otto BJ, Portnoff A, Wang GJ, et al. Critical analysis of complications after robotic-assisted radical cystectomy with identification of preoperative and operative risk factors. BJU Int. 2010;105:520–7.

Kehlet H. Multimodal approach to control postoperative pathophysiology and rehabilitation. Br J Anaesth. 1997;78:606–17.

Khan S, Gatt M, Horgan A, Anderson I, MacFie J. Guidelines for implementation of enhanced recovery protocols. 2009. http://www.asgbi.org.uk/en/publications/issues_in_professional_practice.cfm

Kim SP, Shah ND, Karnes EJ, Weight CJ, Frank I, Moriarty JP, et al. The implications of hospital acquired adverse events on mortality, length of stay and costs for patients undergoing radical cystectomy for bladder cancer. J Urol. 2012;187(6):2011–7.

Kondrup J, Rasmussen HH, Hamberg O, Stanga Z, Ad Hoc ESPEN Working Group. Nutritional risk screening (NRS 2002): a new method based on an analysis of controlled clinical trials. Clin Nutr. 2003;22:321–36.

Koo V, Brace H, Shahzad A, Lynn N. The challenges of implementing Enhanced Recovery Programme in urology. Int J Urol Nurs. 2013;7(2):106–10.

Kouba EJ, Wallen EM, Pruthi RS. Gum chewing stimulates bowel motility in patients undergoing radical cystectomy with urinary diversion. Urology. 2007;70(6):1053–6.

Koupparis A, Dunn J, Gillatt D, Rowe E. Improvement of an enhanced recovery protocol for radical cystectomy. J Clin Urol. 2010;3(6):237–40.

Kurz A, Sessler DI, Lenhardt R. Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. Study of wound infection and temperature group. N Engl J Med. 1996;334:1209–15.

Lambert E, Carey S. Practice guideline recommendations on perioperative fasting: a systematic review. JPEN J Parenter Enteral Nutr. 2016;40(8):1158–65.

Large MC, Kiriluk KJ, DeCastro GJ, Patel AR, Prasad S, Jayram G, et al. The impact of mechanical bowel preparation on postoperative complications for patients undergoing cystectomy and urinary diversion. J Urol. 2012;188:1801–5.

Lee CT, Chang SS, Kamat AM, Amiel G, Beard TL, Fergany A, et al. Alvimopan accelerates gastrointestinal recovery after radical cystectomy: a multicenter randomized placebo-controlled trial. Eur Urol. 2014;66:265–72.

Lewis SJ, Andersen HK, Thomas S. Early enteral nutrition within 24 h of intestinal surgery versus later commencement of feeding: a systematic review and meta-analysis. J Gastrointest Surg. 2009;13:569–75.

Lindström D, Sadr Azodi O, Wladis A, Tønnesen H, Linder S, Nåsell H, et al. Effects of a perioperative smoking cessation intervention on postoperative complications: a randomized trial. Ann Surg. 2008;248(5):739–45.

Ljungqvist O, Jonathan E. Rhoads lecture 2011: insulin resistance and enhanced recovery after surgery. JPEN J Parenter Enteral Nutr. 2012;36(4):389–98.

Magheli A, Knoll N, Lein M, Hinz S, Kempkensteffen C, Gralla O. Impact of fast-track postoperative care on intestinal function, pain, and length of hospital stay after laparoscopic radical prostatectomy. J Endourol. 2011;25(7):1143–7.

Mattei A, Birkhaeuser FD, Baermann C, Warncke SH, Studer UE. To stent or not to stent perioperatively the ureteroileal anastomosis of ileal orthotopic bladder substitutes and ileal conduits? Results of a prospective randomized trial. J Urol. 2008;179:582–6.

Musch M, et al. Comparison of early postoperative morbidity after robot-assisted and open radical cystectomy: results of a prospective observational study. Brit J Urol. 2014;113:458–67.

Nelson R, Edwards S, Tse B. Prophylactic nasogastric decompression after abdominal surgery. Cochrane Database Syst Rev. 2007;(3):CD004929.

Nicholson A, Lowe MC, Parker J, Lewis SR, Alderson P, Smith AF. Systematic review and meta-analysis of enhanced recovery programmes in surgical patients. Br J Surg. 2014;101(3):172–88.

Nix J, Smith A, Kurpad R, Nielsen ME, Wallen EM, Pruthi RS. Prospective randomized controlled trial of robotic versus open radical cystectomy for bladder cancer: perioperative and pathologic results. Eur Urol. 2010;57:196–201.

Nygren J, Thacker J, Carli F, Fearon KC, Norderval S, Lobo DN. Guidelines for perioperative care in elective rectal/pelvic surgery: Enhanced Recovery After Surgery (ERAS) Society recommendations. Clin Nutr. 2012;31:801–16.

Pedziwiatr M, Kisialeuski M, Wierdak M, Stanek M, Natkaniec M, Matlok M, et al. Early implementation of Enhanced Recovery After Surgery (ERAS) protocol—compliance improves outcomes: a prospective cohort study. Int J Surg. 2015;21:75–81.

Pillai P, McEleavy I, Gaughan M, Snowden C, Nesbitt I, Durkan G, et al. A double-blind randomized controlled clinical trial to assess the effect of Doppler optimized intraoperative fluid management on outcome following radical cystectomy. J Urol. 2011;186:2201–6.

Pruthi RS, Nielsen M, Smith A, Nix J, Schultz H, Wallen EM. Fast track program in patients undergoing radical cystectomy: results in 362 consecutive patients. J Am Coll Surg. 2010;210(1):93–9.

Rao W, Zhang X, Zhang J, Yan R, Hu Z, Wang Q. The role of nasogastric tube in decompression after elective colon and rectum surgery: a meta-analysis. Int J Color Dis. 2011;26:423–9.

Recart A, Duchene D, White PF, Thomas T, Johnson DB, Cadeddu JA. Efficacy and safety of fast-track recovery strategy for patients undergoing laparoscopic nephrectomy. J Endourol. 2005;19(10):1165–9.

Richards KA, Steinberg GD. Perioperative outcomes in radical cystectomy: how to reduce morbidity? Curr Opin Urol. 2013;23:456–65.

Sachdeva A, Dalton M, Amaragiri SV, Lees T. Elastic compression stockings for prevention of deep vein thrombosis. Cochrane Database Syst Rev. 2010;(7):CD001484.

Sammour T, Zargar-Shoshtari K, Bhat A, Kahokehr A, Hill AG. A programme of Enhanced Recovery After Surgery (ERAS) is a cost-effective intervention in elective colonic surgery. N Z Med J. 2010;123(1319):61–70.

Schuster R, Grewal N, Greaney GC, Waxman K. Gum chewing reduces ileus after elective open sigmoid colectomy. Arch Surg. 2006;141:174–6.

Shabsigh A, Korets R, Vora KC, Brooks CM, Cronin AM, Savage C, et al. Defining early morbidity of radical cystectomy for subjects with bladder cancer using a standardized reporting methodology. Eur Urol. 2009;55:164–74.

Short V, Herbert G, Perry R, Atkinson C, Ness AR, Penfold C et al. Chewing gum for postoperative recovery of gastrointestinal function. Cochrane Database Syst Rev. 2015;(2):CD006506.

Simpson JC, Moonesinghe SR, Grocott MP, Kuper M, McMeeking A, Oliver CM, et al. Enhanced recovery from surgery in the UK: an audit of the Enhanced Recovery Partnership Programme 2009-2012. Br J Anaesth. 2015;115(4):560–8.

Smith I, Kranke P, Murat I, Smith A, O'Sullivan G, Soreide E, Spies C, et al. Perioperative fasting in adults and children: guidelines from the European Society of Anaesthesiology. Eur J Anaesthesiol. 2011;28:556–69.

Soop M, Nygren J, Thorell A, et al. Preoperative oral carbohydrate treatment attenuates endogenous glucose release 3 days after surgery. Clin Nutr. 2004;23:733–41.

Svanfeldt M, Throell A, Hausel J, Soop M, Rooyackers O, Nygren J, et al. Randomized clinical trial of the effect of preoperative oral carbohydrate treatment on postoperative whole-body protein and glucose kinetics. Br J Surg. 2007;94:1342–50.

The BAUS ERP Group. BAUS enhanced recovery pathway. The British Association of Urological Surgeons. 2015. https://www.baus.org.uk/_userfiles/pages/files/Publications/ERP%20with%20KNB%20markups.pdf

Tobis S, Heinlen JE, Ruel N, Lau C, Kawachi M, Wilson T, et al. Effect of alvimopan on return of bowel function after robot-assisted radical cystectomy. J Laparoendosc Adv Surg Tech A. 2014;24(10):693–7.

Tonnesen H, Nielsen PR, Lauritzen JB, Moller AM. Smoking and alcohol intervention before surgery: evidence for best practice. Br J Anaesth. 2009;102:297–306.

Varadhan KK, Neal KR, Dejong CH, Fearon KC, Ljungqvist O, Lobo DN. The enhanced recovery after surgery (ERAS) pathway for patients undergoing major elective open colorectal surgery: a meta-analysis of randomized controlled trials. Clin Nutr. 2010;29(4):434–40.

Walker KJ, Smith AF. Premedication for anxiety in adult day surgery. Cochrane Database Syst Rev. 2009;(4):CD002192.

Wuethrich PY, Burkhard FC, Thalmann GN, Stueber F, Studer UE. Restrictive deferred hydration combined with preemptive norepinephrine infusion during radical cystectomy reduces postoperative complications and hospitalization time: a randomized clinical trial. Anaesthesiology. 2014;120(2):365–77.

Xu R, Zhao X, Zhong Z, Zhang L. No advantage is gained by preoperative bowel preparation in radical cystectomy and ileal conduit: a randomized controlled trial of 86 patients. Int Urol Nephrol. 2010;42:947–50.

Yuh BE, Nazmy M, Ruel NH, Jankowski JT, Menchaca AR, Torrey RR, et al. Standardized analysis of frequency and severity of complications after robot-assisted radical cystectomy. Eur Urol. 2012;62(5):806–13.

# 26 Techniques and Outcomes of Taeniamyoectomyised Sigmoid Neobladder in MIS Radical Cystectomy

Chunxiao Liu and Abai Xu

**Abstract**

Several types of bladder replacement have been suggested as intra-abdominal urinary reservoir in patients undergoing radical cystectomy for bladder cancer. An optimal neobladder should maintain continence, metabolic balance, good renal function and quality of life. Ileum is the commonest choice for urologist. But due to its complicated surgical procedures and common postoperative complications, like neobladder dilatation, metabolic problems and infections, there is an urgent need for new generation and improvement of intestinal bladder surgery.

In this article, we introduce our techniques and outcomes of taeniamyoectomyised sigmoid neobladder reconstruction. Our experience showed satisfactory results, and since then orthotopic sigmoid neobladder reconstruction can be one of the choice after radical cystectomy.

**Keywords**

Bladder cancer · Orthotopic bladder substitute · Sigmoid neobladder

## 26.1 Introduction

Bladder cancer ranks as the second frequently-diagnosed cancer of the urogenital tract, with men being twice as likely affected than women (Liu et al. 2015). It is estimated that approximately 430,000 new cases of bladder carcinoma are diagnosed worldwide in 2012 while most of the patients are elder people (Egbers et al. 2015). It is widely accepted that cigarette smoking is the most common risk factor, other risk factors including workplace/radiation exposures, arsenic in drinking water, certain medication, chronic bladder inflammation and parasitic infections also play a role in pathogenesis (Nepple and O'Donnell 2009). Between 50 and 70% of all newly diagnosed bladder cancer cases are confined to the epithelium or sub-epithelial connective tissue, which could be dealt with transurethral resection of bladder tumors (TURBTs) (Jurewicz and Soloway 2014) with or without intravesical chemotherapy, depending on depth of invasion and grading of the tumor (Manoharan 2011). However, 75% of these patients suffer recurrence at least once within 5 years, and up to 90% within 12 years, which leads to a substantial burden of healthcare system (Hong et al. 2017).

Muscle-Invasive bladder cancers (MIBC) represent 20–25% of all patients diagnosed with bladder cancer, while 10–15% of those with initial superficial disease will also progress to invasive disease (Asgari et al. 2013). During the last decades, the risk of death of MIBC has not been remarkably changed. Radical cystectomy with pelvic lymphadenectomy (PLND) has long been considered the first-line treatment option for MIBC (Gupta et al. 2008). Radical cystectomy with urinary diversion provide excellent control of the primary tumor and are superior to radiation therapy and organ-conserving surgery, namely TURBTs and partial cystectomy (Apolo et al. 2012), which makes it the most effective treatment for non-metastatic muscle-invasive bladder cancer. For a period of time, most cystectomies are performed via open surgical approaches (Mirza and Choudhury 2016). However, minimally invasive techniques, such as laparoscopic and robotic approaches have recently emerged and became popular in high-volume medical centers (Asgari et al. 2013).

Current options for urinary diversion along with radical cystectomy include continent orthotopic bladder substitution (neobladder), heterotopic continent bladder replacement (pouch), urinary diversion via the rectum, and non-continent cutaneous urinary diversion (Lee et al. 2014). The ileal conduit, which is the most commonly used type of non-continent cutaneous urinary diversion for over 50 years, still remains the most frequently performed urinary diversion around the world

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(Park and Ahn 2011), while continent orthotopic bladder replacement (neobladder) provide an possible better quality of life with curative intent (Stein et al. 2012). Prospective randomized studies with high evidence levels on different types of urinary diversion are considered as impossible (Chang and Lawrentschuk 2015). Nevertheless neobladder is becoming popular among patients and surgeons with an opinion that the substitute reservoir could serve as a natural bladder, compared living with a bag on their side (Nam et al. 2013).

When neobladder is taking account as metastasis being excluded, several contraindications should be considered: renal failure (serum creatinine level less than 2 mg/dl or GFR < 50 ml/m$^2$), liver function disorders, and chronic inflammatory bowel disease (Hautmann 2015). However, there are still some patient-related and cancer-related factors requires attention, including patients' cognitive functions, poor cardiac function, severe COPD, significant peripheral vascular disease and urothelial carcinoma at urethral margin (Stein et al. 1998). The two most widely accepted forms of neobladder around the world are Studer ileal neobladders and Hautmann "W" neobladders, and some various modifications based these two types techniques are also very common (Hautmann et al. 2006). The T-pouch neobladder and extracorporeal tunnel techniques provide another option when an anti-reflux mechanism is desired. These techniques take only slightly longer operation time during radical cystectomy than ileal conduit, and such reservoir could almost be served as a natural bladder, in which patients could benefit from a life of quality with no external appliance or stoma (Sherwani et al. 2009). No matter which type of urinary diversion is favored, all of the current options require learning new processes of patients' in the first several months after radical cystectomy. For common orthotopic neobladder techniques, complications such as nocturnal incontinence, impaired emptying of the reservoir, stenosis of the ureterointestinal anastomosis, metabolic acidosis, urinary tract infections, upper tract deterioration, urinary retention and chologenic diarrhea (ileum-specific) require close and long-term follow-up plan (Anderson et al. 2014).

Currently, orthotopic neobladder (ON) has become the standard method of urinary diversion after radical cystectomy. Techniques in using different segments of intestine have been developed in search of the best solution. Alcini was the first to propose the teniamyotomy technique as a rapid and easy substitute for traditional detubularization because he found that detubularized reservoir will become moderately dilated with time and emptying the neobladder will more difficult. Hence, in 1987, Alcini performed a ileocecal reservoir using the transverse teniamyotomies to lower the incidence of enuresis and to avoid excessive dilatation of the neobladder with time. His transverse incisions on tenia coli and omentalis were made 3–4 cm apart extended down to the submucosal layer (3 on the anterior tenia coli and 2 on the tenia omentalis) (Fig. 26.1). He found that these incisions can lower the internal pressure at capacity by 15 and 20 mmHg and increase the capacity of neobladder almost twofold. After 3 years of follow-up, 67% of patients were continent at night and the mean capacity was 396 ml. For the neobladder, a mean full filling pressure and a mean maximum pressure was 28 cm and 55 cm water, respectively (Alcini et al. 1993). In 2000, Prof. Chunxiao Liu was the first to modify this taeniamyoectomyised technique after considering the powerful peristalsis of sigmoid wall in sigmoid neobladder construction and developed a novel method of bladder replacement: "orthotopic taeniamyoectomyised sigmoid neobladder" (Moinzadeh and Gill 2004). In this modified technique, all omental and tenia as well as the serosal layer with circular smooth muscle are removed continuously. Tenia and serosal layer of sigmoid at central portion and both cutting ends were preserved for urethra-neobladder and ureter-neobladder anastomosis (Fig. 26.2). After 48 months follow-up, 5-year daytime and nighttime complete continence rates were 74.6% and 57.1%, respectively. Mean maximal capacity and post-void residual urine were 328.8 and 22.2 ml, respectively. The mean full filling pressure and a mean maximum pressure were 35.8 and 55 cm $H_2O$, respectively (Xu et al. 2013b). The outcomes suggested that orthotopic taeniamyoectomyised sigmoid neobladder is a safe and feasible alternative for urinary diversion.

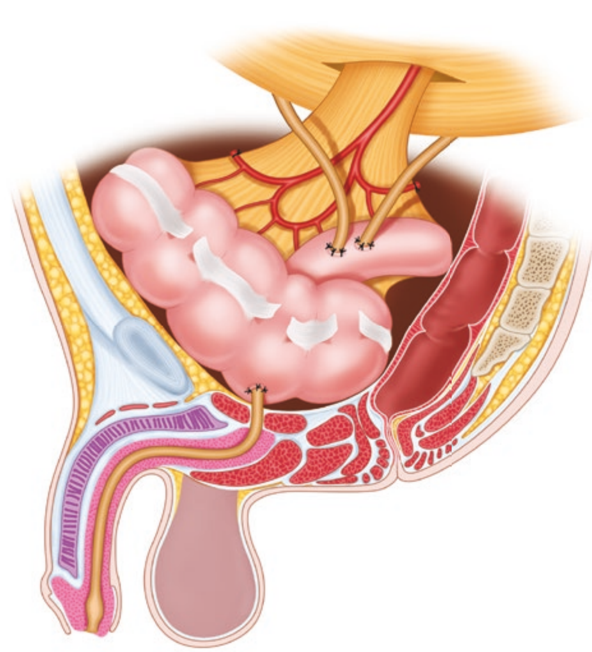

**Fig. 26.1** Ilececal neobladder with teniamyotomies by Alcini

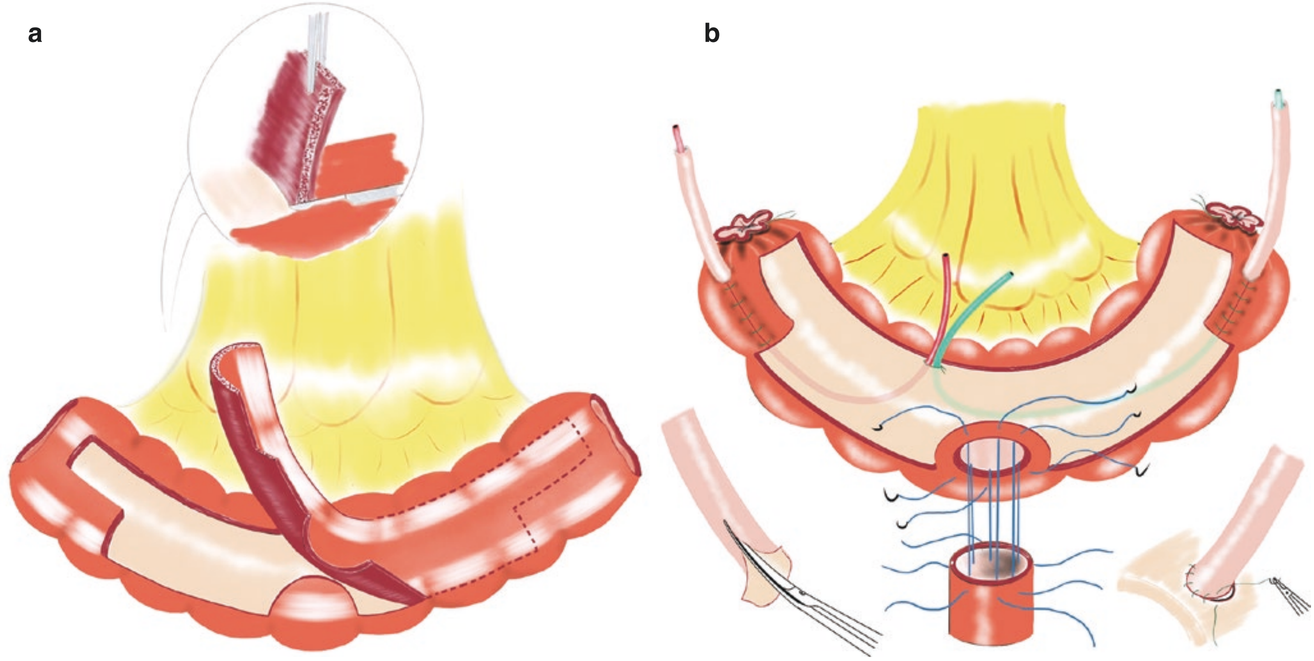


**Fig. 26.2** Sigmoid neobladder with continuous teniamyotomies by Chunxiao Liu

## 26.2 Surgery Procedure

The taeniamyoectomyised technique as an alternative of detubularization is first reported by Alcini et al. (1993). It is adopted as the standard practice in our center because of its technical simplicity and satisfactory functional results.

Due to low compliance of sigmoid neobladders with high pressure and powerful contractions, the technique has been modified accordingly. It requires complete removal of the circular smooth muscle under the serosal layer and almost all the omental, free taeniae as well as the serosal layer between these taeniae (Xu et al. 2013b). Thus, we coin the term detaenial to differentiate the technique from teniamyotomy.

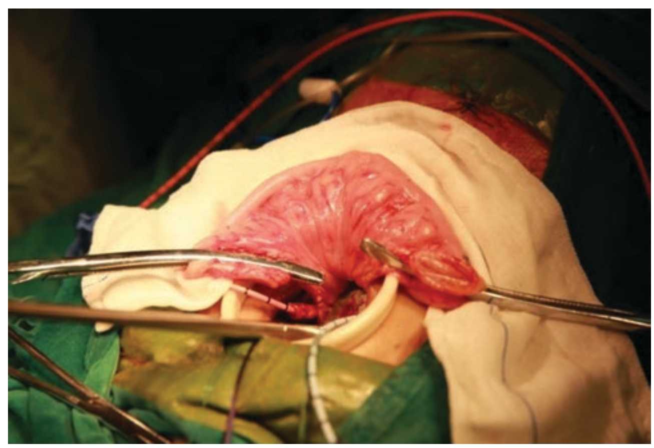

**Fig. 26.3** Sigmoid segment was isolated

### 26.2.1 Pre-surgery Preparation

Biochemical evaluation, computerized tomography and excretory urogram are performed preoperatively. Barium enema was used to assess the sigmoid in all patients before operation. Biopsies of the bladder neck and prostatic urethra were performed to rule out urothelial cancer involvement.

Indications for taeniamyoectomyised sigmoid neobladder include: (1) absent of cancer involvement in bladder neck, prostatic and urethra, (2) normal kidney function, (3) good preoperative continence status. Patients who have inadequate sigmoid length, pre-existing colonic disease such as colitis, sigmoid diverticulitis involving sigmoid colon, severe comorbidities or radiological evidence of extravesical invasion and distant metastasis were excluded.

### 26.2.2 Remove Taeniae and Serosal Layer with Circular Smooth Muscle

After radical cystectomy, the sigmoid was brought out through a mini-laparotomy wound over the lower abdomen. A segment of 15–25 cm sigmoid colon was isolated (Fig. 26.3). Intestinal continuity was restored using a circular stapler. Omenta and free taeniae, and the serosal layer were incised with scalpel down to the submucosal layer until the

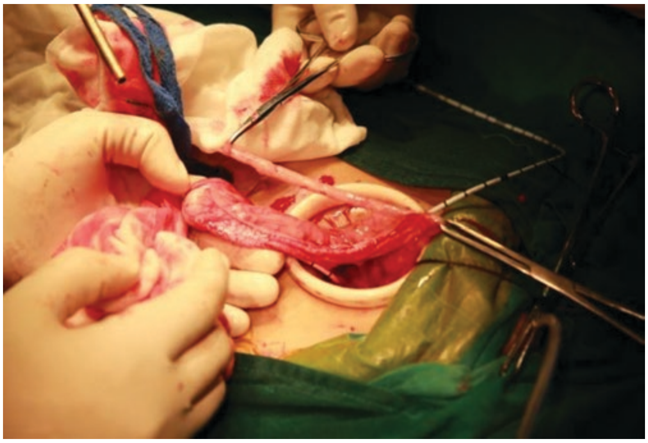

**Fig. 26.4** Taeniae and serosal layer with circular smooth muscle were removed continuously. Only mucosal and submucosal layer were preserved

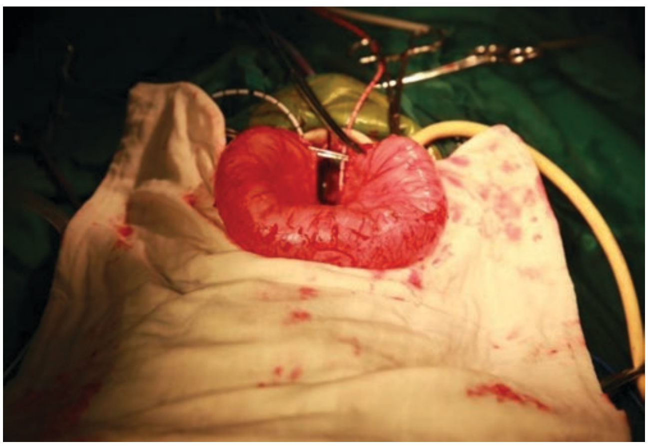

**Fig. 26.5** Taeniae and serosal layer were preserved to strengthen anastmosis at central portion of isolated sigmoid for urethra-neobladder anastomosis and at 2 ends for antireflux ureter-neobladder anastomosis

plane between smooth muscle and the submucosal layer could be clearly identified. The serosal layer with smooth muscle could be dissected free from the submucosal layer and excised continuously (Fig. 26.4). Surgeon could insert a finger inside the lumen and lift up the sigmoid wall to facilitate accurate dissection without bleaching the mucosal and submucosal layers. Approximately 2–3 cm of the taeniae and serosal layer were preserved to strengthen the urethra-neobladder anastomosis at the central portion of the isolated sigmoid and at both ends for the ureter-neobladder anastomosis (Fig. 26.5).

### 26.2.3 Check the Integrity of the Bladder

The taeniamyoectomyised sigmoid was first irrigated for cleansing and then filled with 300–400 ml physiological saline to assess the functional capacity and water-tightness. Residual taeniae were identified and incised during this filling phase to further increase the capacity.

**Fig. 26.6** Ureters were implanted in antireflux fashion in submucosal tunnel with 4-0 polyglactin at 2 ends of isolated sigmoid. Anastomosis was protected with 6Fr Single J stent

### 26.2.4 Implantation of Ureters

The ureters were spatulated and prepared for implantation. They are implanted in antirefluxing fashion in a submucosal tunnel and anastomosed with 4/0 polyglactin sutures at the boths ends of sigmoid (Xu et al. 2013a). 6Fr Single J stent are inserted (Fig. 26.6) and exteriorized through the sigmoid wall. The two ends of the sigmoid were closed by 2-0 polyglactin with the embedded seromuscular layer.

### 26.2.5 Anastomose the Neobladder to the Urethra

Urethrocolonical anastomosis was performed at the most independent mid-point of sigmoid segment which makes anastomosis easier and tension-free with 6, 2-0 multifilament synthetic absorbable interrupted sutures. The central portion of the sigmoid was incised and a 22Fr 3-way catheter was inserted in neobladder. The neobladder was anastomosed to the urethra with 2-0 polyglactin at 2, 4, 6, 8, 10, 12 o'clock directions (Fig. 26.7). The catheter was fixed on to the frenula praeputii. Besides, another fistulation tube should be placed into the neobladder to drain the urine. A drainage tube was placed in retroperitoneum and fixed on the abdominal wall, and then the pelvic peritoneum was intermittently sutured to maintain the integrity of the peritoneal cavity, preventing the formation of internal hernia. A drain was placed in the pelvis. Washout of neobladder was performed twice daily to prevent mucus blockade of catheters.

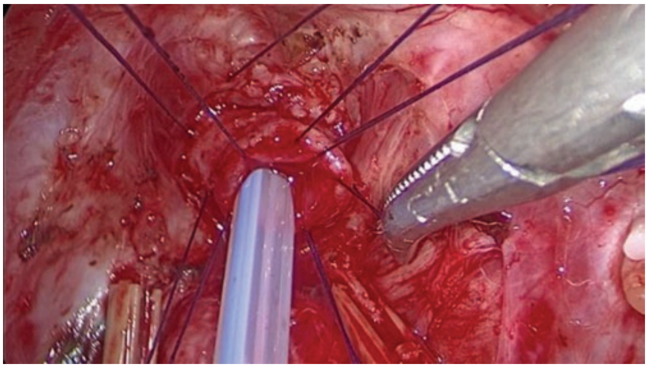

**Fig. 26.7** Neobladder was anastomosed to the urethra with 2-0 polyglactin

## 26.3 The Technique in Rhabdomyosarcoma of Children

It is known to all that rhabdomyosarcoma is a rare cancer (Malempati and Hawkins 2012), it often occurs in children before 15 years old (Egas-Bejar and Huh 2014; Yang et al. 2014). According to the international collaborative Intergroup Rhabdomyosarcoma Study Group (IRSG) (Raney et al. 2001), chemotherapy and radiotherapy are the preferred strategy which is able to maintain the intact function of bladder for the pediatric patients with genitourinary rhabdomyosarcoma while curing the patients at the same time. And radical cystectomy will be adopted only in cases of residual tumor after chemotherapy and radiotherapy or local recurrence.

Our center has applied this technique to the treatment of pediatric patients with bladder/prostate rhabdomyosarcoma since 2003. All of our patients were diagnosed with recurrence or resistant to chemotherapy and/or radiotherapy. Our center completed the first case of laparoscopic radical cystectomy with orthotopic taeniamyoectomyised sigmoid neobladder for pediatric patients with bladder/prostate rhabdomyosarcoma on June 17, 2008.

Unlike adult surgery, we should take into account the sexual function and reproductive function of the patients. Therefore, nerve sparing cystoprostatectomy was performed and the urethra was incised close to the prostatic apex in the males, and the uterus and ovary were retained in some females.

Up to now, more than 40 cases have been completed, and patients recovered well after the operation. Most of them can achieve daytime basic urinary continence. It is difficult to evaluate sexual function for those patients nowadays. We have to wait years to know about it when they grow up. And also, a prospective comparative study with long-term followup is required to evaluate the validity of this type of urinary diversion for bladder/prostate rhabdomyosarcoma.

## 26.4 The Technique in Renal Transplant Recipients (RTRs)

Treatment of renal transplant recipients (RTRs) with immunosuppressive agents was considered to lead to malignancy caused by certain viruses or impairing immune surveillance, which would result in faster tumour growth (Rama and Grinyo 2010). The incidence of bladder cancer in RTRs varies depending on the population studied from 0.08% to 2.8%, which is 2–3 times greater than in the general population (Medani et al. 2014). The underlying possible mechanisms include direct cellular damage by immunosuppressants (e.g., cyclophosphamide) and impaired ability to repair damage to cellular DNA or destroy damaged cells due to the immunocompromised state (Buzzeo et al. 1997). Therefore, if hematuria occurs after renal transplantation, in addition to rejection, it is necessary to pay attention to the possibility of urological tumor. However, the clinical symptoms of bladder cancer are different, the first symptom of about 13.3% of patients is prolonged unhealed urinary tract infections (Wu et al. 2004). According to Herve (Lang et al. 2005), it is possible to perform radical cystectomy and ileal bladder reconstruction in renal transplant recipients with better renal function and better tumor pathology. As long as patients agree, timely radical cystectomy is necessary. For the patients with refractory urinary tract infection and hematuria after renal transplantation, early cystoscopy is necessary.

Patients receiving immunosuppressive drugs after kidney transplantation may cause the reduction of patient's immune function, prone to malignant tumors. Bladder cancer is one of the most common malignant tumors, which is divided into superficial bladder cancer and myometrial invasive bladder cancer. The former can be treated by transurethral resection of the bladder tumor (TURBT), and for myometrial invasive bladder cancer, radical cystectomy is the main treatment.

Our center has successfully implemented three cases of laparoscopic surgeries. The surgical difficulty is that the patient's transplant kidney is usually located on the right lower abdomen. Because of the previous renal transplant surgery, severe adhesions appeared in the right lower quadrant of the local tissue, and anatomical structure is unclear, which brings great challenges to the operation.

Open surgery is a traditional surgery with big trauma, more bleeding, slow recovery after surgery. Compared with open surgery, laparoscopic surgery has less trauma, less bleeding, rapid recovery, but some people criticized the lack of "feel" and worried about the curative effect of tumor. In fact, laparoscopic surgery and open surgery follow the same resection range in radical resection of the tumor, and with laparoscopic magnification, the operator may see more clearly and accurately.

**Tips:** (1) Preoperative discussion of the surgical plan is the basis for success. (2) Select minimally invasive surgery to handle complex cases and minimize trauma. (3) Laparoscopic Trocar placement is important for the completion of surgery, so the operator should take full account of the impact of transplanted kidney to placement of Trocar, and the Trocar should be placed on the inside edge of transplanted kidney, slightly deviated midline, the procedure should be under the monitor of laparoscopy. (4) First to find the normal anatomical plane contralateral to the transplanted kidney, and then use this as a reference line to separate the other side.

## 26.5 Outcomes of Taeniamyoectomyised Sigmoid Neobladder in MIS Radical Cystectom

We have retrospectively reviewed 210 consecutive patients treated with RC plus taeniamyoectomyised sigmoid neobladder between January 2003 and March 2010 for bladder urothelial cancer at our institution (Xu et al. 2013b). The median operative time including RC and DSN was 355 min (295–645), median neobladder construction time (from sigmoid isolation to completion of the urethra-neobladder anastomosis) was 57.5 min, and the medium estimated blood loss was 346 ml.

1. **Complications**
   (a) **Early complications**
   The most common early neobladder-related complications were urinary leakage (3.3%), followed by pyelonephritis (2.9%) and mucus urinary retention (2.4%). Post-operative diarrhoea was observed in four patients (1.9%).
   (b) **Late complications**
   The most common late neobladder-related complication was ureter-neobladder anastomosis stricture, which developed in ten patients (4.8%) (Table 26.1).
2. **Continence and urodynamic findings**
   After catheter withdrawal, 199 patients (95.2%) has spontaneous bladder emptying without significant post-void residual urine. However, most of them had nocturnal incontinence. At 5-year follow-up, 74.6% daytime and 57.1% night-time

**Table 26.1** Complications

| Complications | Clavien-Dindo grade | No. (%) | Treatment |
|---|---|---|---|
| **Mortality (hepatic failure)** | | 1 (0.5) | |
| **Immediate (during operation)** | | | |
| Rectal damage | I | 2 (0.9) | Intraoperative suturing |
| **Early (≤90 d after operation)** | | 65 (31) | |
| Related to neobladder | | 22 (10.5) | |
| Urethral-neobladder leakage | II | 4 (1.9) | Prolonged drainage |
| Ureteral-neobladder leakage | II | 3 (1.4) | Prolonged drainage |
| Pyelonephritis | II | 6 (2.9) | Antibiotics |
| Mucus urinary retention | IIIa | 5 (2.4) | Cystoscopic intervention |
| Vaginal-neobladder fistula | IIIa | 2 (0.9) | Transvaginal operation |
| Colon-neobladder fistula | IIIb | 2 (0.9) | Reoperation |
| Not related to neobladder | | 43 (20.5) | |
| Wound infection | I | 4 (1.9) | Antibiotics and bedside therapy |
| Fat liquefaction of incision | I | 2 (0.9) | Bedside therapy |
| Fever unknown origin | I | 3 (1.4) | Antipyretics |
| Paralytic ileus | II | 3 (1.4) | Conservative |
| Diarrhea | II | 4 (1.9) | Conservative |
| Confusional syndrome | II | 2 (0.9) | Conservative and sedative |
| Minor pulmonary disorders | II | 3 (1.4) | Conservative |
| Delirium tremens | II | 2 (0.9) | Conservative and sedative |
| Deep venous thrombosis | II | 3 (1.4) | Anticoagulation |
| Colitis | II | 2 (0.9) | Conservative |
| Pelvic lymphocoele | II | 3 (1.4) | Drainage |
| Peritonitis | II | 3 (1.4) | Conservative |
| Cardiac arrhythmia | IIIa | 2 (0.9) | Pacemaker implantation |
| Pelvic bleeding | IIIb | 2 (0.9) | Reoperation |
| Colon anastomosis leak | IIIb | 3 (1.4) | Reoperation |
| Acute respiratory distress | IVa | 1 (0.5) | Intubation with respirator |
| Acute hepatic failure | IVa | 1 (0.5) | Dialysis and life-support intervention |

**Table 26.1** (continued)

| | | | |
|---|---|---|---|
| **Late (>90 d after operation)** | | 45 (21.5) | |
| Related to neobladder | | 39 (18.6) | |
| Metabolic disorders | I | 9 (4.3) | Conservative |
| Chronic urinary retention | I | 6 (2.9) | Intermittent catheterisation |
| Pouchitis | II | 8 (3.8) | Antibiotics |
| Neobladder stone | IIIa | 3 (1.4) | Endoscopic lithotripsy |
| Uretero-neobladder anastomosis stricture | IIIa | 10 (4.8) | 7 endoscopic intervention and 3 ureter replantation |
| Urethral-neobladder-anastomosis stricture | IIIa | 3 (1.4) | Endoscopic intervention |
| Not related to neobladder | | 6 (2.9) | |
| Constipation | II | 3 (1.4) | Conservative |
| Diarrhea | II | 2 (0.9) | Conservative |
| Hernia of abdominal incision | IIIb | 1 (0.5) | Hernia repairment |

complete continence was achieved, which had been revealed was age related. A total of 13 patients (6.2%) had voiding dysfunction, including mucus retention in five patients and urethra-neobladder anastomosis strictures in two patients, which were successfully managed endoscopically.

## 26.6 Conclusion

Our experience suggests that taeniamyoectomyised sigmoid neobladder invented by professor Chunxiao Liu is a feasible, stable, safe option for orthotopic bladder substitution after RC with a good functional outcome. A prospective comparative study with long-term follow-up is warranted to evaluate the validity of this type of urinary diversion.

**Remark** Permission is obtained to show the human images in this article according to local regulation.

Ethical approval is granted for the studies involved in this article according to local regulations.

## References


Abai Xu, Bingkun Li, Hulin Li, Shaobo Zheng, Wei Du, Yawen Xu, Yong Zou, Qiangxiang Luo, and Chunxiao Liu. Comparison of Seromuscular Tunnel and Split-cuff Nipple Antireflux Ureteroenteral Anastomosis Techniques in Orthotopic Taenia Myectomy Sigmoid Neobladder: A Prospective, Randomized Study. Urology. 2013;81(3):669–74.

Alcini E, D'Addessi A, Racioppi M, Menchinelli P, Anastasio G, Grassetti F, Destito A, Giustacchini M. Results of 4 years of experience with bladder replacement using an ileocecal segment with multiple transverse teniamyotomies. J Urol. 1993;149:735–8.

Anderson CB, Cookson MS, Chang SS. Principles of bladder cancer surgery. In: Castle EP, Pruthi RS, editors. Robotic surgery of the bladder. New York, NY: Springer New York; 2014. p. 5–25.

Apolo AB, Grossman HB, Bajorin D, Steinberg G, Kamat AM. Practical use of perioperative chemotherapy for muscle-invasive bladder cancer: summary of session at the Society of Urologic Oncology annual meeting. Urol Oncol. 2012;30:772–80.

Asgari MA, Safarinejad MR, Shakhssalim N, Soleimani M, Shahabi A, Amini E. Quality of life after radical cystectomy for bladder cancer in men with an ileal conduit or continent urinary diversion: a comparative study. Urol Ann. 2013;5:190–6.

Buzzeo BD, Heisey DM, Messing EM. Bladder cancer in renal transplant recipients. Urology. 1997;50:525–8.

Chang DT, Lawrentschuk N. Orthotopic neobladder reconstruction. Urol Ann. 2015;7:1–7.

Egas-Bejar D, Huh WW. Rhabdomyosarcoma in adolescent and young adult patients: current perspectives. Adolesc Health Med Ther. 2014;5:115–25.

Egbers L, Grotenhuis AJ, Aben KK, Alfred WJ, Kiemeney LA, Vermeulen SH. The prognostic value of family history among patients with urinary bladder cancer. Int J Cancer. 2015;136:1117–24.

Gupta NP, Kolla SB, Seth A, Dogra PN, Hemal AK, Kumar R, Panda S. Radical cystectomy for bladder cancer: a single center experience. Indian J Urol. 2008;24:54–9.

Hautmann RE. Clinical scenario: T2 bladder tumor. In: Konety BR, Chang SS, editors. Management of bladder cancer: a comprehensive text with clinical scenarios. New York, NY: Springer New York; 2015. p. 327–36.

Hautmann RE, Volkmer BG, Schumacher MC, Gschwend JE, Studer UE. Long-term results of standard procedures in urology: the ileal neobladder. World J Urol. 2006;24:305–14.

Hong X, Li T, Ling F, Yang D, Hou L, Li F, Tan W. Impact of surgical margin status on the outcome of bladder cancer treated by radical cystectomy: a meta-analysis. Oncotarget. 2017;8:17258–69.

Jurewicz M, Soloway MS. Approaching the optimal transurethral resection of a bladder tumor. Turk J Urol. 2014;40:73–7.

Lang H, de Petriconi R, Wenderoth U, Volkmer BG, Hautmann RE, Gschwend JE. Orthotopic ileal neobladder reconstruction in patients with bladder cancer following renal transplantation. J Urol. 2005;173:881–4.

Lee RK, Abol-Enein H, Artibani W, Bochner B, Dalbagni G, Daneshmand S, Fradet Y, Hautmann RE, Lee CT, Lerner SP, Pycha A, Sievert KD, Stenzl A, Thalmann G, Shariat SF. Urinary diversion after radical cystectomy for bladder cancer: options, patient selection, and outcomes. BJU Int. 2014;113:11–23.

Liu JM, Cheng SH, Liu XX, Xia C, Wang WW, Ma XL. Prognostic value of caveolin-1 in genitourinary cancer: a meta-analysis. Int J Clin Exp Med. 2015;8:20760–8.

Malempati S, Hawkins DS. Rhabdomyosarcoma: review of the Children's Oncology Group (COG) Soft-Tissue Sarcoma Committee experience and rationale for current COG studies. Pediatr Blood Cancer. 2012;59:5–10.

Manoharan M. Intravesical therapy for urothelial carcinoma of the bladder. Indian J Urol. 2011;27:252–61.

Medani S, O'Kelly P, O'Brien KM, Mohan P, Magee C, Conlon P. Bladder cancer in renal allograft recipients: risk factors and outcomes. Transplant Proc. 2014;46:3466–73.

Mirza A, Choudhury A. Bladder preservation for muscle invasive bladder cancer. Bladder Cancer. 2016;2:151–63.

Moinzadeh A, Gill IS. Laparoscopic radical cystectomy with urinary diversion. Curr Opin Urol. 2004;14(2):83–7.

Nam JK, Kim TN, Park SW, Lee SD, Chung MK. The Studer orthotopic neobladder: long-term (more than 10 years) functional outcomes, urodynamic features, and complications. Yonsei Med J. 2013;54:690–5.

Nepple KG, O'Donnell MA. The optimal management of T1 high-grade bladder cancer. Can Urol Assoc J. 2009;3:S188–92.

Park J, Ahn H. Radical cystectomy and orthotopic bladder substitution using ileum. Korean J Urol. 2011;52:233–40.

Rama I, Grinyo JM. Malignancy after renal transplantation: the role of immunosuppression. Nat Rev Nephrol. 2010;6:511–9.

Raney RB, Maurer HM, Anderson JR, Andrassy RJ, Donaldson SS, Qualman SJ, Wharam MD, Wiener ES, Crist WM. The Intergroup Rhabdomyosarcoma Study Group (IRSG): major lessons from the IRS-I through IRS-IV studies as background for the current IRS-V treatment protocols. Sarcoma. 2001;5:9–15.

Sherwani AY, Wazir BS, Hamid A, Wani MS, Aziz R. Comparative study of various forms of urinary diversion after radical cystectomy in muscle invasive carcinoma urinary bladder. Int J Health Sci (Qassim). 2009;3:3–11.

Stein JP, Lieskovsky G, Ginsberg DA, et al. The T pouch: an orthotopic ileal neobladder incorporating a serosal lined ileal antireflux technique. J Urol. 1998;159(6):1836–42.

Stein R, Hohenfellner M, Pahernik S, Roth S, Thuroff JW, Rubben H. Urinary diversion—approaches and consequences. Dtsch Arztebl Int. 2012;109:617–22.

Wu MJ, Lian JD, Yang CR, Cheng CH, Chen CH, Lee WC, Shu KH, Tang MJ. High cumulative incidence of urinary tract transitional cell carcinoma after kidney transplantation in Taiwan. Am J Kidney Dis. 2004;43:1091–7.

Xu A, Li B, Li H, Zheng S, Du W, Xu Y, Zou Y, Luo Q, Liu C. Comparison of seromuscular tunnel and split-cuff nipple antireflux ureteroenteral anastomosis techniques in orthotopic taenia myectomy sigmoid neobladder: a prospective, randomized study. Urology. 2013a;81(3):669–74.

Xu K, Liu CX, Zheng SB, Li HL, Xu YW, Xu AB, Chen BS, Shen HY. Orthotopic detaenial sigmoid neobladder after radical cystectomy: technical considerations, complications and functional outcomes. J Urol. 2013b;190:928–34.

Yang L, Takimoto T, Fujimoto J. Prognostic model for predicting overall survival in children and adolescents with rhabdomyosarcoma. BMC Cancer. 2014;14:654.

# 27 Endoscopic Management of Diverticular Calculi

Xiaoshuai Gao, Jixiang Chen, Zirui Li, and Kunjie Wang

**Abstract**

Management of renal diverticular calculi is always a challenge. Accurate diagnosis depends on good pre-operative imaging techniques. There are various proposed surgical approaches to treat diverticular stones. Factors, including invasiveness, availability of specific instrument, stone clearance and complication rates, are needed to be considered before operation. In this article, we will review the method of diagnosis, surgical intervention of renal diverticular calculi. Tips and tricks of surgical techniques will also be explained.

**Keywords**

Calyceal diverticulum · Calyceal diverticulum calculi Flexible ureteroscope · Percutaneous nephrolithotomy

## 27.1 Definition

### 27.1.1 Calyceal Diverticula

Calyceal diverticula are eventuations lying within the renal parenchyma. The cystic cavities of calyceal diverticula are nonsecretory and transitional-cell epithelium-lined, and communicate with the collecting system by a channel (Timmons et al. 1975; Hulbert et al. 1986).

### 27.1.2 Calyceal Diverticular Calculi

The urinary stones in calyceal diverticula are called calyceal diverticular calculi.

## 27.2 Epidemiology

### 27.2.1 Calyceal Diverticula

Calyceal diverticula were first described as kyste urinaire by Rayer in 1841 (Rayer 1841). According to Matlaga et al., the incidence of renal diverticula in adults ranged from 0.21 to 0.6% (Matlaga et al. 2007). The distribution of clyceal diverticula are 21.4, 48.9 and 29.7% in the lower, upper and middle poles, respectively (Waingankar et al. 2014). This disease is more likely to occur in women (63%) than man (37%), and there is no tendency to occur on both sides of the body. The size of calyceal diverticula is 0.5–7.5 cm, and the average size is 1.72 cm (Waingankar et al. 2014).

### 27.2.2 Calyceal Diverticular Calculi

In patients with calyceal diverticula, stones were found in 9.5–50% of them (Middleton and Pfister 1974).

## 27.3 Etiology

### 27.3.1 Calyceal Diverticula

The extract etiology of calyceal diverticula remains unknown.

#### 27.3.1.1 Congenital Factors

- Abnormal junction of posterior renal matrix and ureteral bud: During the branching of the ureteral bud into the metanephric blastema; a diverticulum will form if one of the branching fails to stimulate an appropriate section of the metanephros (Middleton and Pfister 1974).
- Abnormal branching during embryonic development: Abnormal branching describes the renal pelvis as having first-order branches that become major calyces, second-order branches that become secondary calyces, and further branches to the 15th order. In this model, the higher

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order persists as the collecting tubule while the lower order degenerates; therefore, the calyceal diverticulum is considered to be a persistent branch due to the failure of degeneration (Narath 1951; Waingankar et al. 2014).

#### 27.3.1.2 Acquired Factors

- Obstruction secondary to stone or infection has been proposed as a factor of calyceal diverticula (Braasch and Hendrick 1944).
- Flank trauma has been reported as a risk factor of calyceal diverticula (Moore 1950).
- Progressive fibrosis of an infundibulum is a possible cause (Moore 1950).

### 27.3.2 Calyceal Diverticular Calculi

There is no consensus in the medical community of the reason for the formation of calyceal diverticular calculi so far.

#### 27.3.2.1 Metabolic Factor

Matlaga et al. found that the stones in the calyx diverticulum stones were mostly calcium oxalate stones (Matlaga et al. 2007), Auge et al. revealed the presence of hypercalcemia, hypocitraturia, and low urine volume phenomenon in the patients with calyceal diverticular calculi (Auge et al. 2006).

#### 27.3.2.2 Obstructive Factor

The calyceal diverticula with small neck and without systolic function cause them in a long-term urine deposition status, which is considered to be the main cause of the formation of calyceal diverticular calculi.

## 27.4 Classification

Calyceal diverticula can be divided into four types (Dretler 1992).

- Type I: calyceal diverticula with a short and open calyx neck.
- Type II: calyceal diverticula with a short and closed calyx neck.
- Type III: calyceal diverticula with a long and closed calyx neck.
- Type IV: calyceal diverticula with a locked calyx neck.

## 27.5 Clinical Presentation

Most patients with calyceal diverticula are asymptomatic and are often diagnosed during imaging performed for other reasons (Zhang et al. 2016). About 1/3–1/2 of the patients present flank pain, repeat urinary tract infection and gross hematuria. Although they are no specific to the diagnosis, these symptoms are the indications for treatment (Tan et al. 2013; Waingankar et al. 2014).

## 27.6 Diagnosis

### 27.6.1 Diagnostic Idea

When patients with flank pain, repeated urinary tract infection and gross hematuria, ultrasound is the first choice. In case of atypical sonographic appearances, an intravenous urogram is needed to confirm the diagnosis. Computer tomography (CT) or CT urogram can also be used. For the pediatric population, young females and pregnant patients, MRI provides an alternative to CT. Retrograde pyelography will be necessary when the diverticulum is obstructed or imaging diagnosis fails.

### 27.6.2 Diagnostic Imaging

#### 27.6.2.1 Intravenous Urography(IVU) and Retrograde Pyelography

On IVU, the diverticulum is nonsecretory (Waingankar et al. 2014) and filled by retrograde flow from the collecting system through the connecting calyx or the renal pelvis. It will opacify slower than pelvicaliceal system. And the stones would be seen surrounded by contrast (Gross and Herrmann 2007; Stunell et al. 2010). These are the powerful evidence for the diagnosis of calyceal diverticula with stones. However, when the stone obstructs the diverticulum neck, the cavity cannot be filled by the contrast. In this case, it is difficult to clarify the diagnosis.

Retrograde pyelography can better display the anatomical structures of the kidney through the full expansion of the collecting system, especially the infundibulum and its communication neck. It is the smart choice when the diverticulum is obstructed or imaging diagnosis fails (Gross and Herrmann 2007; Stunell et al. 2010).

#### 27.6.2.2 Ultrasound

Ultrasound is commonly used to image the urinary tract, which indicates a diagnosis in about 80% of cases (Gross and Herrmann 2007; Stunell et al. 2010). The stone-containing calyceal diverticulum may present as a cystic renal lesion with curvilinear, plaquelike calcification along its posterior wall. It is often in close proximity to the renal sinus. Because of the mobile and position dependent appearance of hyperechoic stones, the patients need to be scanned in supine and prone position together. Due to the variable appearance on ultrasound and the different experience of sonographers, ultrasound alone might be insufficient for accurately diagnosis (Stunell et al. 2010).

#### 27.6.2.3 Computed Tomography(CT)

Sagittal and coronal reformatted images of CT can better delineate the anatomical structures of the kidney and the location of the calyceal diverticulum. Calyceal diverticulum containing stones is a well-defined, thin walled, low density cystic structure with calcific density on CT. Delayed contrast on contrast-enhanced CT and position dependent stones on non-contrast CT are considered diagnostic of calyceal diverticula containing stones (Stunell et al. 2010; Mullett et al. 2012).

#### 27.6.2.4 Magnetic Resonance Imaging(MRI)

With no ionising radiation, MRI provides an alternative for the special patients, such as the paediatric population, young females and pregnant patients. Multiplanar MRI, which is similar to reconstructed CT, can delineate infundibulum and calyceal diverticula. But it cannot image the stones clearly (Stunell et al. 2010).

#### 27.6.2.5 Plain Abdominal Radiography

Plain abdominal radiography is widely used in renal stone disease, which has a high sensitivity in stones detection. A semilunar or meniscus-shaped calcification can be seen when calyceal diverticula containing stones. And it will change position in erect or lateral decubitus positions (Stunell et al. 2010). Due to the calyceal diverticula may not be seen on plain abdominal radiography, the diagnostic value is limited (Stunell et al. 2010).

### 27.6.3 Differential Diagnoses

#### 27.6.3.1 Hydrocalyx

The key to the differential diagnosis of hydrocalyx and calycea diverticulum is the location. Hydrocalyx is in the normal kidney calices, which is usually caused by obstruction. However, calycea diverticulum is located in the renal parenchyma around the calices.

#### 27.6.3.2 Simple Cyst

Simple Cyst do not have infundibulum neck communicating with the collecting system (Waingankar et al. 2014).

#### 27.6.3.3 Complicated Cystic Lesion

Complicated cystic lesion is too difficult to diagnose on ultrasound, because of no typical sonograph appearances. CT is a better choice to differentiate it with Calyceal diverticulum containing stones (Surendrababu and Govil 2005).

#### 27.6.3.4 Parapelvic Cyst

Parapelvic cysts, which have no communication with the collecting system, are similar to simple cyst. They are usually located adjacent to the renal pelvis (Waingankar et al. 2014).

#### 27.6.3.5 Tubercular Cavity

Tubercular cavity appears as a structure with irregular borders. It will enlarge gradually (Waingankar et al. 2014).

#### 27.6.3.6 Papillary Necrosis

Papillary necrosis, that is located in renal medulla, is related to systemic conditions and nonsteroidal antiinflammatory drug abuse. On CTU, it appears as varying degrees of filling defects (Waingankar et al. 2014).

#### 27.6.3.7 Renal Tumor

Tumor compression will cause the deformation of renal calices. The delayed filling of a calyceal diverticulum is retrograde flow from the collecting system, while a cystic renal mass is supplied by tumor vessels (Waingankar et al. 2014). Combined imaging examination is needed to diagnose the tumor.

## 27.7 Treatment

The calyceal diverticula often has no accompanying symptoms (Waingankar et al. 2014).These patients do not need immediate treatment, but need to check for the presence of infections and calculi (Gross and Herrmann 2007).The indications for treatment include pain, chronic or recurrent pyelonephritis, gross hematuria, renal damage or decline in renal function (Kriegmair et al. 1990; Waingankar et al. 2014). In the past, the treatment of calyceal diverticula included open surgical resection and decompression of the calyceal diverticulum (Waingankar et al. 2014). Since 1980s, minimally invasive surgery has been gradually used, include extracorporeal shock-wave lithotripsy (ESWL), ureteroscopic (URS), percutaneous nephrolithotomy (PCNL) or laparoscopic surgery. The size and location of diverticulum and stone determine the choice of surgical procedure (Parkhomenko et al. 2017).

### 27.7.1 PCNL

PCNL can be used for the treatment of large diverticulum with a large stone burden, especially for the posteriorly located stones (Parkhomenko et al. 2017).PCNL provided the highest stone-free rates and symptom free rates than ESWL and URS, moreover, it afford a chance to fulguration or incision of the diverticular neck (Waingankar et al. 2014).

The key to success of PCNL lies in the establishment of the percutaneous approach to diverticular stones. Preoperative plain film and retrograde pyelogram is the necessary examination for the establishment of percutaneous access (Waingankar et al. 2014). For patients with poorly radiopaque stones or diverticula does not opacify either in intravenous urography or retrograde contrast, contrast agents could be injected under the guidance of CT or ultrasound (Matlaga et al. 2006). The ureteral catheter was inserted before operation, and the contrast was instilled through the catheter. The patient was then prone to puncture directly into the diverticulum with 18G puncture needle (Waingankar et al. 2014). First, the guide wire is inserted through the percutaneous nephrolithotomy needle, Then, under the guidance of the guide wire, the 10 Fr dilator is inserted. Second guidewire is inserted to the renal pelvis if the diverticulum neck is allowed. The tract is again dilated until it can be inserted into a percutaneous nephrolithotomy. The stones are fragmented with pneumatic and ultrasound, and then fragments are removed with a stone basket. Finally, the diverticulum is fulgurated and then the nephrostomy tube is placed into the pelvic through a diverticulum after the neck is dilated (Waingankar et al. 2014).

The overall stone free rates for PCNL in the treatment of diverticulum stones are 69–100% (Waingankar et al. 2014). However, the high efficacy of PCNL is also accompanied by high complications, ranged from 0 to 54% (Waingankar et al. 2014). Although PCNL has a high success rate, it has some limitations. Access to the diverticulum always be tenuous, it may be easily to loss of access and stabilize the guide wire, especially when the kidney parenchyma is thin. Furthermore, it's not easy to percutaneous ablate a wide calyceal diverticulum neck, and urinary leakage usually followed (Canales and Monga 2003).

### 27.7.2 URS

URS has been used for calyceal diverticula since 1980s, and then its safety and efficacy have been improved with the development of the channel sheath and dilators (Canales and Monga 2003). URS is mainly suitable for small diverticulum calculi in a middle or upper pole. URS is a good choice for those patients who are unable to undergo percutaneous nephrolithotomy for poor candidates (Canales and Monga 2003). Difficult to identify the ostium of diverticulum and low rate of obliteration is the main drawbacks of URS (Waingankar et al. 2014).

Cystoscopy and flexible ureteroscopy are the first steps in URS. If a diverticular neck is found, the guide wire is then inserted, and the diverticular neck is dilated or incision. If diverticulum cannot be found through cystoscope or flexible cystoscope, methylene blue can be used to look for diverticular neck. Then the stone fragmentation was conducted by Ho:YAG laser energy through flexible ureteroscope, and the fragments were removed with a stone basket (Waingankar et al. 2014).

Guido Giusti et al. summed up 189 patients with calyceal diverticula calculi in four retrospective experiments, all of these patients were symptomatic before surgery (Giusti et al. 2015). Among these patients, 107 with diverticula calculi located in the upper pole, 28 in the lower, 51 in the middle, and 3 in multiple calyceal diverticula. The overall stone free rates for URS in the treatment of diverticulum stones ranged from 19 to 90% (Giusti et al. 2015), with 35–100% symptom-free rates (Waingankar et al. 2014) and approximately 20% diverticular obliteration (Canales and Monga 2003), weighed against 0–33% complication rates (Waingankar et al. 2014). The stone free rate of URS was higher than that of SWL, and the incidence of complications was lower than that of PCNL (Waingankar et al. 2014). Complications of URS include bleeding, infection, ureteral injury, etc. (Canales and Monga 2003).

### 27.7.3 ESWL

ESWL is usually used for patients with radiologically patent necks and small stone burdens in mid- to upper-pole diverticula (Waingankar et al. 2014). For diverticula with a long and narrow diverticular neck or burden with large stones, stones can be well fragmented, but cannot be evacuated following ESWL.

A series of evidences showed that the stone clearance rate of ESWL in the treatment of diverticulum stones was 20–58% (Psihramis and Dretler 1987; Ritchie et al. 1990; Streem and Yost 1992). Psihramis reported that their stone free rate was 20% and symptoms free was 70% after followup of 5.9 months (Psihramis and Dretler 1987). The study of Ritchie et al. showed a better result in 1990 (Ritchie et al. 1990). their stone-free rate was 25% and 75% were rendered symptom-free. Streem et al. achieved 58% stone-free rates and 86% patients were rendered symptom-free or markedly improved. The study of Streem only included patients with a radiographically patent diverticular neck and the diameter of the stone was less than 1.5 cm (Streem and Yost 1992).

Stone-free rates are the lowest with ESWL, although some research reports asymptomatic reached to 75% with long term follow-up (Waingankar et al. 2014).ESWL is limited by the diverticulum cannot be eliminated, and the stone fragments could not pass through the diverticular neck smoothly (Canales and Monga 2003). ESWL might be an alternative procedure when the stone is less than 1 cm and the diverticular neck is short and patent (Turna et al. 2007).

### 27.7.4 Laparoscopic Surgery

Laparoscopic surgery is a reliable procedure for the treatment of diverticulum especially in (1) anteriorly located, (2) an unrecognized diverticula ostium, (3) thin renal parenchyma overlies or (4) large stone burden (Waingankar et al. 2014). Failure of percutaneous nephrolithotomy due to perirenal adhesions and a thick overlying renal parenchyma is a contraindication to laparoscopy (Miller et al. 2002).

Previous studies reported their stone free rate was more than 90% and symptoms free was over 75% (Canales and Monga 2003). The complications of laparoscopic include channel (intestinal, vascular, etc.) injury, pneumoperitoneum, tissue resection, incisional hernia, etc. (Canales and Monga 2003). As its high invasiveness and complications, laparoscopy is only performed when other endoscopic techniques are not applicable (Waingankar et al. 2014).

## References


Auge BK, Maloney ME, Mathias BJ, et al. Metabolic abnormalities associated with calyceal diverticular stones. BJU Int. 2006;97(5):1053–6.

Braasch WF, Hendrick JA. Renal cysts, simple and otherwise. J Urol. 1944;51:1.

Canales B, Monga M. Surgical management of the calyceal diverticulum. Curr Opin Urol. 2003;13(3):255–60.

Dretler SP. A new useful endourologic classification of calyceal diverticula. J Endourol. 1992;6(suppl):81.

Giusti G, Proietti S, Peschechera R, et al. Sky is no limit for ureteroscopy: extending the indications and special circumstances. World J Urol. 2015;33(2):257–73.

Gross AJ, Herrmann TR. Management of stones in calyceal diverticulum. Curr Opin Urol. 2007;17(2):136–40.

Hulbert JC, Reddy PK, Hunter DW, et al. Percutaneous techniques for the management of caliceal diverticula containing calculi. J Urol. 1986;135(2):225–7.

Kriegmair M, Schuller J, Schmeller N, et al. Diverticular calculi of the kidney calices–extracorporeal shockwave lithotripsy, percutaneous extraction or open surgery. Urologe A. 1990;29(4):204–8.

Matlaga BR, Kim SC, Watkins SL, et al. Pre-percutaneous nephrolithotomy opacification for caliceal diverticular calculi. J Endourol. 2006;20(3):175–8.

Matlaga BR, Miller NL, Terry C, et al. The pathogenesis of calyceal diverticular calculi. Urol Res. 2007;35(1):35–40.

Middleton AW Jr, Pfister RC. Stone-containing pyelocaliceal diverticulum: embryogenic, anatomic, radiologic and clinical characteristics. J Urol. 1974;111(1):2–6.

Miller SD, Ng CS, Streem SB, et al. Laparoscopic management of caliceal diverticular calculi. J Urol. 2002;167(3):1248–52.

Moore T. Hydrocalicosis. Br J Urol. 1950;22:304–19.

Mullett R, Belfield JC, Vinjamuri S. Calyceal diverticulum–a mimic of different pathologies on multiple imaging modalities. J Radiol Case Rep. 2012;6(9):10–7.

Narath PA. Renal pelvis and ureter. New York: Grune and Stratton; 1951.

Parkhomenko E, Tran T, Thai J, et al. Percutaneous management of stone containing calyceal diverticula: associated factors and outcomes. J Urol. 2017;198(4):864–8.

Psihramis KE, Dretler SP. Extracorporeal shock wave lithotripsy of caliceal diverticula calculi. J Urol. 1987;138(4):707–11.

Rayer PP. Traitements des maladies des reins 3. Paris: Baillere; 1841. p. 507.

Ritchie AW, Parr NJ, Moussa SA, et al. Lithotripsy for calculi in caliceal diverticula? Br J Urol. 1990;66(1):6–8.

Streem SB, Yost A. Treatment of caliceal diverticular calculi with extracorporeal shock wave lithotripsy: patient selection and extended followup. J Urol. 1992;148(3 Pt 2):1043–6.

Stunell H, McNeill G, Browne RF, et al. The imaging appearances of calyceal diverticula complicated by uroliathasis. Br J Radiol. 2010;83(994):888–94.

Surendrababu NR, Govil S. Diagnostic dilemma: calyceal diverticulum vs complicated cyst. Indian J Med Sci. 2005;59(9):403–5.

Tan YK, Cha DY, Gupta M. Management of stones in abnormal situations. Urol Clin North Am. 2013;40(1):79–97.

Timmons JW Jr, Malek RS, Hattery RR, et al. Caliceal diverticulum. J Urol. 1975;114(1):6–9.

Turna B, Raza A, Moussa S, et al. Management of calyceal diverticular stones with extracorporeal shock wave lithotripsy and percutaneous nephrolithotomy: long-term outcome. BJU Int. 2007;100(1):151–6.

Waingankar N, Hayek S, Smith AD, et al. Calyceal diverticula: a comprehensive review. Rev Urol. 2014;16(1):29–43.

Zhang JQ, Wang Y, Zhang JH, et al. Retrospective analysis of ultrasound-guided flexible ureteroscopy in the management of calyceal diverticular calculi. Chin Med J. 2016;129(17):2067–73.

# Part III

# Advances in Endourology Technology

# 28 Handbook for Ureteral Stenting

Shingo Yamamoto

**Abstract**

Ureteral stent is an essential item for surgical procedures and clinical examinations in the urological field, but the methods and protocols of insertion, withdrawal, and exchange, as well as the period before replacement are based on the experience of an individual practitioner. Ureteral stenting is frequently associated not only with stent-related symptoms but also complications such as urinary tract infections, encrustation, migration, knotting, and ureteroarterial fistula conditions, which are sometimes life -threatening.

The Japanese Society of Endourology (JSE) established a “the Section meeting for ureteral stenting” in order to establish consensus regarding the practice of the ureteral stenting in a handbook which was first published in Japan in 2017. Herein, we review and discuss about a variety of ureteral stent materials and configuration, indications for ureteral stenting, techniques for placement and exchange of ureteral stent, as well as ureteral stent-related adverse events for safe management of ureteral stenting.

**Keywords**

Ureteral stent · Ureteral catheterization · Techniques Complications

## 28.1 Introduction

A ureteral stent is an essential item for surgical procedures as well as clinical examinations in the urological field, and various types are used depending on the situation. A great variety of such stents are employed throughout the world, though it is unclear whether they become adopted for regular use after gaining substantial understanding of their individual weak and strong points. Furthermore, methods and protocols for insertion, withdrawal, and exchange, as well as the period before replacement are likely based on instructions from a senior doctor or the experience of an individual practitioner, as textbooks and guidelines for ureteral stenting have yet to be published.

In 2012, the Japanese Society of Endourology (JSE) established a “the Section meeting for ureteral stenting” in order to establish consensus regarding performance of such stenting, with the first edition of a handbook published in Japan in 2017. Here we introduce a digest version of that handbook, though we recognize that a number of pros and cons may be stated in regard to the contents, because abundant evidence remains lacking in this field.

## 28.2 Ureteral Stent Materials and Configuration

Presently used ureteral stents are made from polymer materials that are permeability by all types of X-ray devices, with barium, bismuth, tantalum, or tungsten added for visualization. A typical ureteral stent has a double-J shape with multiple side holes, visual markers integrated for better positioning under X-ray visualization, and a pull or extraction string for withdrawal. Some stents have a hydrophilic coating on their surface for smooth passage in the ureter.

The multiple side holes are considered to contribute to efficacious drainage of urine, though may be inefficient in cases with irruption of mucosa induced by a tumor from the outer side. Therefore, a non-side hole stent is preferentially used for cases of ureteral obstruction caused by malignancy or retroperitoneal fibrosis. Non-side hole stents also have the advantage of smooth insertion when the ureter has stenosis that causes friction between the stent and ureteral lumen possibly resulting in accordion phenomenon, which induces folds on the wall of a stent with multiple side holes.

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A pulling string is used for removal after placement for a short period as well as for positioning the stent in a correct position when it has migrated into the ureter after insertion. If the stent must be placed for long period, it is better to cut off the string because dislodgment of stents may cause undesirable complications, such as urinary incontinence or spontaneous removal. Women are more likely to experience stent dislodgment when a pulling string remains at the end of a stent (Althaus et al. 2015).

Metallic stents are more resistant to exclusion due to malignancy than conventional products made from polyurethane or silicon. A metallic stent (Resonance®) has been introduced for management of extrinsic-etiology ureteral obstruction for time periods up to 12 months. Liatsikos et al. reported that the stricture patency rate of Resonance® in patients with extrinsic malignant ureteral obstruction was 100%, though that in patients with benign ureteral obstruction was 44% at a mean follow-up period of 8.5 months (Liatsikos et al. 2010). However, when stent exchange is required, a disadvantage encountered with this type of metallic stent is the requirement to use the same procedure with initial insertion after endoscopic removal by forceps.

## 28.3 Indications for Ureteral Stenting

When advanced cancer causes ureteral obstruction, placement of a ureteral stent may be required. However, the indication for that should be carefully considered before the procedure, because upper urinary tract obstruction by cancer progression has a poor prognosis, with patient survival estimated to range from approximately 3–7 months (Ganatra and Loughlin 2005).

Generally, ureteral stent placement should be considered for patients who have severe symptoms such as back pain, those with good performance status (ECOG 0-1) who are expected to experience extended survival by improvement of renal function, and those in whom improvement of renal function will allow further treatments such as chemotherapy. On the other hand, since placement of a ureteral stent may cause a decline in QOL from adverse events such as bleeding and pain, the indication should be carefully considered by assessing physical status including performance status, as well as the prognosis of the underlying disease. Most types of progressive testicular cancer can be cured by chemotherapy in combination with surgery, thus preservation of renal function is very important. Ikeda et al. reported that ureteral stenting was effective to improve renal function prior to chemotherapy in a case with progressive testicular tumors and retroperitoneal lymph node metastasis causing ureteral obstruction (Ikeda et al. 2012).

Nevertheless, it remains controversial which should be selected for ureteral obstruction due to malignancy, ureteral stenting or percutaneous nephrostomy (PCN). For a ureteral obstruction caused by intrapelvic cancer such as rectal or uterine cancer, PCN is indicated more often than ureteral stenting (Ganatra and Loughlin 2005). Chung et al. reported that stent failure due to extrinsic compression occurred in nearly half of their treated patients within a nearly 1-year follow-up period, and also noted that mild renal insufficiency and metastatic disease requiring chemotherapy or radiation are predictors of stent failure (Chung et al. 2004). Wong et al. found that the success of treatment is dependent on the condition of each individual patient and reported a failure rate of ureteral stenting ranging from 16–58% in cases of upper urinary tract obstruction due to advanced cancer (Wong et al. 2007). Kouba et al. reviewed literature related to ureteral obstruction caused by advanced malignancy and noted that the success rate of retrograde ureteral stenting may be related to the type of pelvic malignancy. For example, cases of ureteral obstruction by bladder, prostatic, or cervical cancer were shown to have low success rates of 15–21%, whereas colorectal and breast cancers were managed with higher rates of success (Kouba et al. 2008). Monsky et al. evaluated the effects of PCN and ureteral stenting on QOL, and reported that urinary symptoms and pain were significantly more frequently reported in patients who received a ureteral stent as compared with PCN at 30 and 90 days, whereas those who underwent PCN were associated with more frequent minor complications requiring additional exchanges as compared to patients with a ureteral stent, suggesting that these QOL factors should be considered when choosing a palliative approach (Monsky et al. 2013).

## 28.4 Techniques for Placement and Exchange of Ureteral Stent

When an indwelling ureteral stent is placed in a retrograde fashion, each of rigid and flexible cystoscopes has their own merits and demerits. A rigid scope provides easy access to the ureteral orifice, and the operative force for insertion and twisting is directly transmitted to the catheter or guidewire. Also, when the operating field is cloudy due to pyuria or hematuria, irrigation can still be easily performed. However, a rigid scope is invasive because the procedure is painful, thus epidural or intravenous anesthesia is required, especially in males. On the other hand, a flexible scope is less invasive, with only local anesthesia and lubricating gel containing lidocaine enough to decrease pain. However, only the guidewire without the stent can be passed through the channel of a flexible scope, thus ureteral stent insertion must be done by covering the guidewire after removal of the scope so that the stent and guidewire easily form a loop in the bladder when insertion is difficult because of severe ureteral obstruction or ureteral looping.

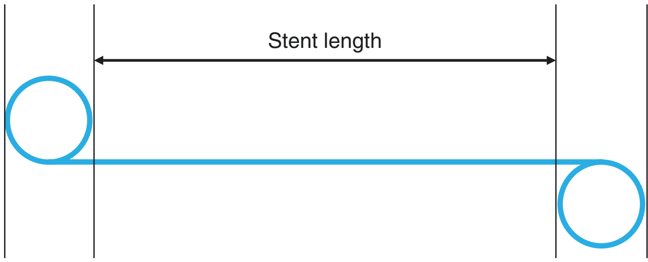


**Fig. 28.1** Determination of ureteral stent length

To avoid adverse events such as migration and knotting of the stent, as well as bladder irritability, an appropriate length stent must be used (Slaton 1996; Kondo et al. 2005). Several methods to determine stent length have been presented, including estimation based on height, measurement by use of images obtained with intravenous pyelography or retrograde pyelography, or direct measurement by insertion of a ureteral catheter under endoscopy (Kawahara 2012a). Since the length of the ureteral stent is presented as the straight part except coils on both ends (Fig. 28.1), it is recommended to choose a stent a few centimeters longer than the distance from the ureteropelvic junction to the vesicoureteral junction. Multi-length stents designed with a variable length curl make stent selection easy by accommodating all ureteral lengths in a single stent, though they are not recommended for routine use because of the high risk of a knotted stent. A longer stent may cause discomfort by irritating the bladder, while a shorter one may migrate into the ureter.

There are many types of guidewires available. As for the floppy end, there are two types; straight and J-shape (angle or bent). A straight tip is convenient for insertion into the ureter at the ureteral orifice, though perforation of the ureteral wall can easily occur. Although the J-shape is safer, it is technically difficult to insert into the ureter especially when a flexible scope is used, thus a J-shaped guidewire is often used with a straight open-ended catheter covering the guidewire. Shaft stiffness is also important for handling the guidewire in various situations. A stiffer shaft makes it easier to handle the guidewire because of more direct force transmission to push, pull, and twist, though perforation of the ureteral wall can easily occur. Use of a softer shaft is preferable to avoid such perforation with a flexed or looped ureter. On the other hand, the softer shaft is more difficult to manipulate because of its slickness, especially the hydrophilic-coated plastic type, which often results in a loop of the guidewire in the bladder or slipping out from the ureter. Regardless of type, unnatural force to the guidewire or stent should be avoided in order to avoid damage to and perforation of the ureter during ureteral stenting. In cases for which an image of the upper urinary tract using contrast media with retrograde urography is not available, passage of the guidewire beyond the obstruction is highly critical. When passage of the guidewire or stent is difficult because of severe stenosis of the ureter, alternative methods including PCN must be considered to avoid causing severe complications.

Before the initial placement of a ureteral stent, retrograde urography should be performed to obtain detailed information about the configuration of the renal pelvis and ureter. Retrograde urography before the exchange may be skipped when no difficulty with the initial placement has been encountered. For exchange of a ureteral stent, flexible cystoscope and forceps are generally used for removal. A method for ureteral stent removal in female patients with a crochet hook has been reported as easy, safe, and cost effective (Kawahara 2012b). Although various methods are widely used, novice practitioners should carefully perform removal under fluoroscopy. When unnatural force is required during pulling, there may be knotting or encrustation present, thus an imaging modality such as ultrasound, X ray, or CT should be performed, and appropriate treatment for the condition must be considered.

## 28.5 Ureteral Stent-Related Symptoms

An indwelling ureteral stent can be associated with various symptoms, such as bladder irritation, urgency, micturition pain, and hematuria, as well as occasionally a febrile urinary tract infection. In 2001, Joshi et al. developed the Ureteral Stent Symptom Questionnaire (USSQ) including 6 domains and 38 questionnaires to assess not only urinary symptoms and body pain, but also general health, work performance, sexual matters (Joshi et al. 2001, 2003). The USSQ has been translated into several different languages, and is routinely used to assess symptoms and adverse events following stent insertion.

Stent-related symptoms may be correlated with its length, rigidity, and shape. Lee et al. evaluated stent-related symptoms using a visual analogue pain scale (VAPS) in Korean patients less than 175 cm tall and with a 22-cm indwelling stent, and concluded that the length was appropriate in those cases (Lee et al. 2010). Ho et al. evaluated the relationship between length and stent-related symptoms, and concluded that stent length is associated with the position of the distal loop and related urinary symptoms, and that a longer stent causes an overlong intravesical segment and more irritative symptoms (Ho et al. 2008). In contrast, Abt et al. reported that the intravesical position of the stent did not significantly influence associated morbidity (Abt et al. 2015a).

Lingeman et al. assessed near-term comfort of two newly designed stents, one with a short loop tail (3 cm) and another with a long loop tail (6 cm), and compared the results with two types already being marketed in 236 patients. They found that patients with the short loop tail stent had lower pain scores and lower levels of pain medication use, though the differences were not statistically significant (Lingeman et al. 2009). Kawahara et al. reported details of 25 patients who underwent a ureteral stent exchange from a double pigtail- to loop-type ureteral stent and found that nearly all stent-related symptoms had a significantly lower score after the exchange (Kawahara et al. 2012a). These findings suggest that ureteral stent-related symptoms are closely related to the materials used to construct the stent, as well as its stiffness and the shape of the peripheral end.

Stent-related symptoms might be preventable by use of medical therapy, such as α-blockers and anti-cholinergic agents. Two reports of meta-analysis showed that α-blocker administration significantly decreased urinary symptom and body pain scores when evaluated by USSQ. There were also reductions in other aspects of USSQ, such as general health and sexual matters scores, though these were not statistically significant or uniformly reported (Lamb et al. 2011; Kwon et al. 2015).

El-Nahas et al. reported that use of tamsulosin or solifenacin alone in patients with ureteral stents can improve QOL by decreasing ureteral stent-related symptoms as compared with a placebo, though found that solifenacin was better than tamsulosin (El-Nahas et al. 2015). Several studies have also shown that combination therapy with an α-blocker and anticholinergic drug improved both irritative and obstructive symptoms as compared to other groups (Lim et al. 2011; Shalaby et al. 2013; Tehranchi et al. 2013; Zhou et al. 2015), though some other studies reported objective results indicating no superiority of combination therapy with an α-blocker and anti-cholinergic drug (Park et al. 2015; Sivalingam et al. 2015).

Interestingly, Abt et al. investigated the influence of patient education on symptoms and problems caused by ureteral stents, and reported that high-quality patient education is highly advisable because it has the potential to reduce ureteral stent-related symptoms (Park et al. 2015; Abt et al. 2015b).

## 28.6 Antimicrobial Prophylaxis for Placement and Exchange of Ureteral Stent

Farsi et al. prospectively studied 266 patients with an indwelling double-J ureteral stent, and reported that long-term ureteral stenting is associated with high rates of bacteriuria and stent colonization, with *Pseudomonas aeruginosa* the most common pathogen isolated from urine and stent samples (Farsi et al. 1995). Lojanapiwat et al. noted colonization rates of 33%, 50%, and 54% when the indwelling time of the ureteral stent was less than 4 weeks, 4–6 weeks, and more than 6 weeks, respectively, with *Escherichia coli*, *Enterobacter*, and *Pseudomonas* spp. the most commonly colonized organisms, while no colonization was found when the indwelling time was less than 2 weeks (Lojanapiwat 2006). Riedl et al. reported bacteriuria and bacterial stent colonization in all patients with permanent stents, as well as in 69.3% with temporary stents, and also found that antibiotic prophylaxis did not prevent stent colonization, leading to their conclusion that antibiotic prophylaxis should not be routinely administered (Riedl et al. 1999).

On the other hand, Kehinde et al. reported that the risks of bacteriuria and colonization with use of a J-shape tip are significantly enhanced by the duration of indwelling stent, female gender, and presence of systemic disease, such as diabetes mellitus, chronic renal failure, and diabetic nephropathy, and recommended that such patients require a shorter duration of indwelling, as well as antimicrobial prophylaxis and careful follow-up examinations to minimize infectious complications (Kehinde et al. 2002). Paz et al. retrospectively evaluated 100 consecutive cases of retrograde stent insertion, and reported that urgent insertion of a double-J stent was associated with increased incidence of febrile infection, suggesting that antimicrobial prophylaxis may be required in such urgent cases (Paz et al. 2005).

In a prospective randomized study, continuous low-dose antimicrobial treatments during the entire period of double-J stent indwelling did not reduce the quantity or severity of urinary tract infections, had no effects on stent-related symptoms, and increased antibiotic side-effect symptoms as compared with a peri-interventional antimicrobial prophylaxis alone, indicating that a continuous administration of antibiotics in general should not be recommended following insertion of a ureteral stent (Moltzahn et al. 2013).

For preparing a sterile barrier, maximal sterile barrier precautions are recommended, including use of a cap and mask, and sterile gown, gloves, and full body drape. Nevertheless, scant clinical evidence has been presented and further investigations are needed.

## 28.7 Complications Encountered with Ureteral Stenting

### 28.7.1 Encrustation

In a retrospective review, el-Faqih et al. examined morbidity and complications associated with use of an internal polyurethane ureteral stent in a series of 290 patients with ureteral stones. They reported encrustation in 9.2% of stents retrieved within 6 weeks of placement, in 47.5% of those indwelling for 6–12 weeks, and in 76.3% of those that remained in place for a longer period. Furthermore, an auxiliary procedure was required to decrease the burden of an encrusted stone and enable stent retrieval in 6.3%. Despite luminal blockage in 30% of the stents retrieved after indwelling times for up to 3 months, the incidence of clinical obstruction in stented tracts in those cases was 4%, indicating that morbidity was minimal when the stent indwelling time did not exceed 6 weeks (el-Faqih et al. 1991). Similarly, Kawahara et al. investigated a total of 330 ureteral stents in 181 patients and found that the rate of those with encrustation was 26.8% at less than 6 weeks, 56.9% at 6–12 weeks, and 75.9% at more than 12 weeks. In addition, a total of 46 (13.9%) stents resisted removal, of which 3 could not be removed by cystoscopy, indicating that an encrusted ureteral stent may occur even with an indwelling time within 3 months and those with heavy encrustation require additional procedures for removal (Kawahara et al. 2012b). Reported risk factors for an encrusted ureteral stent include long-term indwelling, history of urolithiasis, pregnancy, chemotherapy, chronic renal failure, or metabolic disease, and presence of a congenital abnormality (Robert et al. 1997; Mohan-Pillai et al. 1999).

In cases with a capacious ureter and non-impacted stent, an attempt for careful removal can be made under fluoroscopic guidance to minimize the time of lithotripsy with a ureteroscope and related complications (Agarwal et al. 2009). However, patients with stent encrustation often require multiple treatments. The combination of extracorporeal shock wave lithotripsy (SWL) and endourology techniques offers a high chance of successful outcome, and often avoids the need for a more invasive method. Several different algorithms for determining treatment of stent encrustation have been reported, with SWL generally recommended for upper mild or moderate encrustation, while severe encrustation is reported to be better treated by transurethral or percutaneous endoscopic procedures (Agarwal et al. 2009; Singh et al. 2001; Bultitude et al. 2003). Weedin et al. reviewed records of patients who underwent surgical removal of an encrusted and retained ureteral stent, and reported that CT more accurately revealed stone burden as compared to a plain X-ray examination of the kidneys, and suggested that accurate determination of proximal stone burden, preferably by CT, is important for surgical counseling and planning (Fig. 28.2a–c) (Weedin et al. 2011).

The best means to prevent encrustation of a ureteral stent is to minimize the term of indwelling (el-Faqih et al. 1991). Although a "forgotten stent" is an infrequent problem, that is associated with significant medical problems. To prevent stent removal from being forgotten several proposals have been reported, such as a computerized reminder system, stent card registration, and short message reminder service for tracking overdue ureteral stents (Ather et al. 2000; Tang et al. 2008; Sancaktutar et al. 2012).

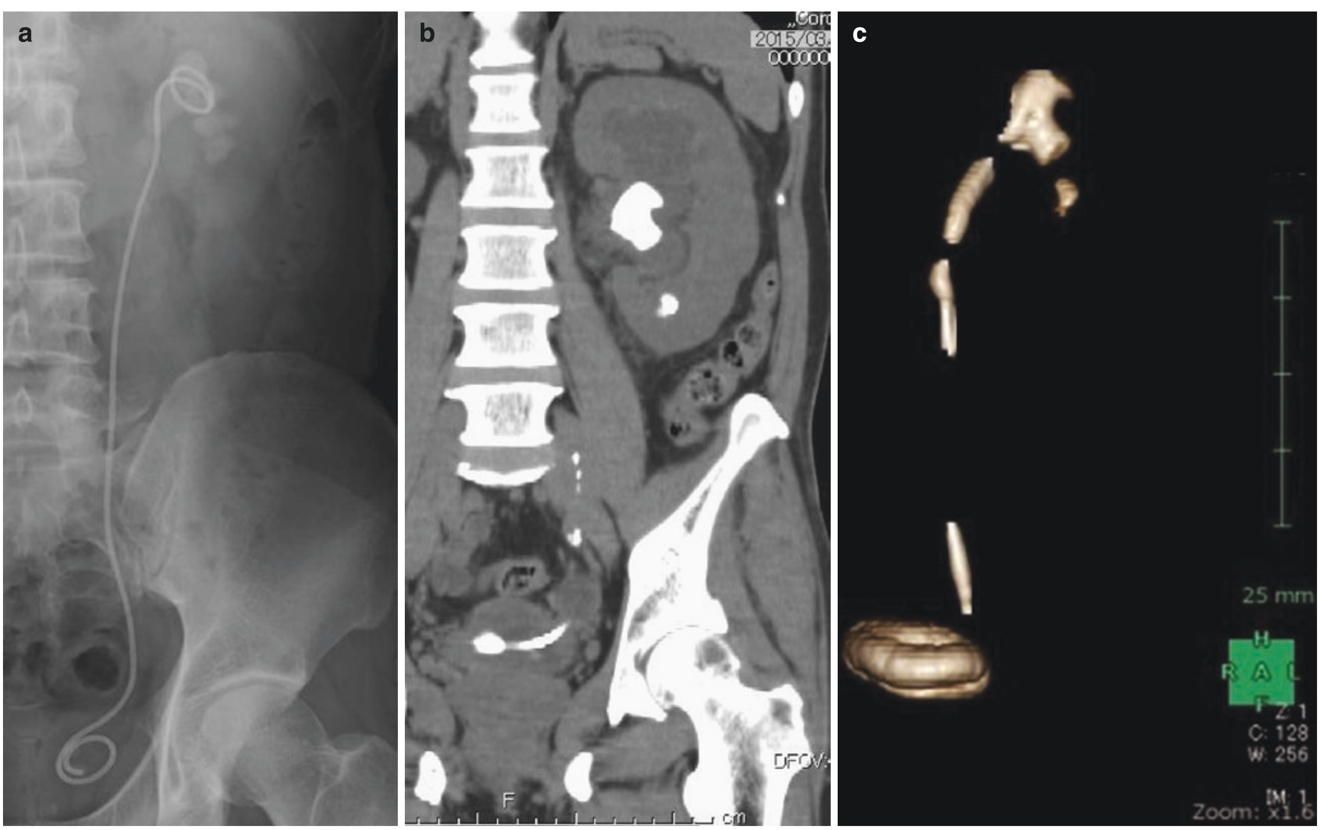


**Fig. 28.2** Images of ureteral stents with encrustation (**a**. KUB, **b**. CT, **c**. 3D-CT)

### 28.7.2 Migration

Proximal migration occurs by movement of the distal end of a ureteral stent into the ureter, mainly because it is too short for a proper fit. Several studies have reported that the rate of migration is closely correlated to mismatch in length between the stent and ureter, and recommended that ureteral length should be measured directly from X-ray images to select the optimal stent length (Kawahara 2012a; Slaton and Kropp 1996; Breau and Norman 2001). A stent with a half coil-type distal end tends to migrate as compared with that with a full coil-type distal end. If it is necessary to continue stenting after migration has been detected, a longer stent should be placed.

Even when proximal migration occurs, if a pulling string is attached at the distal end, it is easy to pull it back and set the stent in a correct position. On the other hand, while a dislocated ureter can be removed by use of grasping forceps under cystoscopy or ureteroscopy guidance, an alternative method using a stone basket was reported in difficult cases (Ho et al. 2009). Most ureteral stent malfunctions are routinely managed with a retrograde technique, while successful fluoroscopic guided-percutaneous removal of a migrated stent has been reported (LeRoy et al. 1986). Extra-vesical, intra-intestinal, and intravascular migration of a ureteral stent are rare but lethal complications (Ioannis et al. 2003; Wall et al. 2008; Billoud et al. 2008; Falahatkar et al. 2012; Michalopoulos et al. 2002).

### 28.7.3 Knotted Ureteral Stent

Knotting rarely occurs with use of a ureteral stent, though it can be a very difficult condition to treat (Fig. 28.3). Since multi-length stents can more easily cause knotting as compared to those with a single coil, a multi-length stent should not be routinely used (Karagüzel et al. 2012). Different management options have been reported, including simple traction, endoscopic removal in a retrograde or percutaneous fashion, and open surgery. When simple traction is attempted, it should be performed under fluoroscopic monitoring and pulling with unnatural force must be avoided to circumvent damage to the ureter. Several techniques have been presented for successful untying of a knot using ureteroscopy with an alligator forceps or holmium laser (Sighinolfi et al. 2005; Flam et al. 1995; Richards et al. 2011), though some difficult cases have required percutaneous removal (Braslis and Joyce 1992) or even open surgery.

**Fig. 28.3** A knotted stent

### 28.7.4 Ureteroarterial Fistula (UAF)

A UAF is also a rare complication, though often life threatening. Risk factors for UAF have been reported to be a chronic indwelling stent, prior external beam radiotherapy or pelvic surgery, and the presence of vascular disease or malignancy (van den Bergh et al. 2009; Krambeck et al. 2005; McCullough et al. 2012). Keller et al. noted a survival rate of 89% among cases in which diagnosis was correctly determined before treatment, while that was only 48% for incorrectly diagnosed cases, indicating that immediate and accurate diagnosis is important (Keller et al. 1990). Also, van den Bergh et al. reviewed 139 UAF cases and reported that only 22% of the fistulas in those were recognized before treatment and that 13% of the patients died of an UAF-related cause. They proposed that a diagnosis of UAF should be considered in patients with unexplained hematuria and history of pelvic cancer or vascular surgery. In these cases, angiographic techniques were required to visualize the fistulas, including selective arterial catheterization, use of multiple projections, and provocative maneuvers (van den Bergh et al. 2009; Quillin et al. 1994).

Recently, there appears to be a shift in type of management for affected patients, from primarily open surgical to primarily angiographic procedures (McCullough et al. 2012). When an accurate diagnosis can be quickly established, UAF patients treated with an endovascular technique followed by arterial embolization or placement of a stent graft had the most favorable outcomes (van den Bergh et al. 2009; McCullough et al. 2012), in contrast to an emergency nephrectomy or renal autotransplantation previously performed (Cass and Odland 1990; Bullock et al. 1992).

The exact mechanism of development of UAF remains unclear. Necrosis of the catheterized ureter caused by pressure is believed to contribute to fistula formation (van den Bergh et al. 2009). Also, pulsation from the iliac artery transmitted through an already compromised ureter to a stiff intraluminal catheter can readily produce necrosis. Previous radiation therapy as well as pelvic or vascular surgical procedures may induce weakening of the ureteral and arterial walls. Thus, when ureteral stenting is necessary for a longer period, it is advisable to use a small and soft silicone stent (Veenstra et al. 2011).

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## References

Abt D, Mordasini L, Warzinek E, et al. Is intravesical stent position a predictor of associated morbidity? Korean J Urol. 2015a;56:370–8.

Abt D, Warzinek E, Schmid HP, et al. Influence of patient education on morbidity caused by ureteral stents. Int J Urol. 2015b;22:679–83.

Agarwal MM, Singh SK, Mandal AK, et al. Endourologic management of forgotten encrusted ureteral stents: can ureteroscopic lithotripsy be avoided? Surg Laparosc Endosc Perctan Tech. 2009;19:72–7.

Althaus AB, Li K, Pattison E, et al. Rate of dislodgment of ureteral stents when using an extraction string after endoscopic urological surgery. J Urol. 2015;193:2011–4.

Ather MH, Talati J, Biyabani R. Physician responsibility for removal of implants: the case for a computerized program for tracking overdue double-J stents. Tech Urol. 2000;6:189–92.

Billoud E, Savoye G, Hervé S, et al. Double J ureteral stent as an unusual endoscopic finding in a patient with rectal bleeding. Gastrointest Endosc. 2008;68:1239–40.

Braslis KG, Joyce G. Spontaneous knotting of a pigtail ureteric stent in the ureter requiring percutaneous removal. Aust N Z J Surg. 1992;62:825–6.

Breau RH, Norman RW. Optimal prevention and management of proximal ureteral stent migration and remigration. J Urol. 2001;166:890–3.

Bullock A, Andriole GL, Neuman N, et al. Renal autotransplantation in the management of a ureteroarterial fistula: a case report and review of the literature. J Vasc Surg. 1992;15:436–41.

Bultitude MF, Tiptaft RC, Glass JM, et al. Management of encrusted ureteral stents impacted in upper tract. Urology. 2003;62:622–6.

Cass AS, Odland M. Ureteroarterial fistula: case report and review of literature. J Urol. 1990;143:582–3.

Chung SY, Stein RJ, Landsittel D, et al. 15-year experience with the management of extrinsic ureteral obstruction with indwelling ureteral stents. J Urol. 2004;172:592–5.

van den Bergh RC, Moll FL, de Vries JP, et al. Arterioureteral fistulas: unusual suspects-systematic review of 139 cases. Urology. 2009;74:251–5.

El-Nahas AR, Tharwat M, Elsaadany M, et al. A randomized controlled trial comparing alpha blocker (tamsulosin) and anticholinergic (solifenacin) in treatment of ureteral stent-related symptoms. World J Urol. 2015;34:963–8.

Falahatkar S, Hemmati H, Monghaddam KG, et al. Intracaval migration: an uncommon complication of ureteral Double-J stent placement. J Endourol. 2012;26:119–21.

el-Faqih SR, Shamsuddin AB, Chakrabarti A, et al. Polyurethane internal ureteral stents in treatment of stone patients: morbidity related to indwelling times. J Urol. 1991;146:1487–91.

Farsi HM, Mosli HA, Al-Zemaity MF, et al. Bacteriuria and colonization of double-pigtail ureteral stents: long-term experience with 237 patients. J Endourol. 1995;9:469–72.

Flam TA, Thiounn N, Gerbaud PF, et al. Knotting of a double pigtail stent within the ureter: an initial report. J Urol. 1995;15:1858–9.

Ganatra AM, Loughlin KR. The management of malignant ureteral obstruction treated with ureteral stents. J Urol. 2005;174:2125–8.

Ho CH, Chen SC, Chung SD, et al. Determining the appropriate length of a double-pigtail ureteral stent by both stent configurations and related symptoms. J Endourol. 2008;22:1427–31.

Ho CH, Chung SD, Huang KH, et al. Retrieval of a misplaced double-J ureteral stent in the renal pelvis: a novel technique. Surg Laparosc Endosc Percutan Tech. 2009;19:e24–2.

Ikeda A, Kawai K, Ando S, et al. Management of ureteral obstruction in advanced testicular tumor with lymph node metastasis. Jpn J Clin Oncol. 2012;42:748–52.

Ioannis C, Ioannis Z, Evangelos I, et al. Retrovesical migration of malpositioned double-j ureteral stent. Int Urol Nephrol. 2003;35:325–6.

Joshi HB, Stainthorpe A, Keeley FX, et al. Indwelling ureteral stents: evaluation of quality of life to aid outcome analysis. J Endourol. 2001;15:151–4.

Joshi HB, Newns N, Stainthorpe A, et al. Ureteral stent symptom questionnaire: development and validation of a multidimensional quality of life measure. J Urol. 2003;169:1060–4.

Karagüzel E, Kutku O, Karaz IO, et al. Knotted ureteral stent: a rare complication of ureteral stent usage. Urol Res. 2012;40:793–5.

Kawahara T. Choosing an appropriate length of loop type ureteral stent using direct ureteral length measurement. Urol Int. 2012a;88:48–53.

Kawahara T. Ureteral stent retrieval using the crochet hook technique in females. PLoS One. 2012b;7:e29292.

Kawahara T, Ito H, Terao H, et al. Changing to a loop-type ureteral stent decreases patients' stent-related symptoms. Urol Res. 2012a;40:763–7.

Kawahara T, Ito H, Terao H, et al. Ureteral stent encrustation, incrustation, and coloring: morbidity related to indwelling times. J Endourol. 2012b;26:178–82.

Kehinde EO, Rotimi VO, Al-Awadi KA, et al. Factors predisposing to urinary tract infection after J ureteral stent insertion. J Urol. 2002;167:1334–7.

Keller FS, Barton RE, Routh WD, et al. Gross hematuria in two patients with ureteral-ileal conduits and double-J stents. J Vasc Interv Radiol. 1990;1:69–77.

Kondo N, Yoshino Y, Shiono Y, et al. A case demonstrating knot formation at the upper end of a ureteral stent. Hinyokika Kiyo. 2005;51:385–7.

Kouba E, Wallen EM, Pruthi RS. Management of ureteral obstruction due to advanced malignancy: optimizing therapeutic and palliative outcomes. J Urol. 2008;180:444–50.

Krambeck AE, DiMarco DS, Gettman MT, et al. Ureteroiliac artery fistula: diagnosis and treatment algorithm. Urology. 2005;66:990–4.

Kwon JK, Cho KS, Oh CK, et al. The beneficial effect of alpha-blockers for ureteral stent-related discomfort: systematic review and network meta-analysis for alfuzosin versus tamsulosin versus placebo. BMC Urol. 2015;15:55.

Lamb AD, Vowler SL, Johnson R, et al. Meta-analysis showing the beneficial effect of α-blockers on ureteric stent discomfort. BJU Int. 2011;108:1894–902.

Lee BK, Paick SH, Park HK, et al. Is a 22 cm ureteric stent appropriate for Korean patients smaller than 175 cm in height? Korean J Urol. 2010;51:642–6.

LeRoy AJ, Williams HJ Jr, Segura JW, et al. Indwelling ureteral stents: percutaneous management of complications. Radiology. 1986;158:219–22.

Liatsikos E, Kallidonis P, Kyriazis I, et al. Ureteral obstruction: is the full metallic double-pigtail stent the way to go? Eur Urol. 2010;57:480–6.

Lim KT, Kim YT, Lee TY, et al. Effects of tamsulosin, solifenacin, and combination therapy for the treatment of ureteral stent related discomforts. Korean J Urol. 2011;52:485–48.

Lingeman JE, Preminger GM, Goldfischer ER, et al. Assessing the impact of ureteral stent design on patient comfort. J Urol. 2009;181:2581–7.

Lojanapiwat B. Colonization of internal ureteral stent and bacteriuria. World J Urol. 2006;24:681–3.

McCullough MC, Oh EE, Lucci JA 3rd, et al. Ureteroarterial fistula. J Obstet Gynaecol. 2012;32:617–20.

Michalopoulos AS, Tzoufi MJ, Theodorakis G, et al. Acute postoperative pulmonary thromboembolism as a result of intravascular migration of a pigtail ureteral stent. Anesth Analg. 2002;95:1185–8.

Mohan-Pillai K, Keeley FX Jr, Moussa SA, et al. Endourological management of severely encrusted ureteral stents. J Endourol. 1999;13:377–9.

Moltzahn F, Haeni K, Birkhäuser FD, et al. Peri-interventional antibiotic prophylaxis only vs continuous low-dose antibiotic treatment in patients with JJ stents: a prospective randomised trial analysing the effect on urinary tract infections and stent-related symptoms. BJU Int. 2013;111:289–95.

Monsky WL, Molloy C, Jin B, et al. Quality-of-life assessment after palliative interventions to manage malignant ureteral obstruction. Cardiovasc Intervent Radiol. 2013;2013(36):1355–63.

Park J, Yoo C, Han DH, et al. A critical assessment of the effects of tamsulosin and solifenacin as monotherapies and as a combination therapy for the treatment of ureteral stent-related symptoms: a 2 × 2 factorial randomized trial. World J Urol. 2015;33:1833–40.

Paz A, Amiel GE, Pick N, et al. Febrile complications following insertion of 100 double-J ureteral stents. J Endourol. 2005;19:147–50.

Quillin SP, Darcy MD, Picus D. Angiographic evaluation and therapy of ureteroarterial fistulas. AJR Am J Roentgenol. 1994;162:873–8.

Richards MM, Khalil D, Mahdy A. Successful treatment of stent knot in the proximal ureter using ureteroscopy and holmium laser. Case Rep Med. 2011;2011(2011):50219.

Riedl CR, Plas E, Hübner WA, et al. Bacterial colonization of ureteral stents. Eur Urol. 1999;36:53–9.

Robert M, Boularan AM, El Sandid M, et al. Double-J ureteric stent encrustations: clinical study on crystal formation on polyurethane stents. Urol Int. 1997;58:100–4.

Sancaktutar AA, Tepeler A, Söylemez H, et al. A solution for medical and legal problems arising from forgotten ureteral stents: initial results from a reminder short message service (SMS). Urol Res. 2012;40(3):253–8.

Shalaby E, Ahmed AF, Maarouf A, et al. Randomized controlled trial to compare the safety and efficacy of tamsulosin, solifenacin, and combination of both in treatment of double-j stent-related lower urinary symptoms. Adv Urol. 2013;2013(2013):752382.

Sighinolfi MC, De Stefani S, Micali S, et al. A knotted multi-length ureteral stent: a rare complication. Urol Res. 2005;33:70–1.

Singh I, Gupta NP, Hemal AK, et al. Severely encrusted polyurethane ureteral stents: management and analysis of potential risk factors. Urology. 2001;58:526–31.

Sivalingam S, Streeper NM, Sehgal PD, et al. Does combination therapy with tamsulosin and tolterodine improve ureteral stent discomfort compared with tamsulosin alone? A double-blind, randomized, controlled trial. J Urol. 2015;195:385–90.

Slaton JW. Proximal ureteral stent migration: an avoidable complication? J Urol. 1996;155:58–61.

Slaton JW, Kropp KA. Proximal ureteral stent migration: an avoidable complication? J Urol. 1996;155:58–61.

Tang VC, Gillooly J, Lee EW, et al. Ureteric stent card register—a 5-year retrospective analysis. Ann R Coll Surg Engl. 2008;90:156–9.

Tehranchi A, Razaei Y, Khalkhali H, et al. Effects of terazosin and tolterodine on ureteral stent related symptoms: a double-blind placebo-controlled randomized clinical trial. Int Braz J Urol. 2013;39:832–40.

Veenstra GM, Fossion LMCL, Debonnaire G, et al. Endovascular treatment of a right-sided ureteroiliac fistula in a patient with a simultaneous left-sided ureteroileal fistula. Case Rep Urol. 2011;2011:284505.

Wall I, Baradarian R, Tangorra M, et al. Spontaneous perforation of the duodenum by a migrated ureteral stent. Gastrointest Endosc. 2008;68:1236–8.

Weedin JW, Coburnt M, Link RE. The impact of proximal stone burden on the management of encrusted and retained ureteral stents. J Urol. 2011;185:542–7.

Wong LM, Cleeve LK, Milner AD, et al. Malignant ureteral obstruction: outcomes after intervention. Have things changed? J Urol. 2007;178:178–83.

Zhou L, Cai X, Li H, et al. Effects of α-blockers, antimuscarinics, or combination therapy in relieving ureteral stent-related symptoms: a meta-analysis. J Endourol. 2015;29:650–6.

# 29 Treatment of BPH: What Is the Gold Standard?

Chunxiao Liu, Abai Xu, and Peng Xu

**Abstract**

Transurethral resection of prostate (TURP) is considered as the gold standard surgical treatment of benign prostate hyperplasia (BPH). This recommendation has been challenged over the years due to high postoperative complication rates and symptoms recurrence. Modification and innovation of surgical techniques in BPH treatment is deemed necessary. In this article, we introduce the techniques of transurethral enucleation and resection of prostate, which will be the new standard of BPH management.

**Keywords**

BPH · TURP · Enucleation · Endoscopic · Morcellation

## Abbreviations

| | |
|---|---|
| BPH | Benign prostatic hyperplasia |
| CHD | Coronary heart disease |
| COPD | Chronic obstructive pulmonary disease |
| DM | Diabetic mellitus |
| HoLEP | Holmium laser nucleation of the prostate |
| LUTS | Lower urinary tract symptoms: |
| PK | Plasma kinetics |
| QoL | Quality of life |
| TUERP | Transurethral enucleation and resection of the prostate |
| TUIP | Transurethral incision of the prostate |
| TURP | Transurethral resection of the prostate |

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## 29.1 Introduction

Lower urinary tract symptoms (LUTS) are the common presenting symptoms in older men with benign prostatic hyperplasia (BPH), which have a substantial influence on the quality of life (QoL) and economic burden. BPH may results in acute urinary retention, urinary incontinence, recurrent urinary tract infection, or obstructive uropathy. Currently, the treatments of LUTS caused by BPH include watchful waiting, pharmacological therapy and surgical intervention, intending to alleviate the symptoms, improve QoL, delay disease progression and prevent associated complications. Actually, BPH is a kind of progressive disease, and some patients finally have to receive surgery to alleviate LUTS. In this chapter, we will focus on the surgical approaches of BPH.

Guideline from European Association Urology suggested that transurethral resection of the prostate (TURP) and transurethral incision of the prostate (TUIP) are effective treatments for moderate-to-severe LUTS secondary to BPH. The treatment options are based on the prostate volume (< 30 ml and 30–80 ml suitable for TUIP and TURP, respectively). They are common urologic operation but not without complication rate. The reported complication rate is about 15–18%, including bleeding requiring blood transfusion, TUR syndrome and myocardial arrhythmia (Mebust et al. 1989). Urologists therefore make efforts to look for new endoscopic treatments for patients with symptomatic BPH.

In 1989, Hiraoka and Akimoto (1989) first proposed the concept of transurethral enucleation and resection of the prostate (TUERP), which mimicked the index finger in open prostatectomy by using a detaching blade, to minimize the potential risk of capsular perforation as compared to standard TURP. Advances in technology of laser and Plasma Kinetics (PK) have widened the armamentarium in BPH surgery. PK and laser energies make enucleation of the prostate more effective. Gilling et al. (1998) pioneered holmium laser nucleation of the prostate (HoLEP), and made this technique recognized as an effective, safe and suitable for any prostate


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size (Shah et al. 2008). Durable improvement in clinical outcomes, low complication and reoperation rate after HoLEP has been proven (Elzayat and Elhilali 2007). Neil et al. (2006) subsequently demonstrated that bipolar PK energy can be safely used in the same endoscopic enucleation procedure. In 2003, Liu et al. (2006) published a case series of totally retrograde bipolar-TUERP. Prostate glands are enucleated by dissecting along the surgical capsule, removing the intact lobes using the bipolar resectoscope tip combined with a loop. The resected adenoma is removed by the morcellator system (Xu et al. 2013, 2018; Liu et al. 2010).

TUERP is an alternative technique that can remove prostatic adenoma anatomically and also may offer comparable results to open surgery by minimally invasive endoscopic surgery. It can broaden the indications for managing prostate glands of any size and had been verified with its immediate and durable effect. Ninty-six percent of the patients (1057 out of 1100 patients) had with improved uroflow and a significant PSA reduction from 7.8 ng/ml (range 3.4 ng/ml to 15 ng/ml) to 0.89 ng/ml at a mean 4.3-year follow-up after TUERP (Liu et al. 2010). Chen et al. suggested that HoLEP can be safely applied to prostates of all sizes with less risk of hemorrhage, less bladder irrigation and shorter catheter times, as well as shorter hospital stay (Chen et al. 2013). A randomized clinical trial comparing diode laser enucleation of the prostate (DiLEP) with PK enucleation and resection of the prostate also showed DiLEP provided less bleeding rate, bladder irrigation and catheterization times (Xu et al. 2013).

Enucleation epitomizes an improvement of surgical technique in which this procedure is based on the same principle regardless of the devices used for the surgery, and can be widely conducted due to the easy accessibility to the surgery equipment. Although TURP is still considered as the gold standard for treatment of BPH, TUERP appears to be the safe and effective alternative to TURP in small-to-moderate size prostate and open prostatectomy for large prostate.

## 29.2 Surgery Procedure

1. **Pre-surgery preparation**
   Generally, we use lumbar or continuous epidural anesthesia, usually the anterior one for its reliability and simplicity. Sometimes with sacral canal anesthesia is even better for patients with prostate smaller than 60 g or expected operation time less than 1 h.

   The patient should be placed in what we call post-lithotomy position, for the leg holders should be placed underneath popliteal fossa and have legs outreached, and also have the bottom of hip exposed 1–2 cm over the edge of the table, so that we may extend resectoscope beyond hyperplastic adenoma and reach the surgical capsule.

2. **Entering the urethral and identifying key anatomical structure**
   Physiologic saline should be served during the entire operation as irrigation fluid. The 27F resectoscope was placed in the bladder under direct endoscopic guidance. The reason for this is to make sure if there's any anterior urethral stricture, tumor, stone or other possible causes for the dysuria, and also to avoid vice-damage. When we reach the prostate, we should observe the position of verumontanum, if the mid-lobe is hyperplastic, is there any intravesical prostatic protrusion (IPP), if the bladder has any trabecula or other stricture symptom, to exclude the possibility of neurogenic bladder.

3. **Making incision and finding surgical capsule**
   The incision should begin just behind verumontanum from the 5 or the 7 o'clock positions, corresponding to right or left lobe, depending on your habit. And we should incise deep through urethral mucosa to the level of surgical capsule. After we find this specific anatomical level, horizontally use the tip of the resectoscope to bluntly separate the adenoma and the capsule, then we move the other way across the posterior of verumontanum, beyond the 6 o'clock position, and push to peel open the connective tissue in between to isolate the bottom of the mid-lobe.

4. **Separating mid-lobe**
   The distal mid-lobe and mucosa is dissected in retrograde fashion toward the bladder neck by the resectoscope tip combined with a loop. The loop was used to cut off the adhesive fibers between the lobe and the surgical capsule and coagulate denuded blood vessels and bleeding spots on capsular surface. This procedure progressed toward the bladder neck until the circular fiber of the bladder neck was identified. Due to the connective tissue and supply vessels connecting mid and bilateral lobes, we should avoid blunt dissect all the way up, or we may accidently make a false passage through surgical capsule at 6 o'clock and go right through bladder neck. The right procedure should be making a V-shape resect using bipolar loop and isolate the mid-lobe first, and be caution of cutting open the bladder neck during the process. When mid-lobe is isolated, we may use resectoscope bluntly separate the mid-lobe toward the bladder neck until the circular fiber of the bladder neck was identified, and have the mid-lobe pushed into bladder. If in some cases, the patient has a very big mid lobe that the bladder neck is completely covered, we should also resect part of the mid-lobe until we can see the bladder neck before enucleation, so that when we are separating from the bottom, we may see the bladder neck easily and avoid vice-damage.

5. **Spherical enucleating bilateral lobe**
After enucleated the mid-lobe, we may use the anatomical level of the surgical capsule to bluntly separate the bilateral lobes to 1 and 11 o'clock, and then make the way through into bladder neck at these 2 exact points. After cutting open at these 2 points, we go back all the way to 5 and 7 o'clock, and only leave the bilateral lobes still attached to bladder neck at these 2 points. In the process, we should coagulate simultaneously to have a clear view. It is important to keep the bilateral lobes attached at 5 and 7 o'clock, for it's easier to cut without the adenoma floating around, and safer to deal with in the prostatic fossa.
After separation at 12 o'clock, the only attached point is 5 and 7 o'clock. Now the bilateral lobes are cut off from blood supply, and remain stable. We now may use the bipolar loop to resect them into 2 isolate lobes, and then resect the adenoma into pieces from top to bottom, and finally finished at the attached point. We should do this strictly in this order, or the remaining adenoma may float into bladder. In that case, we should take the floating adenoma back into the prostatic fossa to avoid damaging the bladder. After all the adenoma is fragmentized, we may use Ellic washer to clean up all the fragments to avoid clogging the catheter. Or we can have the adenoma pushed into bladder and use the morcellator to morcellate the adenoma into fragments and suck out using suction.

6. **Completing surgery and post-surgery management**
Finally, after all the adenoma is removed, check carefully around the surgical capsule to see if there's any of the nodule remaining, try to peel off or cut off, and in the meantime also smoothen the surface to make the urine flow more smoothly. The prostatic apex is too close to the sphincter, so we leave them untouched to avoid any vice-damage to the sphincter. Use only short burst coagulating or no coagulate at all to avoid heat damage to the sphincter. The prostatic fossa and bladder neck should be thoroughly coagulated and stop the irrigation to see if there's any more hemorrhage. After the operation, a 22F 3-way catheter should be placed into the bladder with continuing irrigation.

7. **The TUERP as described above, is suitable for all sizes of prostate, even for ultra-large prostate over 200 g**
   (a) When dealing with large prostate, it is important to make the V-shape resection between the bilateral lobes and mid-lobe as described before, for the size of the mid-lobe in these cases are usually very large, and making this resection helps protecting the bladder neck, also make it much easier to separate the mid-lobe.
   (b) When dealing with large to ultra-large prostate, it is always safer to prepare 2 units of blood. For patients with this size of prostate, the blood vessel is very abundant in the adenoma, and the operating time is quite long (usually more than 2 h), with patients usually at high age (over 70), so it is important to prepare blood, have major intravenous line ready and closely monitor the vital of patient during the surgery. In surgery, we should resect each lobe separately to avoid the large adenoma block the sight, and thoroughly coagulate hemorrhage, to avoid massive blood loss when dealing with other lobes.
   (c) Be extra careful when dealing with the 12 o'clock position, for the prostatic apex is very close to the external urethral sphincter, it is important to leave some urethral mucosa to avoid vice-damage to the sphincter, and try best not to coagulate directly on the sphincter, only short burst of coagulation when small artery erupts.
   (d) It is important to use a 30° resectoscope for through separation at 12 o'clock and coagulation around bladder neck. But sometimes the back of the bladder neck is hard to reach due to its angle, so we may have the catheter balloon blown up to 40 ml, and keep tension outside of urethral orifice using a gauze or other method, to have direct pressure on the bleeding spot and stop the bleeding.

## 29.3 TUERP in Special Situation

1. **TUERP for huge prostate**
   (a) Certain amount of 5-αreductase inhibitors were needed to reduce the volume of huge prostate and proactively reduce the intraoperative bleeding.
   (b) Preparated blood before operation. Such patients tend to be elder, coagulation function is poor, there is risk of bleeding due to the large wound.
   (c) Follow the principles of enucleation by lobes and steps.
   (d) Wash out the tissue after every step of enucleation, make room for next step. To prevent omissions, completely hemostasis is needed for every step of enucleation.

2. **TUERP for post TURP**
   (a) Prostate fossa wounds bound to be covered with fibrous adhesions and scars for the man who had TURP before, which often makes surgical capsular interface not clear and difficult to operate.
   (b) The most important thing is to identify the anatomical marks, generally do the TUERP from the obvious side of the recurrent lobe, combine with brief cutting instead of blunt dissection when necessary.

3. **TUERP for ultra-aged patients**
For patient more than 90 years old, TUERP is also an option. The oldest patient underwent TUERP in our center is 106 years old. These patients are always accompanied with cerebral infarction, stroke, chronic obstructive pulmonary disease (COPD), respiratory failure, heart failure, coronary heart disease (CHD), hypertension, liver cirrhosis, hepatic dysfunction, diabetic mellitus (DM), severe pancreatitis and so on. Good preoperative assessment, including the risk of anesthesia, risk of surgical and the estimated effect of surgery, will help doctors and patients better communication. Effective removal of tissue can better accelerate the recovery after surgery. Our clinical practices over these many years suggest that tissue morcellator can be used as a satisfactory tool in TUERP, which can significantly shorten the operation time without increasing the potential risk of the surgeries (Xu et al. 2016). For patients with long-term oral anticoagulation before surgery, laser surgery is thought to be an optimal choice.

4. **TUERP for sclerosing small prostate**
Due to the adhesion of inflammatory tissue, the surgical plane between hypertrophic gland and normal prostate is not obvious and it is often showed up as a whole tissue, which cause the difficulty to enucleate. These glands are toughness, containing more fibers and smooth muscles, associated with inflammatory lesions and calcifications. For less experienced urologists, we suggest that firstly used sharpness cut to release adhesive band rather than tearing method. Once found the wrong plane, it should be back along the surface of the glands to find the correct plane.
Perforation is easy to occur because of the surgical capsule plane is often show up as an unsmooth inflamed tissue plane. Termination of operations when find the adipose tissue, it can generally be self-healing by indwelling catheter for2 weeks.

## 29.4 Tips and Tricks

1. **Identifying**
   (a) The verumontanum is not the boundary, the adenoma is (Fig. 29.1).
   (b) It is easier to perform TUERP in patients with larger prostate, more difficult in patients with smaller gland, 50–60 g is suitable for beginners.

2. **Preserving**
   (a) Enucleation along the existed plane from 6'clock, preserve the original anatomical slope of the bladder neck.

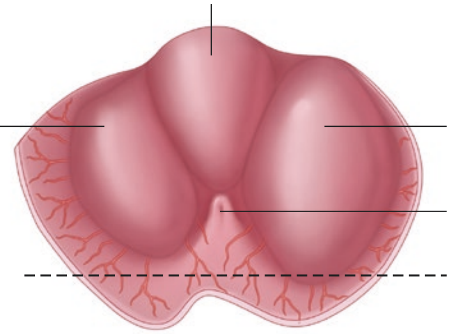


**Fig. 29.1** Schematic diagram shows boundary of verumontanum and hyperplasia gland. The apical portions of the adenoma were more than 1 cm distal to the verumontanum. The black dotted line on behalf of distal boundary of hyperplasia gland

   (b) Enucleate the median lobe first for following purposes (Fig. 29.2):
   - Set the mark of cutting depth in position 6 'clock, to prevent over dissection;
   - Preserve the physiological curve of the bladder neck to prevent retrograde ejaculation;
   - Making space for lateral lobes enucleation.

   (c) Properly handle 12 points of urethral valve. Must perform sharp dissection of urethral valve at 12 o'clock (connecting prostatic urethral mucosa and membranous urethral mucosa, Fig. 29.3). Blunt dissection may injure the sphincter.

3. **Vision**
   (a) It is important to use a 30° resectoscope for through separation at 12 o'clock and coagulation around bladder neck.
   (b) In the process, we should coagulate simultaneously to have a clear view. Throughout coagulation of the surgical site before cut or morcellate the enucleated glands.

4. **Morcellation (Single center experience)**
   (a) The tissue morcellation procedure should start with wound hemostasis in which all the hemorrhages shall be managed properly to maintain a clear vision.
   (b) Keep the bladder properly filled, and establish an extra perfusion channel as necessary using the sheath and outlet valve to avoid accidental injury during aspiration of the smashed tissues.
   (c) Inverted morcellation, a proven and effective technique according to the long-term clinical practice of our institute, is characterized by inverting the electrotome bit to aspirate the smashed tissues so that

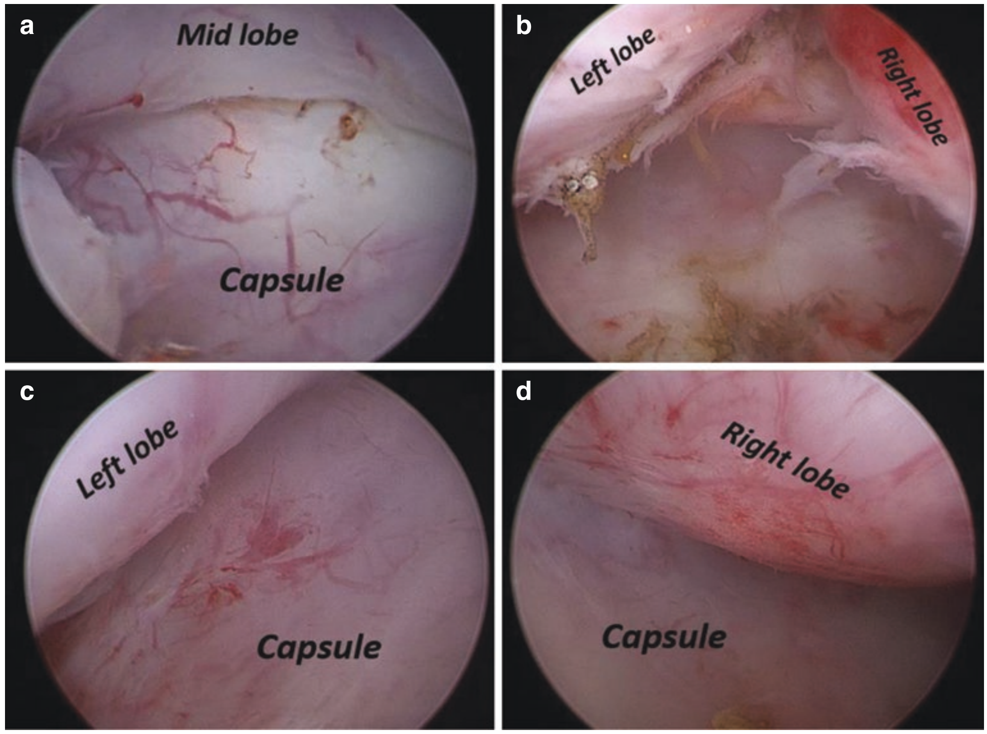


**Fig. 29.2** Enucleation procedure. (**a**) Enucleation of the middle lobe; (**b**) Preserving the physiological gradient of the bladder neck; (**c**) Enucleation of the left lobe; (**d**) Enucleation of the right lobe

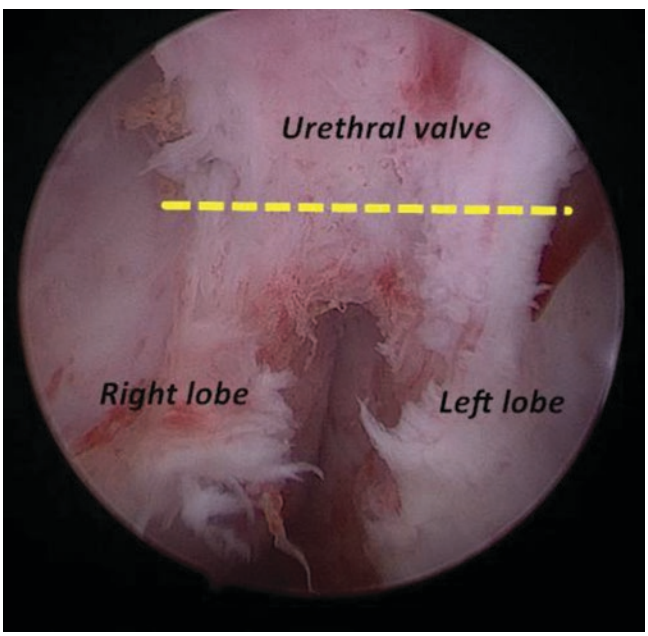


**Fig. 29.3** Treatment of 12 o'clock. Use brief cutting instead of blunt dissection without cutting beyond the yellow line to preserve partial urethral valve at 12 o'clock, that avoiding injury of the sphincter

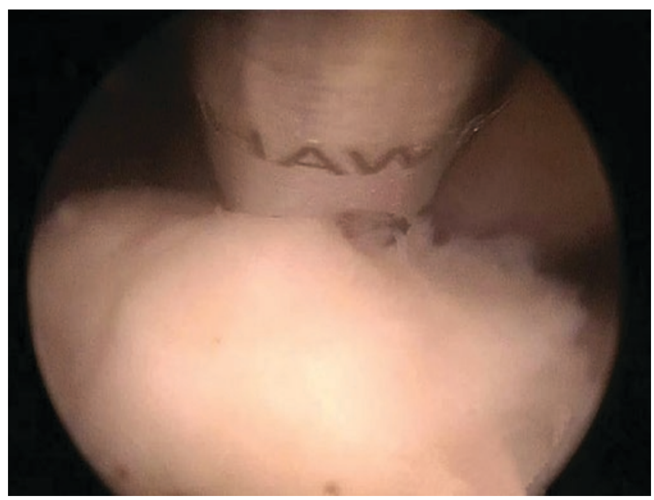

**Fig. 29.4** Tissue morcellation method to retrieve adenoma

the glands can be kept in suspension in the bladder, by wh*ich potential damage to the bladder mucosa can be avoided, and surgical complications minimized* (Fig. 29.4).

(d) Keep the force and speed of the morcellator at a proper level when performing tissue aspiration, as an excessively fast aspiration may cause bladder injury, while a slow operation may lead to inefficiency.

5. **Micturition experiment (Single center experience)** Urethral sphincter injury was examined intraoperatively after the completion of resection using "Micturition Experiment" by instilling appropriate saline into the blad-

der to simulate the urinary storage period. The urine coming out under the pressing on the suprapubic area and ceasing when the pressing stopped can lead to a preliminary judgment that the urethral sphincter is undamaged (Walz et al. 2007, 2010, 2016).

## 29.5 Discussion

1. **Enucleation and efficacy**
   Voiding symptoms associated with clinical enlarged prostate adversely could significantly interfere with their daily and affects patients' quality of life (Gratzke et al. 2015). Meanwhile, storage symptoms are also troubling for patients with BPH. The recovery of detrusor function is possible after a surgical procedure by relieving bladder outlet obstruction (Elkoushy et al. 2015). TURP is limited by the extend of resection due fear of capsular perforation and severe bleeding. Residual adenoma tissues remain after TURP, leading to a high postoperative recurrence rate (Shimizu et al. 2005). Our single center experience showed that prostate enucleation can remove up to 74.7% of prostate tissue, which is much higher than that in traditional TURP, contributes to a significant improvement in postoperative IPSS, QoL and Qmax.

2. **Enucleation and PSA**
   The PSA level is related to the size of the adenoma in the prostate transition zone. It also reflects the completeness of prostate tissue removal after surgical procedures (Furuya et al. 2000). A randomized trial confirmed that there was a similar reduction of the PSA level and postoperative prostate volume in the enucleation group as compared to the open surgery group during 1-year follow-ups (Geavlete et al. 2013). According to Palaniappan (Palaniappan et al. 2016), the patient after enucleation had a significantly lower postoperative PSA level (1.2 ng/ml vs. 1.9 ng/ml, p 0.01), and higher reduction in the mean PSA level (88.8% vs. 71.6%) than the TURP group. These findings, together with the similar results reported by other studies, suggest that a lower PSA level and higher peak urinary flow may be considered as the surrogate markers of a more complete adenoma removal (Geavlete et al. 2013, 2015; Zhao et al. 2010; Zhu et al. 2013).

   In addition, long-term follow-up data from authors' institute indicate that the patients who received TUERP had stable PSA level, ranging from 0.41 to 1.08. A hypothesis suggests that an abnormal increase of the PSA level after operation may raise the suspicious of prostate cancer in the residual prostate gland. Therefore, PSA level after prostate enucleation is considered not only an indicator of the completeness of adenoma removal, but also a tool for early warning of prostate cancer in case of progressive PSA elevation.

3. **Enucleation and complications**
   The reported risk of capsular perforation or undermining of the bladder neck was about 8% in patients undergoing endoscopic resection (da Silva et al. 2015). During TUERP, the vascular network running on the inner surface of the surgical capsule and its perforating vessels given out to the prostatic adenoma make hemostasis an easy work under endoscopic monitoring. With the advantage of precisely positioned surgical plane in TUERP, preservation of physiological gradient of the bladder neck is possible and results in uncompromised postoperative sexual and urinary functions (Liu et al. 2010; Xu et al. 2013).

   Temporary urinary retention and transient urinary incontinence may be found in patients within 1 month after TUERP which were correlated to a variety of factors such as urinary tract infection and overactive bladder. These postoperative complications were mostly self-limiting without treatment. In case of bladder neck contracture and urethral stricture, routine urethral dilation and/or urethrotomy may be necessary.

4. **Enucleation and sexual function**
   Sexual dysfunction after prostate operation is a potential side effect, which is related patient's age, general condition, psychological state and other surgical factors including intraoperative blood loss and thermal damage (Zong et al. 2012). TURP had minimal adverse effect on sexual functions. Mishriki et al. (2012) even demonstrated a long-lasting improvement on the pre-operative erectile dysfunction in a 12-year follow-up study. Similar results were also obtained in patients undergoing prostate enucleation procedures (Capogrosso et al. 2016). According to current data, TURP showed no statistically significant difference in the recovery of sexual function after surgery as compared with enucleation. Studies have showed that sexual satisfaction is positively correlated with the improvement of LUTS (Kim et al. 2014).

   Retrograde ejaculation is a common adverse event after transurethral prostate procedures. Up to 50% of the patients complained of retrograde ejaculation after TURP. There is a speculation that, sexual dysfunction is more commonly associated with prostate enucleation that TURP, as the glandular tissues are removed more completely in the former. However, the authors argue to the contrary for the following reasons:
   (a) Enucleation maximally relieve the strain of surgical capsule and pressure of the hypertrophic gland on the erectile nerves, in turns, improve in the hemodynamic

parameters of erectile function. These will facilitate the postoperative recovery of sexual function in elderly men.

(b) Enucleation along the surgical capsule plane provides better preservation of the physiological structure of intravesical sphincter and prostatic fossa and reduces postoperative incidence of retrograde ejaculation (Xu et al. 2010).

There are no reliable data showing statistical differences post-operative sexual function between enucleation and traditional TURP, let alone meta-analysis. Rigorous-designed trials with extended follow-ups and larger sample size are warranted.

5. **Choice of energy**
From the technical point of view, TUERP with bipolar energy shares the same principles with HoLEP, which mostly dependent on the surgeons' preference and the availability in the institutes. Equipment for bipolar resection is cost-effective and commonly available in most centers, even in most of the developing Asia countries. Most urologists are familiar it, so shortening of the learning curves for TUERP. It forms a very viable alternative to laser in Asia.

6. **Conclusion**
Transurethral enucleation epitomizes an improvement of surgical technique, which is based on the same principle as classical simple prostatectomy. Regardless of the devices used for the procedure, it can be conducted worldwide due to the easy accessibility to the surgery equipment. Enucleation procedures can effectively remove the obstructing adenoma, enabling better long-term clinical outcomes. TUERP will eventually supersede TURP as the gold standard for prostate endoscopic procedure.

## References

Capogrosso P, Ventimiglia E, Ferrari M, Serino A, Boeri L, Capitanio U, Briganti A, Damiano R, Montorsi F, Salonia A. Long-term sexual outcomes after holmium laser enucleation of the prostate: which patients could benefit the most? Int J Impot Res. 2016;28(5):189–93.

Chen YB, Chen Q, Wang Z, et al. A prospective, randomized clinical trial comparing plasmakinetic resection of the prostate with holmium laser enucleation of the prostate based on a 2-year followup. J Urol. 2013;189(1):217–22.

Elkoushy MA, Elshal AM, Elhilali MM. Postoperative lower urinary tract storage symptoms: does prostate enucleation differ from prostate vaporization for treatment of symptomatic benign prostatic hyperplasia? J Endourol. 2015;29(10):1159–65.

Elzayat EA, Elhilali MM. Holmium laser enucleation of the prostate (HoLEP): long-term results, reoperation rate, and possible impact of the learning curve. Eur Urol. 2007;52(5):1465–71.

Furuya Y, Akakura K, Tobe T, Ichikawa T, Igarashi T, Ito H. Changes in serum prostate-specific antigen following prostatectomy in patients with benign prostate hyperplasia. Int J Urol. 2000;7(12):447–51.

Geavlete B, Stanescu F, Iacoboaie C, Geavlete P. Bipolar plasma enucleation of the prostate vs open prostatectomy in large benign prostatic hyperplasia cases—a medium term, prospective, randomized comparison. BJU Int. 2013;111(5):793–803.

Geavlete B, Bulai C, Ene C, Checherita I, Geavlete P. Bipolar vaporization, resection, and enucleation versus open prostatectomy: optimal treatment alternatives in large prostate cases? J Endourol. 2015;29(3):323–31.

Gilling PJ, Kennett K, Das AK, et al. Holmium laser enucleation of the prostate (HoLEP) combined with transurethral tissue morcellation: an update on the early clinical experience. J Endourol. 1998;12(5):457–9.

Gratzke C, Bachmann A, Descazeaud A, Drake MJ, Madersbacher S, Mamoulakis C, Oelke M, Tikkinen KA, Gravas S. EAU guidelines on the assessment of non-neurogenic male lower urinary tract symptoms including benign prostatic obstruction. Eur Urol. 2015;67(6):1099–109.

Hiraoka Y, Akimoto M. Transurethral enucleation of benign prostatic hyperplasia. J Urol. 1989;142(5):1247–50.

Kim SH, Yang HK, Lee HE, Paick JS, Oh SJ. HoLEP does not affect the overall sexual function of BPH patients: a prospective study. Asian J Androl. 2014;16(6):873–7.

Liu CX, Xu AB, Zheng SB, Li HL. Real endo-enucleation of prostate for treatment of benign prostatic hyperplasia. J Urol. 2006;(Suppl. 17):453.

Liu C, Zheng S, Li H, et al. Transurethral enucleation and resection of prostate in patients with benign prostatic hyperplasia by plasma kinetics. J Urol. 2010;184(6):2440–5.

Mebust WK, Holtgrewe HL, Cockett AT, et al. Transurethral prostatectomy: immediate and postoperative complications. A cooperative study of 13 participating institutions evaluating 3,885 patients. J Urol. 1989;141(2):243–7.

Mishriki SF, Grimsley SJ, Lam T, Nabi G, Cohen NP. TURP and sex: patient and partner prospective 12 years follow-up study. BJU Int. 2012;109(5):745–50.

Neill MG, Gilling PJ, Kennett KM, et al. Randomized trial comparing holmium laser enucleation of prostate with plasmakinetic enucleation of prostate for treatment of benign prostatic hyperplasia. Urology. 2006;68(5):1020–4.

Palaniappan S, Kuo TL, Cheng CW, Foo KT. Early outcome of transurethral enucleation and resection of prostate compared with transurethral resection of the prostate. Singap Med J. 2016;57(12):676–80.

Shah HN, Sodha HS, Kharodawala SJ, et al. Influence of prostate size on the outcome of holmium laser enucleation of the prostate. BJU Int. 2008;101(12):1536–41.

Shimizu Y, Hiraoka Y, Iwamoto K, Takahashi H, Abe H, Ogawa H. Is complete resection of hypertrophic adenoma of the prostate possible with TURP? J Nippon Med Sch. 2005;72(3):146–8.

da Silva RD, Bidikov L, Michaels W, Gustafson D, Molina WR, Kim FJ. Bipolar energy in the treatment of benign prostatic hyperplasia: a current systematic review of the literature. Can J Urol. 2015;22(Suppl 1):30–44.

Walz J, Graefen M, Huland H. Basic principles of anatomy for optimal surgical treatment of prostate cancer. World J Urol. 2007;25(1):31–8.

Walz J, Burnett AL, Costello AJ, Eastham JA, Graefen M, Guillonneau B, Menon M, Montorsi F, Myers RP, Rocco B, et al. A critical analysis of the current knowledge of surgical anatomy related to optimization of cancer control and preservation of continence and erection in candidates for radical prostatectomy. Eur Urol. 2010;57(2):179–92.

Walz J, Epstein JI, Ganzer R, Graefen M, Guazzoni G, Kaouk J, Menon M, Mottrie A, Myers RP, Patel V, et al. A critical analysis of the current knowledge of surgical anatomy of the prostate related to optimisation of cancer control and preservation of continence and erection in candidates for radical prostatectomy: an update. Eur Urol. 2016;70(2):301–11.

Xu YW, Liu CX, Zheng SB, Li HL, Fang P, Chen BS, Xu K, Shen HY. Transurethral enucleation of the prostate for treatment of benign prostatic hyperplasia in patients less than 50 years old. Nan Fang Yi Ke Da Xue Xue Bao. 2010;30(12):2708–10.

Xu A, Zou Y, Li B, et al. A randomized trial comparing diode laser enucleation of the prostate with plasmakinetic enucleation and resection of the prostate for the treatment of benign prostatic hyperplasia. J Endourol. 2013;27(10):1254–60.

Xu AB, Luo F, Zou ZH, Du W, Zhao PP, Liu CX. Application of morcellator in transurethral bipolar plasmakinetic anatomical enucleation of the prostate. Nan Fang Yi Ke Da Xue Xue Bao. 2016;36(8):1100–4.

Xu P, Xu A, Chen B, et al. Bipolar transurethral enucleation and resection of the prostate: whether it is ready to supersede TURP? Asian J Urol. 2018;5(1):48–54.

Zhao Z, Zeng G, Zhong W, Mai Z, Zeng S, Tao X. A prospective, randomised trial comparing plasmakinetic enucleation to standard transurethral resection of the prostate for symptomatic benign prostatic hyperplasia: three-year follow-up results. Eur Urol. 2010;58(5):752–8.

Zhu L, Chen S, Yang S, Wu M, Ge R, Wu W, Liao L, Tan. Electrosurgical enucleation versus bipolar transurethral resection for prostates larger than 70 ml: a prospective, randomized trial with 5-year followup. J Urol. 2013;189(4):1427–31.

Zong HT, Peng XX, Yang CC, Zhang Y. The impact of transurethral procedures for benign prostate hyperplasia on male sexual function: a meta-analysis. J Androl. 2012;33(3):427–34.

# Advances in Surgery for Benign Prostatic Hyperplasia

30

Phil Hyun Song and Yeong Uk Kim

**Abstract**

Benign prostatic hyperplasia (BPH) is most commonly observed in men of advancing age. Patients with BPH may experience urinary symptoms. For moderate lower urinary tract symptoms (LUTS), pharmacotherapy is recommended, but many patients have symptom progression and require additional surgical intervention such as transurethral resection of prostate (TURP) or prostatectomy. However, these procedures are still associated with significant perioperative morbidity. As a result, treatment-related complications have led to the development of new technologies for the management of BPH.

Various treatment options include thermoablative strategies, mechanical, water vapor system, and intraprostatic injection. We review the available clinical data with specific emphasis on unique features of the technology, procedural efficacy and safety, and potential impact on current treatment paradigms.

There are new techniques which have been shown to be equivalent to the gold-standard treatment (TURP and prostatectomy), with improvement of LUTS, but significantly fewer adverse effects. Advances in BPH surgery represent a paradigm shift in the treatment of LUTS with BPH. Further studies will help to identify the role of these treatment options for LUTS.

**Keywords**

Benign prostate hyperplasia · TURP · Laser surgery
Prostate stent · Embolization

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## 30.1 Introduction

Benign prostatic hyperplasia (BPH) is most commonly found in men of advancing age. It is associated with troublesome lower urinary tract symptoms (LUTS). Lifelong hormonal exposure to androgens is thought to cause an ongoing growth response in the prostatic glandular tissue, leading to compression of the prostatic urethra with bladder outlet obstruction (BOO) and LUTS (Christidis et al. 2017). Patients with BPH may experience symptoms such as weak urinary stream, urgency, and nocturia. In moderate LUTS, drug treatment with alpha-blockers, 5-alpha-reductase inhibitors, or beta-3 agonists, is recommended (Gratzke et al. 2015). Despite this, many patients have symptom progression, and need additional surgical intervention. The current gold standard for the surgical treatment of BPH is either transurethral resection of the prostate (TURP) or simple prostatectomy. However, these are still associated with significant perioperative morbidity (Ow et al. 2018). As a result, treatment-related complications have led to the development of new technologies for BPH such as minimally invasive surgical techniques (MISTs). These have the advantages of an outpatient procedure with a local anesthetic, no catheterization, protection of sexual function and a similar efficacy to TURP and may well take the lead in the future (Chung and Woo 2014).

In this chapter, we will discuss the new technologies for LUTS with BPH. We will also review the available clinical data, with specific emphasis on unique features of the technology, procedural efficacy and safety, and potential impact on current treatment paradigms.

## 30.2 Review of New Technologies

### 30.2.1 Transurethral Microwave Therapy

Microwave therapy for LUTS with BPH has evolved considerably in the last 30 years (Blute and Lewis 1991). The mechanism of action of transurethral microwave therapy


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(TUMT) is to utilize microwave-radiation heat generation to produce coagulative necrosis in prostatic tissue. This microwave radiation is emitted via a specialized intraurethral catheter with an antenna, which delivers heat to targeted regions of the prostate (Christidis et al. 2017). The surrounding non-targeted tissue such as the external urethral sphincter, bladder neck, and rectum maintain normal temperatures. The benefit of this procedure is that it can be performed in the office, using local anesthesia (Eliasson and Wagrell 2000). Cystoscopy should be performed before TUMT to exclude the presence of a median lobe, which is an exclusion criterion (Floratos et al. 2000). Prostatic volume should be 30 to 100 g for this procedure. While TUMT has been shown to improve symptoms and sustain this effect, it remains inferior to TURP in its efficacy. Recent literature reports improvements in International Prostate Symptom Score (IPSS) at 12-month follow-up of 65% and 77% after TUMT and TURP, respectively (Thalmann et al. 2002). Urinary flow rates increased by 70% following TUMT, while there was an increase of 119% after TURP (Thalmann et al. 2002; Bostwick and Larson 1995). Furthermore, after TUMT a high proportion of patients require retreatment. A recent study showed that 22% of patients required retreatment with repeat TUMT, TURP, or suprapubic catheterization (Thalmann et al. 2002). TUMT thus carries a potentially prohibitive need for retreatment because of persistent LUTS with BPH. Nevertheless, TUMT is a new technique that has the advantages of improved sexual function, less hospitalization, decreased hematuria, and lower requirement for transfusion when compared with invasive treatment (Hoffman et al. 2012).

### 30.2.2 Transurethral Vaporization of the Prostate

Transurethral vaporization of the prostate (TUVP) was originally described by Te and Kaplan in 1995. This technique is similar to standard TURP. TUVP uses the same set of equipment as TURP but exchanges the resecting loop for a specific electrode for vaporization (Kaplan and Te 1995). TUVP utilizes heat from monopolar or bipolar electrical current, resulting in tissue ablation (Kaplan and Te 1995). TUVP has demonstrated symptomatic benefits comparable to conventional TURP. In some studies, significant improvements in IPSS, peak urine flow rate, and post-void urine volume were shown in both the TUVP and the TURP groups (Elsakka et al. 2016). Use of TUVP also resulted in a short duration of catheterization, a decreased incidence of postoperative hematuria, and fewer perioperative complications (Geavlete et al. 2014). Overall, initial results of monopolar TUVP were similar to TURP with a decrease in some adverse events.

### 30.2.3 Transurethral Needle Ablation of the Prostate

Transurethral needle ablation (TUNA) was first performed in 1993. The TUNA system consists of a radiofrequency (RF) generator, an optic system, and a urethral catheter (Schulman et al. 1993). TUNA is achieved by the placement of two electrodes into the target prostatic tissue with creation of an RF signal between them, resulting in thermal energy creation and ablation of tissues through coagulative necrosis (Chapple et al. 1999). Transrectal ultrasound should be done before the procedure is performed, to check the prostate width, volume, and anatomy. The prostate volume and width are important because the lengths determine the number of levels at which needle deployment will be required (Schulman et al. 1993). TUNA is indicated in patients who have prostate volumes of up to 80 ml. The benefit of TUNA is that it can be done under local anesthesia (Chapple et al. 1999). Most patients are able to return to work within 2–3 days. A meta-analysis of randomized trials showed that TUNA and TURP were equivalent in results at 3-month follow-up (Schulman et al. 1993). TUNA has a favorable morbidity profile when compared to TURP. Despite this, the durability of TUNA is under question because of a lack of high-quality studies with significant long-term data.

### 30.2.4 Transurethral Incision of the Prostate

Transurethral incision of the prostate (TUIP) is a similar method to TURP. However, an electrocautery device or laser is used to incise the prostate tissue from the bladder neck down to the verumontanum (Aho and Gilling 2003). This incision is usually made posterolaterally (the 5 and 7 o'clock positions), allowing the crowded circumferential band of hypertrophied tissue to separate, and the bladder outlet is "opened up." TUIP is typically recommended for young men who are concerned about either a loss of ejaculation or fertility, and for men with smaller prostate glands (<30 ml) (Hedlund and Ek 1985). Patients with a median lobe are excluded from this procedure. The technique is simple: a cold knife, hot knife, resectoscope with a thin loop, or an end-firing holmium laser can be used to complete the procedure. Outcomes relating to symptomatic improvement are similar for TUIP and TURP (Lourenco et al. 2010). However, improvement in peak urine flow rate was lower for TUIP than for TURP (Orandi 1987). Other complications such as urinary retention, urinary tract infection, urethral stricture, and incontinence did not differ between the two procedures (Lourenco et al. 2010). Retrograde ejaculation was less of a concern with TUIP than with other BPH treatment (Orandi 1987). Overall, TUIP is a reasonable technique in selected patients.

### 30.2.5 Intraprostatic Stent

The principle of intraprostatic stenting is the placement of a stent into the prostate for relief of urinary obstruction. Intraprostatic stents can be classified into many groups, including permanent or temporary, epithelializing or nonepithelializing. The temporary and nonepithelializing version has the advantage that it may be inserted in a compressed state, minimizing the risk of urethral injury and pain usually associated with intraprostatic stents (Perry et al. 2002). On the other hand, epithelialization of an intraprostatic stent has the advantage of reducing the rate of migration, infection, and encrustation (Armitage et al. 2007). The major disadvantages of this type of stent are the limited tolerability under local anesthesia, and the difficulties associated with its removal (Armitage et al. 2007). This technique has been used for treatment of an enlarged prostate in patients with detrusor sphincter dyssynergia, post-brachytherapy obstruction, and the complications of radical prostatectomy (Chartier-Kastler et al. 2000; Meulen et al. 1991).

UroLume (American Medical Systems, Minnetonka, MN, USA) was a popular and better studied epithelializing permanent stent. In a systematic review, about 84% of catheter-dependent patients were able to void spontaneously after the procedure (Armitage et al. 2007). However, about 16% of patients needed removal of the stent within one year because of migration, penile pain, and irritative symptoms. The Memokath® stent (Doctors and Engineers, Kvistjaard, Denmark) is a nickel-titanium and thermoexpandable stent, with ease of removal based on its physical properties at different temperatures (Armitage et al. 2006). A recent study on the use of this device reported improvement in the American Urological Association Symptom Score (AUASS) at three months, with almost no change in the next 7 years (Perry et al. 2002). However, migration was still a major limitation to widespread acceptance of this device. The polyurethane Spanner® prostatic stent (Abbey Moor Medical, Parkers Prairie, MN, USA) was developed as a temporary stent (Vanderbrink et al. 2007). Some studies reported that this device was easily inserted and removed under local anesthesia (Corica et al. 2004). A significant improvement in IPSS, peak urine flow rate, and post-void urine volume was also shown in these studies. Recently, the properties of stents have been developed by using biodegradable materials such as polylactic acid, polyglycolic acid, and copolymers of lactide and glycolide (Papatsoris et al. 2011).

However, relatively higher complication rates associated with these devices limit their utility as a long-term durable option in surgical treatment for LUTS with BPH.

### 30.2.6 Prostatic Urethral Lift

Prostatic urethral lift (PUL), called Urolift® (Neotract Inc., Pleasanton, CA, USA) is a new technique for BPH without ablating tissue. This device is composed of an extracapsular nitinol anchor and a urethral stainless steel clip, linked by an individualized nonabsorbable suture. The sutures are delivered by a handheld device through a cystoscope to open the prostatic urethra by compressing the prostatic tissue. The implantation of the anchors is relatively quick and prostatic tissue is not resected during this procedure (Woo et al. 2011). The total number of implants is determined by the prostatic volume and the length of the prostatic urethra. Advantages of this technique include the minimization of sexual factors such as erectile dysfunction and ejaculatory function (McVary et al. 2014).

The Luminal Improvement Following Prostatic Tissue Approximation (L.I.F.T) study demonstrates improvement of the IPSS score from 21.6 to 12.7, a decrease of 8.9 points compared to 5.9 points with sham alone (Roehrborn et al. 2015). Quality of Life (QoL) and peak urine flow rate improved from 4.5 to 2.2 and from 8.3 to 11.8 ml/s, respectively. Incontinence was not induced and sexual function was preserved.

Sonksen et al. reported the results of a prospective, randomized, multinational study, the BPH6 study, of prostatic urethral lift versus transurethral resection of the prostate over a 12-month period (Sonksen et al. 2015). Efficacy was shown significantly earlier (6–12 months), and sexual function was maintained in the PUL group. Noninferiority was proven in the relief of LUTS, postoperative recovery, and sexual function. Jones et al. undertook a systematic review that included 440 patients from several studies (Jones et al. 2016). Patients demonstrated an improvement in their mean peak urine flow rates from 8.4 to 11.3 ml/s, and post-void urine volume decreased from 93 to 84.7 ml. The mean IPSS scores improved from 24.1 to 14 after the procedure. International Index of Erectile Function (IIEF-5) scores remained stable. Data of long-term follow-up for durability is currently being collated.

### 30.2.7 Prostatic Artery Embolization

Prostatic artery embolization (PAE) is a new technique that could be an alternative for the treatment of BPH. This procedure is performed under radiological guidance, and involves highly selective injection into the prostatic arteries to induce ischemia of the prostatic tissue. Either unilateral or bilateral prostatic artery injection is performed with an embolizing agent (alcohol, microspheres). The procedure times range from 75 to 150 min with fluoroscopy times of 30–50 min (Pisco et al. 2011). Patients with an allergy to the contrast medium should be excluded from this procedure. The cohort study involving 630 patients showed significant improvement in IPSS, QoL, prostatic size, prostate specific antigen (PSA), peak urine flow rate, post-void urine volume, and

IIEF (Pisco et al. 2016). The medium- (1–3 years) and long-term (>3 years) success rates without incontinence and sexual dysfunction were 81.9 and 76.3%, respectively. The major complication was partial bladder necrosis because of nonselective embolization. Recently, a randomized controlled trial of TURP versus PAE was performed (Gabr et al. 2016). Throughout the period of follow-up (1, 3, and 9 months after procedure), there was a significant improvement in peak urine flow rate and reduction in prostatic volume without major complications. However, the improvement occurred significantly earlier in the TURP group than in the PAE group. Complications after this procedure included pain, fever, hematuria, hematospermia, and rectal bleeding. The risk of untargeted ischemia of the bladder, corpus cavernosum, or anus is rare.

### 30.2.8 Aquablation (Water Jet Ablation)

Aquablation (Aquebeam®, Procept BioRobotics, Redwood Shores, CA, USA) is a new technique for treatment of LUTS with BPH. This technology was first described for liver dissection in dogs, and subsequently in humans for selective dissection of the liver (Baer et al. 1993). Aquablation utilizes a high-pressure beam of saline to mechanically disintegrate prostatic tissue. The flow rate of saline is modulated to control the depth of tissue destruction. The depth of ablation and real-time monitoring is determined by endoscopic and transrectal ultrasound guidance. Electrocautery is required after the procedure for hemostasis. One study related to the prostate was reported in 2015 (Gilling et al. 2016). The mean of the IPSS and peak urine flow rate improved from 23.1 to 8.6 and from 8.6 to 18.6 ml/s, respectively. The mean post-void urine volume decreased from 91 to 30 ml/s and mean QoL score decreased from 5.0 to 2.5. More long-term data is necessary to define the safety and feasibility of aquablation.

### 30.2.9 Histotripsy

Histotripsy is a modern application of high intensity ultrasound technology that destroys targeted tissue by inducing acoustic cavitation (microbubble formation) to homogenize cellular and connective components of tissue. This mechanism is similar to shockwave lithotripsy (SWL), so the transducer is extracorporeal and positioned for a transperineal delivery of acoustic energy. A transrectal ultrasound probe is inserted and fixed in position, and images captured. The treatment boundary is overlaid on the real-time ultrasound image for guidance. With delivery of energy, a cavitation bubble cloud is created at the focus, and translated through the targeted volume. Some studies in canine models demonstrated a decrease in the canine prostatic volume of 31%, coupled with a limited inflammatory response within 6 weeks (Roberts et al. 2014). However, the clinical trial in humans did not confirm these findings. Initiation of human pilot trials is in progress and is sure to add valuable information to this experimental entity.

### 30.2.10 Rezum

Rezum (NxThera, Inc., Maple Grove, MN, USA) is a thermoablative technique that uses water vapor energy. This technique allows thermal energy in the form of water vapor to travel through the interstitium of the transition zone of the prostate. The water vapor disrupts cell membranes without a discernible thermal gradient, reducing the risk of injury to surrounding tissues by dissipated heat (Hahn 2012). The vapor is delivered through a cystoscope, and a thin needle is deployed into the hyperplastic transition zone. Water vapor is delivered rapidly (in 8–10 s) and directly into the hyperplastic transition zone, and is immediately dispersed through the tissue interstices. The total number of injections is determined by the prostatic size and prostatic urethral length. In a multinational, prospective study, prostatic volume was reduced by a mean of 28.9% and the transition zone volume by 38.0% at 6 months (Mynderse et al. 2015). A multicenter randomized controlled trial reported a significant improvement in IPSS with sustainable results of 50% or more at 12-month follow-up (McVary et al. 2016). Peak urine flow rates were increased by 6.2 ml/s at three months, but decreased to 5.4 ml/s at 1 year. Ejaculatory dysfunction, assessed by the Male Sexual Health Questionnaire (MSHQ), did not change compared with the preoperative evaluation.

### 30.2.11 Intraprostatic Injection

Intraprostatic injection was initially used as a minimally invasive treatment for LUTS in 1910 (Cano 1910). The mechanism of this technique is that injection agents decrease the prostatic volume by inducing apoptosis and tissue necrosis, and act on afferent nerves to improve LUTS. The injection agent is commonly delivered via a transurethral, transperineal, or transrectal approach into the prostatic tissue. Injecting agents, including acid mixtures, ethanol, and botulinum-neurotoxin A, have been used for treatment (Talwar and Pande 1966; Plante et al. 2007).

Anhydrous ethanol treatment of the prostate is to date the most widely investigated intraprostatic injection. A multicenter, prospective clinical trial showed improvement of IPSS, QoL score, and peak urine flow rate at three months after the procedure (Grise et al. 2004). The perineal pain experienced after the procedure, which was associated with extraprostatic extravasation, diminished after the advent of transrectal ultrasound and understanding of the anatomical landmarks. A study with 4-year follow-up suggested a sustained response in 73% of patients, with the remaining 23% requiring other alternative treatment (El-Husseiny and Buchholz 2011). The most common complications reported after ethanol injection were hematuria, irritative voiding symptoms, perineal pain, and transient urinary retention.

NX-1207 (Nymox Pharmaceutical Corp, Hasbrouck Heights, NJ, USA) is a novel agent for intraprostatic injection that is administered via transrectal ultrasound-guided injection and causes apoptotic cell death. NX-1207 showed significant treatment success for LUTS with BPH (Shore and Cowan 2011). In phase II trials, over half of the participants treated with NX-1207 required no further surgical treatment or medication. Two large phase II trials are ongoing to confirm the validity of these promising findings. PRX-302 (Sophiris Bio Corp, La Jolla, CA, USA) is a modified form of proaerolysin, a highly toxic bacterial pore-forming proton altered to include a PSA-selective sequence that activates following interaction with active PSA within prostatic tissue. PRX-302 is administered via a transperineal approach within the transition zone under transrectal ultrasound guidance. Phase I and II studies have demonstrated improvement in IPSS, QoL, and prostatic volume (Denmeade et al. 2011). A recent randomized controlled trial demonstrated improvement in IPSS of 4.1 and 2.8 points at 6 months and 12 months, respectively (Elhilali et al. 2013). The QoL was improved by 1.4 points, and peak urine flow rate increased by 2.2 ml/s at 12 months. The only documented adverse effect was irritative voiding symptoms for several days.

Botulinum neurotoxin-A (BoNT-A) is also a new intraprostatic injection agent for treatment of LUTS with BPH. This exotoxin may have influence over both the static and dynamic components of BPH (Chuang et al. 2006). A designed study concluded that BoNT-A induces prostatic atrophy in the rat that results in impairment of sympathetic nerve function, which plays a role in prostatic volume regulation (Silva et al. 2009). A randomized, double-blind study demonstrated significant improvement of peak urine flow rate, post-void urine volume and prostatic volume (Marberger et al. 2013). Urodynamic effects showed benefit in post-void urine volume and IPSS, but no effect on urodynamic outcomes including peak urine flow rate (de Kort et al. 2012). However, Marberger et al. reported no significant improvement in either the control or the treatment groups. Despite this, BoNT-A is a new option for treatment of LUTS with an already established record for use in urology.

## 30.3 Summary

There are new techniques shown to be equivalent to the gold-standard treatment (TURP and prostatectomy) in terms of improvement in LUTS with significantly fewer adverse effects. Advances in BPH surgery represent a paradigm shift in the treatment of LUTS with BPH. In addition, these treatment options are varied and continually growing in the range of options available, based on patient and pathological factors. These techniques should be used in patient selection dependent on factors such as age and morbidity, and the need for preserved sexual function and continence. Further studies will help to identify the role of these treatment options for LUTS.

## References


Aho TF, Gilling PJ. Laser therapy for benign prostatic hyperplasia: a review of recent developments. Curr Opin Urol. 2003;1:39–44.

Armitage JN, Rashidian A, Cathcart PJ, et al. The thermo-expandable metal stent for managing benign prostatic hyperplasia: a systematic review. BJU Int. 2006;98:806–10.

Armitage JN, Cathcart PJ, Rashidian A, et al. Epithelializing stent for benign prostatic hyperplasia: a systematic review of the literature. J Urol. 2007;177:1619–24.

Baer HU, Stain SC, Guastella T, et al. Hepatic resection using a water jet dissector. HPB Surg. 1993;6:189–96.

Blute ML, Lewis RW. Local microwave hyperthermia as a treatment alternative for benign prostatic hyperplasia. J Androl. 1991;12:429.

Bostwick DG, Larson TR. Transurethral microwave thermal therapy: pathologic findings in the canine prostate. Prostate. 1995;26:116–22.

Cano FG. Intraprostatic injection of antiseptic substances. Arch Rosales Hosp. 1910.

Chapple CR, Issa MM, Woo H. Transurethral needle ablation (TUNA). A critical review of radiofrequency thermal therapy in the management of benign prostatic hyperplasia. Eur Urol. 1999;35:119–28.

Chartier-Kastler EJ, Thomas L, Bussel B, et al. A urethral stent for the treatment of detrusor-striated sphincter dyssynergia. BJU Int. 2000;86:52–7.

Christidis D, McGrath S, Perera M, et al. Minimally invaisve surgical therapies for benign prostatic hypertrophy: the rise in minimally invasive surgical therapies. Prostate Int. 2017;5:41–6.

Chuang YC, Chiang PH, Yoshimura N, et al. Sustained beneficial effects of intraprostatic botulinum toxin type A on lower urinary tract symptoms and quality of life in men with benign prostatic hyperplasia. BJU Int. 2006;98:1033–7.

Chung A, Woo HH. What's truly minimally invasive in benign prostatic hyperplasia surgery? Curr Opin Urol. 2014;24:36–41.

Corica AP, Larson BT, Sagaz A, et al. A novel temporary prostatic stent for the relief of prostatic urethral obstruction. BJU Int. 2004;93:346–8.

Denmeade SR, Egerdie B, Steinhoff G, et al. Phase 1 and 2 studies demonstrate the safety and efficacy of intraprostatic injection of PRX302 for the targeted treatment of lower urinary tract symptoms secondary to benign prostatic hyperplasia. Eur Urol. 2011;59:747–54.

Elhilali MM, Pommerville P, Yocum RC, et al. Prospective, randomized, double-blind, vehicle controlled, multicenter phase IIb clinical trial of the pore forming protein PRX302 for targeted treatment of symptomatic benign prostatic hyperplasia. J Urol. 2013;189:1421–6.

El-Husseiny T, Buchholz N. Transurethral ethanol ablation of the prostate for symptomatic benign prostatic hyperplasia: long-term follow-up. J Endourol. 2011;25:477–80.

Eliasson T, Wagrell L. New technologies for the surgical management of symptomatic benign prostatic enlargement: tolerability and morbidity of high energy transurethral microwave thermotherapy. Curr Opin Urol. 2000;10:15–7.

Elsakka AM, Eltatawy HH, Almekaty KH, et al. A prospective randomized controlled study comparing bipolar plasma vaporization of the prostate to monopolar transurethral resection of the prostate. Arab J Urol. 2016;14:280–6.

Floratos DL, Sonke GS, Francisca EA, et al. High energy transurethral microwave thermotherapy for the treatment of patients in urinary retention. J Urol. 2000;163:1457–60.

Gabr AH, Gabr MF, Elmohamady BN, et al. Prostatic artery embolization: a promising technique in the treatment of high-risk patients with benign prostatic hyperplasia. Urol Int. 2016;97:320–4.

Geavlete B, Stanescu F, Moldoveanu C, et al. Continuous vs conventional bipolar plasma vaporization of the prostate and standard monopolar resection: a prospective, randomized comparison of a new technological advance. BJU Int. 2014;113:288–95.

Gilling P, Reuther R, Kahokehr A, et al. Image guided robotically-assisted waterjet ablation of the prostate: initial clinical experience. BJU Int. 2016;117:923–9.

Gratzke C, Bachmann A, Descazeaud A, et al. EAU guidelines on the assessment of nonneurogenic male lower urinary tract symptoms including benign prostatic obstruction. Eur Urol. 2015;67:1099–109.

Grise P, Plante M, Palmer J, et al. Evaluation of the transurethral ethanol ablation of the prostate (TEAP) for symptomatic benign prostatic hyperplasia (BPH): a European multi-center evaluation. Eur Urol. 2004;46:496–501.

Hahn DW. Heat conduction. 3rd ed. Hoboken, NJ: Wiley; 2012. p. 718.

Hedlund H, Ek A. Ejaculation and sexual function after endoscopic bladder neck incision. Br J Urol. 1985;57:164–7.

Hoffman RM, Monga M, Elliott SP, et al. Microwave thermotherapy for benign prostatic hyperplasia. Cochrane Database Syst Rev. 2012;9:Cd004135.

Jones P, Rajkumar GN, Rai BP, et al. Medium-term outcomes of Urolift (minimum 12 months follow-up): evidence from a systematic review. Urology. 2016;97:20–4.

Kaplan SA, Te AE. Transurethral electrovaporization of the prostate: a novel method for treating men with benign prostatic hyperplasia. Urology. 1995;45:566–72.

de Kort LM, Kok ET, Jonges TN, et al. Urodynamic effects of transrectal intraprostatic Ona botulinum toxin A injections for symptomatic benign prostatic hyperplasia. Urology. 2012;80:889–93.

Lourenco T, Shaw M, Fraser C, et al. The clinical effectiveness of transurethral incision of the prostate: a systematic review of randomized controlled trials. World J Urol. 2010;28:23–32.

Marberger M, Chartier-Kastler E, Egerdie B, et al. A randomized double blind placebo-controlled phase 2 dose-ranging study of onabotulinumtoxin A in men with benign prostatic hyperplasia. Eur Urol. 2013;63:496–503.

McVary KT, Gange SN, Shore ND, et al. Treatment of LUTS secondary to BPH while preserving sexual function: randomized controlled study of prostatic urethral lift. J Sex Med. 2014;11:279–87.

McVary KT, Gange SN, Gittelman MC, et al. Minimally invasive prostate convective water vapor energy ablation: a multicenter, randomized, controlled study for the treatment of lower urinary tract symptoms secondary to benign prostatic hyperplasia. J Urol. 2016;195:1529–38.

Meulen T, Zambon JV, Janknegt RA. Treatment of anastomotic strictures and urinary incontinence after radical prostatectomy with UroLume Wallstent and AMS 800 artificial sphincter. J Endourol. 1991;13:517–20.

Mynderse LA, Hanson D, Robb RA, et al. Rezum system water vapor treatment for lower urinary tract symptoms/benign prostatic hyperplasia: validation of convective thermal energy transfer and characterization with magnetic resonance imaging and 3-dimensional renderings. Urology. 2015;86:122–7.

Orandi A. Transurethral incision of prostate compared with transurethral resection of prostate in 132 matching cases. J Urol. 1987;138:810–5.

Ow D, Papa N, Perera M, et al. Trends in the surgical treatment of benign prostatic hyperplasia in a tertiary hospital. ANZ J Surg. 2018;88(1-2):95–9.

Papatsoris GA, Junaid I, Zachou A, et al. New developments in the use of prostatic stents. Open Access J Urol. 2011;3:63–8.

Perry MJ, Roodhouse AJ, Gidlow AB, et al. Thermo-expandable intraprostatic stents in bladder outlet obstruction: an 8-year study. BJU Int. 2002;90:216–23.

Pisco JM, Pinheiro LC, Bilhim T, et al. Prostatic arterial embolization to treat benign prostatic hyperplasia. J Vasc Interv Radiol. 2011;22:11–9.

Pisco JM, Bilhim T, Pinheiro LC, et al. Medium- and long-term outcome of prostate artery embolization for patients with benign prostatic hyperplasia: results in 630 patients. J Vasc Interv Radiol. 2016;27:1115–22.

Plante MK, Marks LS, Anderson R, et al. Phase I/II examination of transurethral ethanol ablation of the prostate for the treatment of symptomatic benign prostatic hyperplasia. J Urol. 2007;177:1030–5.

Roberts WW, Teofilovic D, Jahnke RC, et al. Histotripsy of the prostate using a commercial system in a canine model. J Urol. 2014;191:860–5.

Roehrborn CG, Rukstalis DB, Barkin J, et al. Three year results of the prostatic urethral L.I.F.T. study. Can J Urol. 2015;22:7772–82.

Schulman CC, Zlotta AR, Rasor JS, et al. Transurethral needle ablation (TUNA): safety, feasibility, and tolerance of a new office procedure for treatment of benign prostatic hyperplasia. Eur Urol. 1993;24:415–23.

Shore N, Cowan B. The potential for NX-1207 in benign prostatic hyperplasia: an update for clinicians. Ther Adv Chronic Dis. 2011;2:377–83.

Silva J, Pinto R, Carvallho T, et al. Mechanisms of prostate atrophy after glandular botulinum neurotoxin type A injection: an experimental study in the rat. Eur Urol. 2009;56:134–40.

Sonksen J, Barber NJ, Speakman MJ, et al. Prospective, randomized, multinational study of prostatic urethral lift versus transurethral resection of the prostate: 12-month results from the BPH6 study. Eur Urol. 2015;68:643–52.

Talwar GL, Pande SK. Injection treatment of enlarged prostate. Br J Surg. 1966;53:421–7.

Thalmann GN, Mattei A, Treuthardt C, et al. Transurethral microwave therapy in 200 patients with a minimum follow-up of 2 years: urodynamic and clinical results. J Urol. 2002;167:2496–501.

Vanderbrink BA, Rastinehad AR, Badlani GH. Prostatic stents for the treatment of benign prostatic hyperplasia. Curr Opin Urol. 2007;17:1–6.

Woo HH, Chin PT, McNicholas TA, et al. Safety and feasibility of the prostatic urethral lift: a novel, minimally invasive treatment for lower urinary tract symptoms (LUTS) secondary to benign prostatic hyperplasia (BPH). BJU Int. 2011;108:82–8.

# Thulium: YAG Laser Resection for Benign Prostatic Enlargement

31

Karl Marvin M. Tan, Sid C. Sergio, and Romeo Lloyd T. Romero

**Abstract**

*Introduction*: Benign prostatic enlargement has been a major part of urology and its treatment has been challenged by numerous technologies arising as the years go by. TURP remains a standard in comparison to new techniques that has been introduced. Recently laser, specifically thulium:yag, has been found to be a promising contender for TURP.

*Techniques*: Two techniques are available when using thulium:yag laser for the benign prostate. It includes laser enucleation which involves the use of a morcellator and vaporesection which is done if the morcellator is not available.

*Outcomes and complications*: Based on numerous studies, outcomes and complication rates of TLRP compared to that of TURP is very much comparable.

*Conclusion and recommendations*: TLRP is relatively safe and practical and offers a good alternative to TURP. Results from various studies with this new laser technology are encouraging.

**Keywords**

Thulium · Laser prostatectomy · Laser resection · TLRP ThuVEP · ThuVARP · Vaporesection · Benign prostatic enlargement · TURP · Laser

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## 31.1 Introduction

Obstruction in urine flow as a result of benign prostatic enlargement is one of the common problems most urologists encounter. Transurethral resection of the prostate (TURP) offers a good and solid treatment for benign prostatic disease to alleviate patients from their urinary obstruction.

New technologies that offers minimally invasive techniques allows the practitioner to add options for treatment for patients suffering urinary obstruction. These new techniques are often embraced quickly but somehow may not live up to the expectations due to a small series of patients.

More often these new techniques are compared to the classic TURP. This treatment is still clearly the gold standard and the goal is to achieve the outcomes comparable or maybe surpassing that of the success and safety of the said procedure in researches like that of a randomised controlled trial.

Recently, a surge of lasers has arrived and has been part of the equipment in the surgical treatment of benign prostatic enlargement. These includes diode lasers, Greenlight laser, Holmium:YAG and Thulium:YAG.

Thulium is the latest addition to the laser family which can be used in the treatment of benign prostatic enlargement (BPE). The thulium:yttrium aluminum garnet (Tm:YAG) laser is a continuous wave of 2013 nm energy. It has the same wavelength as that of the holmium laser that is absorbed in the irrigant but at the same time without the pulsatile nature of holmium. According to Chung and Te (2009), the continuous energy emission can lead to a cleaner incision, and with a slightly shorter wavelength than holmium, absorption by tissue is theoretically more pronounced and efficient. The optical penetration depth of different lasers depends mainly on tissue-laser interaction. This is determined by the laser wavelength and power output. Thulium-based lasers have the shallowest penetration depth at 0.2 mm (see Table 31.1).

However, thermal damage is noted to be increased using thulium laser and holmium laser which may lead to scarring and formation of strictures (Fried and Murray 2005).


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**Table 31.1** Laser types and techniques for laser prostatectomy

| Wavelength (nm) | Predominant surgical technique | Mode of operation | Optical penetration depth (mm) |
|---|---|---|---|
| Ho:YAG | Enucleation | Pulsed | 0.4 mm |
| Tm:YAG | Vaporization, vaporesection, enucleation | Continuous | 0.2 mm |
| Green light | Vaporization | Continuous | 0.8 mm |
| Diode | Vaporization, enulceation | Continuous | 0.5–5.0 mm |

As with TURP, Thulium:YAG lasers is also used in the treatment of benign prostatic enlargement. Several clinical trials have proven that the aforementioned techniques are all safe and effective for patients with BPE (Netsch et al. 2014; Gross et al. 2013; Szlauer et al. 2009; Wendt-Nordahl et al. 2008). The thulium laser resection of the prostate (TLRP) technique is also a relatively new approach, and was first reported in 2005 (Iacono et al. 2012). In TLRP, a wavelength of approximately 2 μm is emitted in continuous-wave mode, thus enabling the precise incision of tissue by using a wavelength that matches the water absorption peak of 1.92 μm in tissue (Hong et al. 2015). Thus, the procedure ensures more effective resection and vaporization of prostate tissue (Iacono et al. 2012).

## 31.2 Pre-operative Clinical Assessment

### 31.2.1 Patient Selection

Pre-operatively, a thorough history, physical examination, a digital rectal examination, routine laboratory tests and an IPSS determination will be obtained (Kim et al. 2014). Usually, men who are candidates for Thulium: YAG Laser Resection would be the same as those men suitable for TURP, these are men who are assessed with urinary retention secondary to BPO and those who will present with bothersome LUTS (Worthington et al. 2017), both are due to prostate gland enlargement (Carmignani et al. 2015). This will include patients who are refractory to medical management, other strong indications would be refractory urinary retention, recurrent urinary infection, recurrent hematuria refractory to medical treatment with 5-alpha reductase inhibitors, renal insufficiency due to BPH and bladder stones (Carmignani et al. 2015). In some cases, patients with Prostate Adenocarcinoma who presents with LUTS or BPO may undergo the procedure.

### 31.2.2 Pre-procedure Imaging and Selection of Imaging Guidance

A baseline Uroflemetry is usually requested to acquire the Qmax and PVR, for these are the parameters that would be monitored after surgery (Worthington et al. 2017; Vartak Ketan et al. 2016).

TRUS would identify the prostate size and hypoechoic lesions such as nodules and may warrant biopsy prior to surgery (Kim et al. 2014; Yan et al. 2013).

### 31.2.3 Pre-procedure Laboratory Work-Up

According to literatures, most surgeons would require a baseline Serum PSA prior to a transurethral prostate surgery. The Serum PSA findings will be correlated to TRUS findings, biopsy may be indicated based on the prostate densities (Kim et al. 2014).

Additional Urinalysis and Urine Culture must be obtained to ensure sterility during surgery.

### 31.2.4 Prophylactic Antibiotics

It is proven by various evidences that the use of preoperative antibiotics would be optimal to prevent Urinary Tract Infections and fever in Urologic procedures. The dose should be given within 60 min before the procedure (Alsaywid and Smith 2013; Stuart Wolf et al. 2016). Several guidelines such as the AUA, would recommend the use of Fluoroquinolone or TMP-SMX as the antimicrobial of choice. Other alternatives would be Aminoglycoside ± Ampicillin, first/second gen. Cephalosporin or Amoxicillin/Clavulanate (Stuart Wolf et al. 2016).

In another guideline provided by the CUA (Canadian Urologic Association), they recommend that the choice of a prophylactic antibiotic should be in part, on the local epidemiology of drug resistance. It is important to note that most of these RCTs were based on Cystourethroscopy with urologic manipulations. The RCTs also indicated that these guidelines were established in the backgrounds that all had a negative urine culture (Mrkobrada et al. 2015).

### 31.2.5 Anesthetic Considerations

Adequate anesthesia must be given to ensure adequate laser resection, most operations will be done under spinal anesthesia. General anesthesia may also be an option for those patients that a spinal anesthesia is inadequate or contraindicated (Kim et al. 2014).

## 31.3 Techniques

Like other laser techniques, thulium can also be used in enucleation and vaporesection. This technique would involve peeling the prostate off the prostatic capsule and controlling the bleeders along the way. As thulium is a continuous laser, there is less mechanical effect than with holmium, but higher generation of continuous heat (Lerner and Rajender 2015). Thulium Laser Enucleation of the Prostate (ThuLEP) users

**Table 31.2** ThuLEP outcomes in selected publications (Lerner and Rajender 2015)

| ThuLEP patients | IPSS | QoL | QMax (ml/s) | PVR (ml) | Incontinence | Strictures/ contractures | Follow up |
|---|---|---|---|---|---|---|---|
| Yang et al. (2013) n = 79 | 22.7 ± 4.3 → 5.7 ± 2.1 | 3.9 ± 1.2 → 1.2 ± 1.1 | 22.7 ± 4.3 → 5.7 ± 2.1 | 79.5 ± 29.3 → 30.7 ± 15.2 | NR | 0/79 (0%) | 1.5 years |
| Iacono et al. (2012) n = 148 | 21.1 ± 7.1 → 3.9 ± 2.4 | 4.4 ± 1.3 → 0.9 ± 0.7 | 8.2 ± 3.7 → 28.7 ± 10.7 | 146.1 ± 132.3 → 12.9 ± 20.9 | NR | 2/79 (2.5%) | 1 year |
| Zhang et al. (2012) n = 71 | 24.6 ± 3.2 → 5.2 ± 1.3 | 5.6 ± 0.3 → 1.5 ± 0.2 | 6.8 ± 3.9 → 23.4 ± 5.2 | 64.6 ± 32.5 → 10 ± 1.1 | NR | NR | 1 year |
| Rausch et al. (2015) n = 234 | 18.2 ± 7.4 → 4.5 ± 4.6 | 3.9 ± 1.5 → 1.0 ± 0.9 | 10.2 ± 5.2 → 23.5 ± 8.2 | 131.5 ± 148 → 18.7 ± 40.61 | 8/234 (3.4%) | 5/234 (2.1%) | 2 years |
| Swiniarski et al. (2012) n = 54 | 20.4 ± 2.6 → 6.6 ± 4.5 | 4.7 ± 1 → 1.5 ± 1.1 | 7.7 ± 3.5 → 23 ± 8.3 | 166.2 ± 110.5 → 26.5 ± 28.8 | 1/54 (1.9%) | 3/54 (5.6%) | 3 months |

*ThuLEP* thulium laser enucleation of the prostate, *IPSS* International Prostate Symptom Score, *Qmax* maximal flow rate, *PVR* post void residual, *QoL* quality of life, *Re-op* reoperative rate, *NR* not recorded

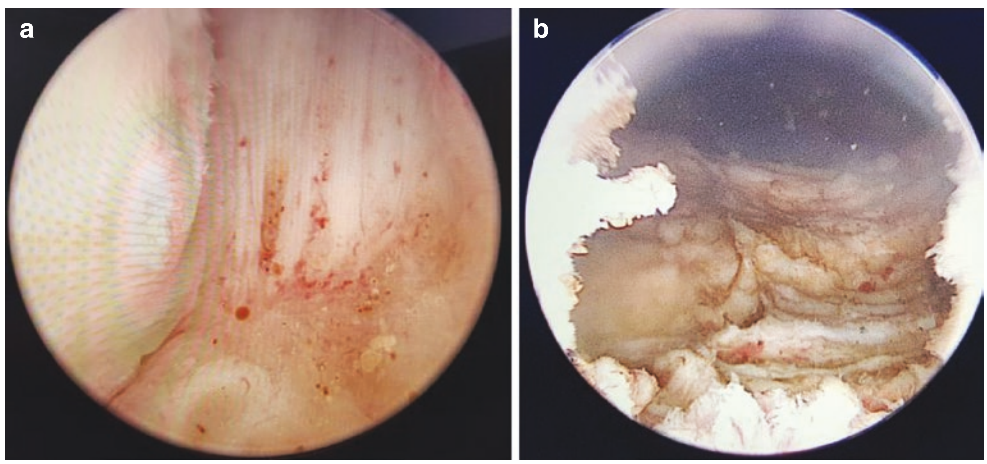

**Fig. 31.1** Photo of a prostatic fossa pre (**a**) & post (**b**) -transurethral laser resection of the prostate of a 65 year old male with a 60 g prostate in acute urinary retention

describe utilizing a combination of laser energy and blunt dissection to complete an anatomic enucleation along the surgical capsule, basically similar to the original iteration of HoLEP including the use of a morcellator when they select this option. The outcomes of selected publications (Iacono et al. 2012; Yang et al. 2013; Zhang et al. 2012; Rausch et al. 2015; Swiniarski et al. 2012) showed favorable results in using thulium laser for prostatectomy. Results showed are very much comparable to transurethral resection of the prostate included are IPSS, Qmax, PVR & QoL scores (Table 31.2).

Multiple approaches have been used in thulium laser enucleation, but all of which are based upon identification of the surgical capsule and retrograde enucleation along this plane. One of the initial approaches utilized incisions at 5 o'clock and 7 o'clock, with enucleation of the middle lobe between the incisions, moving from proximal to the verumontanum to the bladder neck, with release of the lobe off the bladder neck. The lateral lobes are similarly enucleated along the capsule, moving from a clockwise fashion towards the right lateral lobe or counterclockwise going to the left lateral lobe. A 12 o'clock incision is often made to separate the right and left lateral lobes. Other surgeons have employed a single bladder neck incision in either the 5 o'clock or 7 o'clock position, with incorporation of the middle lobe with one of the lateral lobes and the other lateral lobe removed after. If the middle lobe is not present, a single 6 o'clock incision can be made. Lastly, some surgeons will enucleate a lateral lobe and continue across the anterior connection (12 o'clock) over to the other side, taking the two lateral lobes together (Lerner and Rajender 2015). This procedure is followed by the use of a morcellator to evacuate the lobes of the prostate located within the bladder.

Depending on the availability of the morcellator, some centers have opted to use the vaporesection technique. Initially, it starts similar to that of the enucleation technique and prior to releasing the lobes from the prostate capsule, the prostatic lobes are resected into chips (Szlauer et al. 2009). Other authors have used another resection-type technique where multiple incisions are made in the prostate parenchyma down to the capsule. Smaller sections of prostate are then liberated from the capsule. These chips are then evacuated through aspiration using the same resectoscope. Vaporization or ablation technique are advisable to be used for prostate sizes 40 g and below (Fig. 31.1).

**Table 31.3** Overall analysis of peri-operative outcomes comparing thulium laser resection of the prostate and transurethral resection of the prostate

| Outcome of interest | No. of patients TLRP/TURP | WMD (95% CI) | p value | Favors |
|---|---|---|---|---|
| Operative time (min) | 489/539 | 9.00 [2.53, 15.47] | 0.006 | TURP |
| Serum Na decreased (mmol/l) | 200/202 | −3.58 [−4.04, −3.12] | <0.001 | TLRP |
| Serum hemoglobin decreased, g/dl | 322/363 | −0.94 [−1.44, −0.44] | <0.001 | TLRP |
| Catheterization (days) | 447/453 | −2.07 [−2.66, −1.49] | <0.001 | TLRP |
| Hospital days | 383/411 | −1.87 [−2.41, −1.33] | <0.001 | TLRP |

*TLRP* thulium laser resection of the prostate, *TURP* transurethral resection of the prostate, *WMD* weighted mean difference (from the meta-analysis of Tang et al. 2014)

**Table 31.4** Overall analysis of complications comparing thulium laser resection of the prostate and transurethral resection of the prostate

| Outcome of interest | No. of patients TLRP/TURP | WMD (95% CI) | p value | Favors |
|---|---|---|---|---|
| Overall complications | 405/452 | 0.29 [0.20, 0.41] | <0.001 | TLRP |
| Blood transfusion | 244/286 | 0.28 [0.09, 0.93] | 0.04 | TLRP |
| TUR syndrome | 135/142 | 0.33 [0.12, 0.89] | 0.03 | TLRP |
| Recatheterization | 164/180 | 0.89 [0.42, 1.85] | 0.75 | None |
| UTI | 176/188 | 0.57 [0.24, 1.39] | 0.22 | None |
| Retrograde ejaculation | 114/101 | 0.61 [0.35, 1.05] | 0.08 | None |
| Urethral stricture | 375/422 | 0.29 [0.12, 0.71] | 0.007 | TLRP |

*TLRP* thulium laser resection of the prostate, *TURP* transurethral resection of the prostate, *WMD* weighted mean difference (from the meta-analysis of Tang et al. 2014)

After the procedure, 3-way foley catheter inserted and irrigated with normal saline for 24 h. The indwelling catheter is removed ranging from 24 to 48 h after the procedure.

## 31.4 Patient Follow-Up

In the perioperative period, the patient should be observed on the day of catheter removal and the succeeding days post operation to observe for immediate complications.

In a meta analysis done by Barbalat et al., no standard follow up visits were suggested. However, a similarity of follow up schedule within the 1st month, and during the 6th month and 12th month post operation was noted.

For long term follow up, as with conventional TURP and patients after prostate surgery as suggested by the 2016 EAU Guidelines in the management of LUTS, patients should be reviewed 4–6 weeks after catheter removal to evaluate treatment response and adverse effects. If no complications or adverse effects are noted, no further re-assessment is necessary. Moreover to evaluate further the response to treatment, the following tests are recommended at follow-up visit after 4–6 weeks: IPSS and Qol, uroflowmetry for Qmax and PVR volume.

## 31.5 Outcomes and Complications

In the meta-analysis of Tang et al., they analyzed the overall postoperative efficacy parameters comparing thulium laser resection of the prostate and transurethral resection of the prostate by means of Qmax, PVR volume, QoL and IPSS (Table 31.3).

The present meta-analysis showed TLRP had good results comparable to those of TURP on both subjective (IPSS, QoL) and objective (Qmax, PVR) variables. Though at the 1-month follow-up, the QoL and IPSS were slightly higher in the TLRP group, at a statistically significant difference, the parameters of both groups showed similar and comparable results at future follow-ups. The meta-analysis showed that TLRP was as effective as TURP in improving subjective and objective treatment outcome variables.

Complication rate with the use of Thulium is relatively low, owing to the fact that lasers offer excellent hemostasis and coagulation. However as with other endoscopic modality in prostate surgery, intraoperative, early (<30 days) and late (>30 days) complications are still encountered. Complications seen are as follows: bleeding and TUR syndrome during the intraoperative period, urinary retention, febrile/afebrile UTI, and gross hematuria during the perioperative period and late complications (>30 days) such bladder neck contracture and urethral strictures (Table 31.4).

In a meta-analysis done by Tang et al., they analyzed complications of TLRP, compared to conventional B-TURP and M-TURP. A pooled data including 857 patients reporting complications where a significant reduction in the overall complication rate was observed. As with complications, seen in the intraoperative period, despite a longer operative time with the TLRP group compared to both B-TURP and M-TURP, there was a lower incidence of TUR syndrome, blood transfusion rate, and serum decrease in sodium.

Furthermore, as assessed by the better coagulation, it was also noted that the catheterization time among those in the TLRP group was significantly shorter than among those in the TURP group, resulting in their shorter hospital stay. With regards to the post-operative complications the meta-analysis found that there were no differences in between groups with respect to the need for re-catheterization for urinary retention, UTI and retrograde ejaculation. Further as to the late post-operative complications, there were no significant difference in between groups with regards to bladder neck contracture and urethral strictures. Overall, the meta-analyses proved that the use of Thulium in the management of prostatic enlargement are similar to TURP but with lower morbidity.

## 31.6 Conclusions

TLRP is a relatively safe, practical and effective alternative to the conventional TURP with dependable perioperative safety, fewer intraoperative and postoperative complications, and comparable efficacy in terms tof Qmax, PVR, QoL and IPSS with overall smaller declines in serum sodium and hemoglobin levels, shorter durations of catheterization, shorter lengths of hospital stay and fewer total complications.

Based on the 2017 European Association of Urology Guidelines on Non-Neurogenic LUTS, thulium enucleation may be an alternative to TURP and holmium laser enucleation in men with moderate-to-severe LUTS leading to immediate and mid-term objective and subjective improvements. Furthermore, they added Tm:YAG laser resection is an alternative to TURP for small- and medium-size prostates (EAU 2017).

## 31.7 Recommendations

Results from various studies with this new laser technology are encouraging. It appears that there is potentially an enhancement in tissue removal rate compared to other endoscopic technologies owing to the combined vaporization and incision modality seen in this technology.

Though this technology is relatively new, urologists must have an eye and be conscientious enough to scrutinize carefully to fully examine the results of this new treatment. In reality, the gold standard operation for any patient is the one that meets the needs and expectations while still being safe. The decision making as to what operation to consider should go hand in hand, in the sense that a careful consideration of patient's factors and surgeon's expertise and familiarity with the type of surgery should always be given importance.

## References


Alsaywid BS, Smith GHH. Antibiotic prophylaxis for transurethral urological surgeries: systematic review. Urol Ann. 2013;5(2):61–74.

Carmignani L, et al. One day surgery in the treatment of benign prostatic enlargement with thulium laser: a single institution experience. Korean J Urol. 2015;56(5):365–9.

Chung DE, Te AE. New techniques for laser prostatectomy: an update. Ther Adv Urol. 2009;1:85–97.

EAU. Guidelines on non neurogenic male LUTS. 2017.

Fried NM, Murray KE. High-power thulium fiber laser ablation of urinary tissues at 1.94 micron. J Endourol. 2005;19:25–31.

Gross A, Netsch C, Knipper S, Hölzel J, Bach T. Complications and early postoperative outcome in 1080 patients after thulium vapoenucleation of the prostate: results at a single institution. Euro Urol. 2013;63:859–67.

Hong D, et al. Comparison between thulium laser resection of prostate and transurethral plasmakinetic resection of prostate or transurethral resection of prostate. Sci Rep. 2015;5:14542. https://doi.org/10.1038/srep14542.

Iacono F, et al. Efficacy and safety profile of a novel technique, ThuLEP (Thulium laser enucleation of the prostate) for the treatment of benign prostate hypertrophy. Our experience on 148 patients. BMC Surg. 2012;12:1471–2.

Kim JW, et al. An analytical comparison of short-term effectiveness and safety between Thulium:YAG laser vaporesection of the prostate and bipolar transurethral resection of the prostate in patients with benign prostatic hyperplasia. Korean J Urol. 2014;55(1):41–6.

Lerner LB, Rajender A. Laser prostate enucleation techniques. Can J Urol. 2015;22(Suppl 1):53–9.

Mrkobrada M, Ying I, Mokrycke S, Dresser G, Elsayed S, Bathini V, Boyce E, Luke P. CUA guidelines on antibiotic prophylaxis for urologic procedures. Can Urol Assoc J. 2015;9(1–2):13–22.

Netsch C, Engbert A, Bach T, Gross A. Long-term outcome following Thulium VapoEnucleation of the prostate. World J Urol. 2014;32(6):1551–8. https://doi.org/10.1007/s00345-014-1260-2.

Rausch S, Heider T, Bedke J, et al. Analysis of early morbidity and functional outcome of thulium:yttrium-aluminum-garnet laser enucleation for benign prostate enlargement: patient age and prostate size determine adverse surgical outcome. Urology. 2015;85(1):182–8.

Stuart Wolf Jr J, et al. Urologic surgery antimicrobial prophylaxis. Am Urol Assoc. 2016.

Swiniarski P, Stepien S, Dudzic W, et al. Thulium laser enucleation of the prostate (TmLEP) vs. transurethral resection of the prostate (TURP): evaluation of early results. Cent Euro J Urol. 2012;65(3):130–4.

Szlauer R, Götschl R, Razmaria A, Paras L, Schmeller NT. Endoscopic vaporesection of the prostate using the continuouswave 2-μm thulium laser: outcome and demonstration of the surgical technique. Euro Urol. 2009;55:368–75.

Szlauer R, et al. Endoscopic vaporesection of the prostate using the continuous-wave 2-microm thulium laser: outcome and demonstration of the surgical technique. Eur Urol. 2009;55(2):368–75. https://doi.org/10.1016/j.eururo.2008.10.034. Epub 2008 Nov 12.

Tang K, et al. Early outcomes of thulium laser versus transurethral resection of the prostate for managing benign prostatic hyperplasia: a systematic review and meta-analysis of comparative studies. J Endourol. 2014;28(1):65–72. https://doi.org/10.1089/end.2013.0404. Epub 2013 Nov 4.

Vartak Ketan P, et al. Thulium laser enucleation of the prostate is a safe and a highly effective modality for the treatment of benign prostatic hyperplasia: our experience of 236 patients. Urol Ann. 2016;8(1):76–80.

Wendt-Nordahl G, et al. Systematic evaluation of a recently introduced 2-microm continuous-wave thulium laser for vaporesection of the prostate. J Endourol. 2008;22:1041–5.

Worthington J, et al. A randomised controlled trial to determine the clinical and cost effectiveness of thulium laser transurethral vaporesection of the prostate (ThuVARP) versus transurethral resection of the prostate (TURP) in the National Health Service (NHS)—the UNBLOCS trial: a study protocol for a randomised controlled trial. Trials. 2017;18(1):179.

Yan H, et al. Thulium laser vaporesection versus standard transurethral resection of the prostate: a randomized trial with transpulmonary thermodilution hemodynamic monitoring. Int J Urol. 2013;20(5):507–12.

Yang Z, Wang X, Liu T. Thulium laser enucleation versus plasmakinetic resection of the prostate: a randomized prospective trial with 18-month follow-up. Urology. 2013;81(2):396–400.

Zhang F, Shao Q, Herrmann T, Tian Y, Zhang Y. Thulium laser versus holmium laser transurethral enucleation of the prostate: 18-month follow-up data of a single center. Urology. 2012;79(4):869–74.

# Thermal Ablation for Small Renal Masses

# 32

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**Abstract**

Renal masses are now being detected and properly staged earlier because of advances in imaging. Surgery remains as the gold standard for treatment, with partial nephrectomy as the treatment of choice for small renal masses. A less invasive, nephron-sparing treatment alternative is ablation therapy, especially offered to patients with small renal masses (3 to 4 cm or less), elderly patients, patients with impaired renal function, or patients with co-morbidity, as it entails less anesthetic requirements, lower cost, shorter hospital stay, faster recovery, and reduced mortality and morbidity. Such ablative techniques include radiofrequency and microwave ablation that can be done through open surgery, laparoscopic surgery, or image-guided percutaneous techniques. Evaluation prior to thermal ablation should include contrast-enhanced CT scan. A biopsy is also done prior to tumor ablation to confirm the diagnosis. Major complications, such as hemorrhage, are infrequent. Patients are followed up regularly with imaging to determine treatment success.



**Keywords**

Small renal masses · Thermal ablation · Radiofrequency ablation · Microwave ablation



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## 32.1 Introduction

Tumors arising from the kidneys account for approximately 4% of all malignancies; 85% of these are diagnosed to be renal cell carcinomas (RCCs) (Krokidis et al. 2017; Ramanathan and Leveillee 2010), whether sporadic or genetic.

Small renal masses are asymptomatic, making it extremely difficult, if not impossible, to detect them based on clinical parameters. However, with the improvement and widespread use of non-invasive diagnostic imaging modalities, such as computed tomography and ultrasound, these asymptomatic masses are now being detected and treated much earlier (Chiou et al. 2005; Krokidis et al. 2017).

Once detected and diagnosed, proper staging of the lesion is paramount. Tumor grade, local invasion, and presence of nodal or distant metastases at presentation are considered to be the most important prognostic factors. Metastases to the bone, lung, adrenals, brain, and liver are most common (Krokidis et al. 2017).

Various international guidelines dictate that the treatment of RCCs varies depending on the tumor stage. Early stage tumors (stage TIa or TIb) are treated with either surgery or ablative therapy. Stage II and stage III tumors are best addressed with open or laparoscopic radical nephrectomy. Metastatic advanced tumors (stage IV) are treated with cytoreductive surgery combined with metastasectomy, prior to palliative chemotherapy (Kachura et al. 2016; Krokidis et al. 2017; Williams et al. 2007). With appropriate treatment, the 5-year survival rate for renal cancer is 92% for localized disease and 12% for advanced disease (Krokidis et al. 2017).

Surgery, whether open or laparoscopic, is regarded as the gold standard for treatment of renal cancers (Krokidis et al. 2017). Partial or radical nephrectomy (open or laparoscopic) for early-stage cancer provides excellent 5-year cause-specific survival rates (Ramanathan and Leveillee 2010). Surgery offers a more definitive oncological outcome, although with a slightly higher major complication rate, more blood loss, and longer hospital stay. However, results are highly dependent on the surgeon's experience (Williams et al. 2007).



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Development of ablation therapy resulted from the endeavors to provide a less invasive, nephron-sparing treatment alternative for patients with small renal tumors that cannot or do not wish to undergo surgical management (Krokidis et al. 2017). The first published case of percutaneous thermal ablation with the use of radiofrequency was published in the Journal of Urology in 1998 by McGovern et al. It was a case of an 84-year-old patient with a 3.5-cm exophytic mass who refused to undergo open surgery, and was successfully treated with radiofrequency ablation under ultrasound guidance using local anaesthesia and conscious sedation (McGovern et al. 1999a). From then on, a variety of ablation modalities have been studied extensively.

Several ablative modalities are currently existing. Numerous thermal and non-thermal ablation modalities are available for different organs, including radiofrequency (RF) ablation, microwave ablation, cryoablation, high-intensity focused ultrasonography (HIFU), laser ablation, irreversible electroporation, chemical ablation (with ethanol and acetic acid), and brachytherapy (Hinshaw et al. 2014a). Depending on the clinical setting, these can be applied via open surgery, laparoscopy, or via percutaneous access using image guidance. The advantages of image guided-ablative therapies include reduced morbidity and mortality, lower procedural cost, repeatability, ability to perform ablations in an outpatient setting, and synergy with other cancer treatments.

In the selection of the optimal ablation modality for a particular urologic case, the decision usually comes down to “heat versus cold”. This decision can be a complex one based on different factors including organ-specific considerations, approach, tumor location with consideration of proximity to vulnerable structures, and patient factors such as co-morbid conditions. The next sections will discuss some of the common thermal ablation modalities used in addressing small renal tumors, including their mechanism of action, safety profiles, efficacy and outcomes.

## 32.2 Pre-procedure Clinical Considerations

The European Association of Urology currently recommends cryoablation and radiofrequency ablation as alternatives in treatment of small renal masses (<4 cm) in elderly patients or patients with co-morbidities.

On the other hand, the American Urologic Association recommends the use of percutaneous thermal ablation as an alternative in the management of cT1a lesions (<3 cm in size). This includes radiofrequency ablation and cryoablation.

### 32.2.1 Patient Selection

Patients with significant co-morbidities (such as advanced COPD, heart failure, etc), in general, benefit most from treatment of small renal tumors with ablation. These also include patients with a single functioning kidney as well as those with impaired renal function (total GFR equal to or less than 60 ml/min per 1.73 $m^2$). Furthermore, patients with more than one small renal tumor on one side and renal impairment on the other, local ablation is most often beneficial. In the absence of an informed consent for invasive surgery, local ablation may prove to be a good treatment modality (Krokidis et al. 2017).

Uncorrectable coagulopathy is an absolute contraindication to local ablation of renal masses, as it significantly increases the risks of intra- and post-procedural hemorrhage. Gross physical deformities that provide but a limited window for safe percutaneous access to the tumor are a relative contraindication; laparoscopic or open ablation may be better options for such cases.

Special precaution has to be taken for patients with cardiac pacemakers who will undergo RFA.

### 32.2.2 Pre-procedure Evaluation

#### 32.2.2.1 Pre-procedure Imaging and Selection of Imaging Guidance

Prior to treatment performance, feasibility of the procedure, site of access, number and pathway of the probes, risk of adjacent organ injury and the necessity of ancillary procedures all need to be established based on pre-procedural imaging (Georgiades and Rodriguez 2013; Schmit et al. 2014a).

Although it is the most accessible, ultrasound (US) is the least sensitive modality for the detection of T1a RCCs (Warshauer et al. 1988). The use of microbubble contrast may help increase its diagnostic yield. However, confident determination of the relationship of the tumor to the adjacent structures to ensure proper needle pathway mapping still necessitates the use of contrast-enhanced CT or MRI (Paudice et al. 2012).

Despite some cases demonstrating the superiority of MRI in the characterization of renal masses (Hindman et al. 2012; Pedrosa et al. 2008; Rosenkrantz et al. 2010), CT remains to be the preferred modality of most operators for probe guidance and pre-procedural planning. In our setting, MRI is not used for guidance since MR-compatible devices are not readily available.

#### 32.2.2.2 Biopsy

Despite the high diagnostic accuracy of current abdominal imaging for large renal masses, diagnosis of small masses can still be challenging. Essentially, any enhancing solid lesion is considered RCC until proven otherwise. However, 10–20% of those lesions tend to be benign after biopsy (Campbell et al. 1998).

The recent recommendations of the European Association of Urology state that percutaneous biopsy of small renal masses is necessary (a) when the mass is characterized as indeterminate from imaging, (b) to select patients that would undergo the pathway of active surveillance and (c) to obtain histology before ablative treatments (Campbell et al. 1998). The biopsy is usually performed independently from the ablation of tumor; however, some operators, as with our practice, prefer to perform both procedures on the same day using co-axial technique to avoid tumor seeding (Zagoria et al. 2004b) and to minimize trauma to the structures surrounding the needle track. However, in patients who will be managed conservatively regardless of biopsy result, i.e. the elderly and those with significant co-morbidities, biopsy is not required as stated in the 2017 European Association of Urology guidelines on small renal masses.

Considering the importance of accurate histologic classification of malignancies for proper treatment strategies, such as histology-guided adjuvant chemotherapy, multiple core biopsies via coaxial technique is preferred to fine needle aspiration cytology.

#### 32.2.2.3 Pre-procedure Laboratory Work-Up

Routine pre-procedure laboratory work-up include complete blood count, biochemistry tests (urea, creatinine, and electrolytes), and clotting parameters (platelet count and international normalized ratio). Severe anemia (hemoglobin of less than 60 g/l), international normalized ratio of more than 1.5, and platelet count of less than 50,000 have to be addressed prior to the procedure. Special precautions have to taken in patients on anticoagulants.

#### 32.2.2.4 Prophylactic Antibiotics

Currently, there is no existing consensus on antibiotic use prior to the procedure. Antibiotic prophylaxis relies on the physician's preference. However, patients with diabetes, and those with an ileal loop diversion or a ureteral stent for pyeloperfusion require prophylactic antibiotics (Fotiadis et al. 2007; Krokidis et al. 2013). Local antibiograms must guide the use of antibiotics.

#### 32.2.2.5 Anesthetic Considerations

Anesthetic support is a vital part of the procedure. Although it is recommended that general anesthesia (GA) be used for prolonged pain control and reduction of intraoperative patient awareness and recall (Breen and Railton 2010; Georgiades and Rodriguez 2013; Gervais et al. 2005; Uppot et al. 2009; Zagoria et al. 2004a), conscious sedation proves to be sufficient and preferable in most procedures in our practice.

## 32.3 Ablative Techniques

### 32.3.1 Radiofrequency Ablation (RFA)

Radiofrequency ablation is a heat-based modality which utilizes the interaction between high-frequency (150 kHz to 1 MHz) electric current and biological tissue. The electric current causes vibration of the tissue's water molecules that is then transmitted between adjacent molecules with resulting frictional energy loss. The energy is deposited in the tissues in the form of a rise in temperature that leads to coagulation necrosis (Goldberg and Gazelle 2001).

Radiofrequency electrodes come in many forms. Electrodes can be unipolar or multipolar, straight (single or in clusters of three) or multi-tined. Since there is a target temperature range to facilitate effective ablation, most of these electrodes are engineered to have an internal cooling system (Goldberg and Gazelle 2001).

The target temperature for RFA is between 55 °C and 100 °C. Tissue death results within 2 s at 55 °C while cell death is instantaneous at 100 °C. In order for RFA to be effective, good electric and tissue conductivity must be ensured. The aim of RFA is, therefore, to deliver the target temperature for 4–6 min without causing charring or vaporization, as both charred tissue and gas act as insulators and thus limit energy transmission (Krokidis et al. 2017).

One of the considerations when it comes to procedure planning for RFA is the heat-sink effect that occurs when tissue vascularity within and around the tumor increases heat dissipation, thereby decreasing the total volume of the ablated area. Due to this heat-sink effect, it is more difficult to attain the target temperature in hypervascular tumors and in tumors that are adjacent to large blood vessels, resulting in less effective ablation and increased probability of residual tumor. Some larger tumors may require adjunctive selective embolization for better ablation (Takaki et al. 2010).

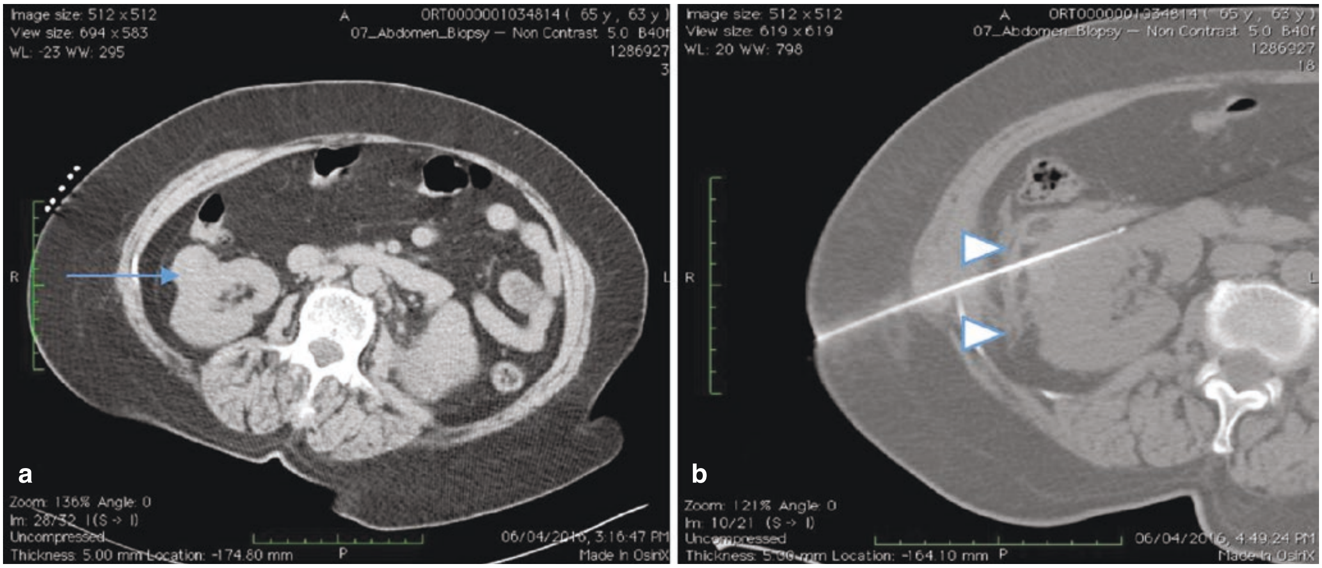


**Fig. 32.1** Case of An 82 y.o. female who underwent radiofrequency ablation (RFA). (**a**) Preoperative imaging shows a 2.7-cm peripherally located, partially exophytic right renal nodule (arrow) surrounded by fat with a safe distance away from the descending colon. A core biopsy that was done prior to the RFA confirmed the diagnosis of renal cell carcinoma, clear cell type. (**b**) The renal nodule in the interpolar region was accessed under ultrasound and CT guidance using a single G15 Cool-tip needle. The anteroinferior portion of the lesion was first treated for a total of 5 min, achieving a maximum tissue temperature of approximately 74 °C. The probe was repositioned to reach the posteromedial portion of the lesion, which was treated for a total of 12 min, achieving a maximum tissue temperature of approximately 103 °C. Minimal perinephric hematoma, fat stranding and thickening of the anterior renal, posterior renal, and lateral conal fasciae that had developed after the first burn are demonstrated as well (arrow).The needle track was ablated as well after each burn

In tumors that are smaller than 3 cm, it has been shown that RFA treatment may lead to 100% ablation. For sizes between 3 and 5 cm, up to 90% ablation has been achieved. Tumors larger than 5 cm show worse outcomes (~25%) (Zagoria et al. 2004a). It has been shown that for every centimeter above 3.6 cm the chance of recurrence-free survival decreases significantly by an estimated factor of 2.19 (Breen and Railton 2010) (Fig. 32.1).

### 32.3.2 Microwave Ablation (MWA)

Microwave technology utilizes a high frequency electromagnetic wave that increases temperature in tissues by increasing the kinetic energy of water molecules within an oscillating field (Kim et al. 2012). Like RFA, it is a heat-based modality. The transformation of the kinetic energy of water molecules to thermal energy that is transferred to cells causes coagulation necrosis (Liang and Wang 2007).

Since microwaves radiate through all biological tissues, including those with high impedance to electricity such as bone, lung, and desiccated tissues (Brace 2009), heat can be continuously generated in a much larger volume of tissue surrounding the applicator (Andreano and Brace 2013). This provides microwave energy with the advantage to generate faster, hotter, and larger ablation volumes as compared with RF current (Andreano and Brace 2013; Brace 2009). The applicator used to transmit the electromagnetic wave is called an antenna.

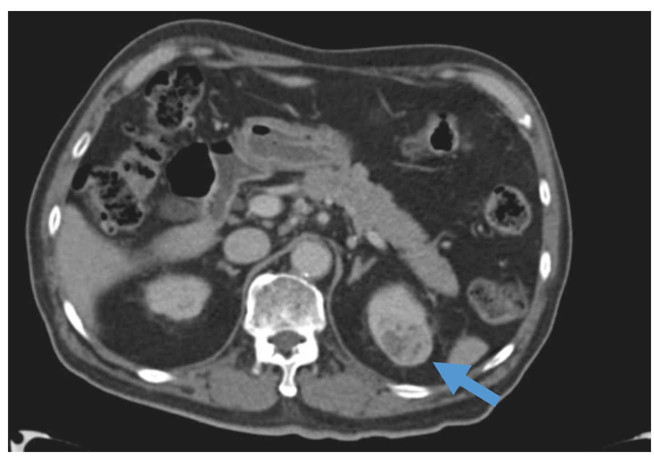

**Fig. 32.2** Contrast-enhanced CT scan of the abdomen of an 83-year-old man revealed an ill-defined, isodense, heterogeneously enhancing, solid nodule at the upper pole of the left kidney (arrow), measuring 3 × 2.7 × 3 cm (craniocaudal × transverse × anteroposterior)

Microwave applicators, or antennae, differ in diameter, number, frequency, phase control, and generated power. System performance can vary widely, so it is critical that physicians understand the ablation-zone shapes and sizes created by different time and power combinations in a particular system (Hinshaw et al. 2014b). A patient with a small renal nodule is shown in Figures 32.2 to 32.5, from the time the nodule was detected, to the time it was ablated, until 7 months post-ablation.

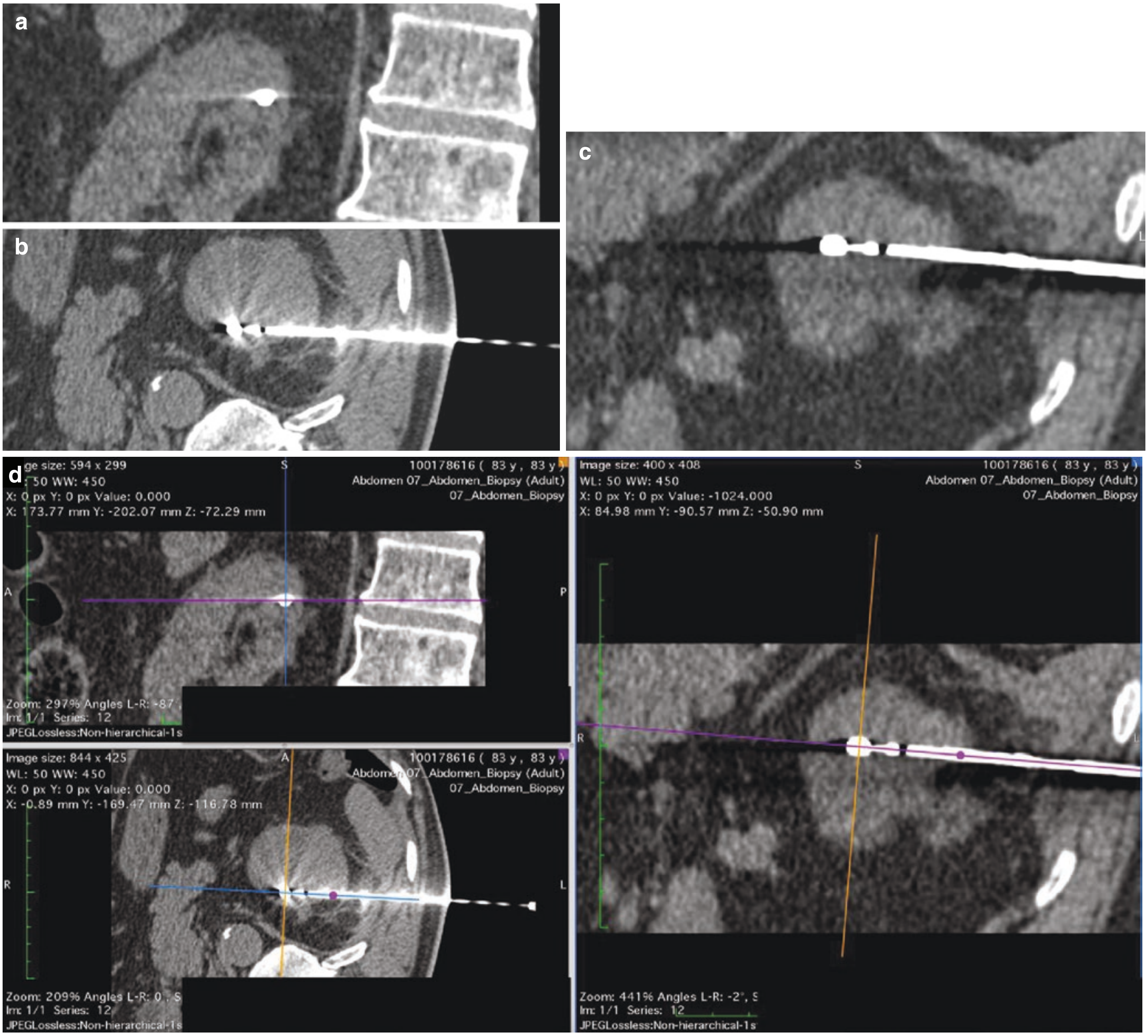


**Fig. 32.3** (**a**)–(**e**) Under ultrasound and CT guidance, core biopsy of the nodule at the upper pole of the left kidney was done, followed by microwave ablation. CT images above show sagittal (**a**), transverse (**b**), oblique coronal (**c**), and multi-planar reconstruction (**d**). A G13 x 15 cm microwave antenna was used to treat the nodule, initially for 2 min and 45 s at 100 W. The antenna was then repositioned and the lateral and medial aspects of the nodule were treated at 100 W at 45 s each. Immediate post-ablation CT scan (**e**) showed trace perinephric fluid and fat stranding densities

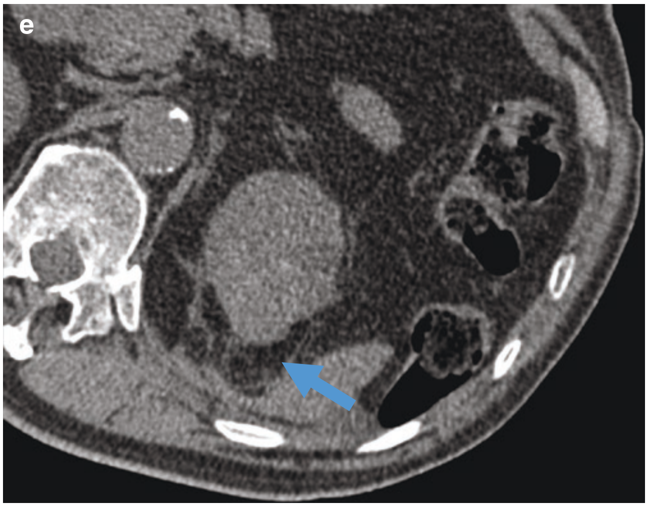


**Fig. 32.3** (continued)

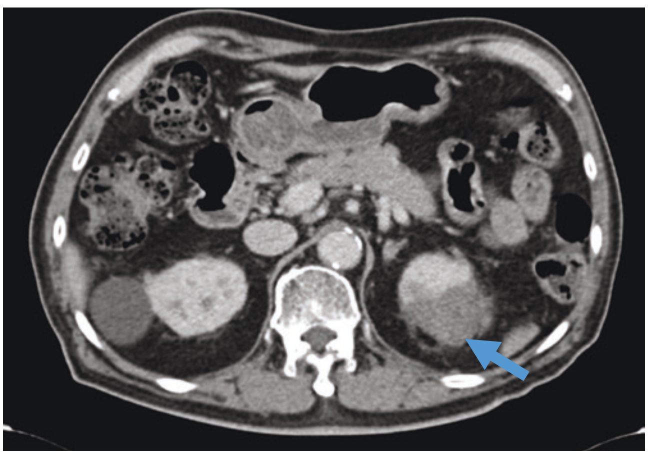

**Fig. 32.4** One-month post-microwave ablation of the solid nodule at the upper pole of the left kidney showed a fairly defined, isodense, non-enhancing focus replacing the previously noted solid, heterogeneously enhancing nodule. The absence of contrast enhancement is a favorable finding, indicating complete ablation of the lesion

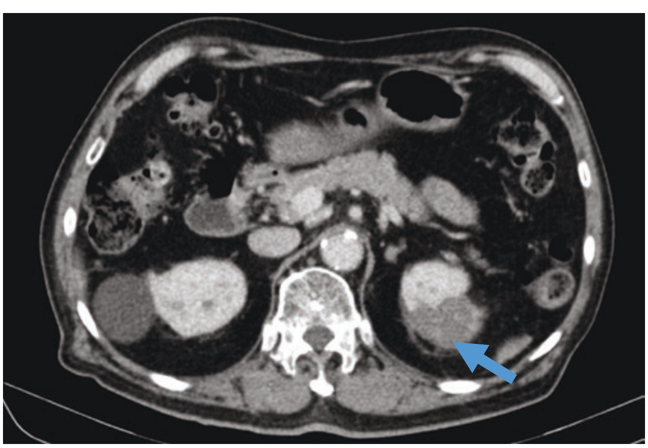

**Fig. 32.5** Seven months post-microwave ablation of the solid nodule at the upper pole of the left kidney again showed the same isodense, non-enhancing focus in the said area, with no evidence of residual or recurrent tumor

### 32.3.3 Cryoablation

The mechanism of cell death with cold temperatures is different from that with heat. The freezing process results in both intracellular and extracellular ice formation, both of which can result in cellular death (Hinshaw et al. 2014b). In cryoablation, alternating freezing and thawing cycles ultimately lead to cellular membrane disruption and potential rapid release of cellular debris into the systemic circulation. This results in a serious systemic complication known as cryoshock, one that is not common in heat-based modalities.

A limitation of cryoablation is that the surface area of its cryoprobe determines its cooling efficiency—smaller probes result in smaller ablation zones. Most tumors require multiple cryoprobes for complete ablation, thus prolonging the treatment time (Hinshaw et al. 2014b).

In cryoablation, the zone of ablation can be precisely monitored under ultrasound or CT scan in real time as it expands unlike in RFA or microwave (Hinshaw et al. 2014b). In addition to this advantage, the heat-sink effect in RFA or, to a lesser degree, in microwave ablation, is generally not encountered in this procedure (Campbell et al. 1998; Weld et al. 2006).

## 32.4 Adjunctive Techniques

Location of the tumor is an important factor in planning treatment strategy. Surrounding organs such as bowel loops that are in close proximity to exophytic or peripherally-located small renal tumors should be protected from thermal injury. Dissection using fluid or $CO_2$ is used to separate adjacent organs (Zargar et al. 2016; Zorn et al. 2007).

Under image guidance, a non-ionic solution (usually dextrose 5%) is injected into the retroperitoneum to act as insulators of the electric current, as well as push an adjacent bowel loop to safety (Kam et al. 2004; Park et al. 2007).

An alternative to fluid is $CO_2$ which has low thermal conductivity, minimal toxicity and low cost. When absorbed, it has virtually no risk of embolism due to its very high solubility and easy elimination through respiration (Kam et al. 2004; Park et al. 2007).

In more centrally-located lesions near the collecting system, a retrograde ureteral stent which is continuously perfused with 5% dextrose can be used to lessen the risk of thermal injury. In RFA, cold fluid should be used with temperature ranging from 2 °C to 6 °C, while for cryoablation, warm saline should be used. An indwelling bladder catheter is also placed to drain the perfused fluid (Wah et al. 2005).

Transarterial embolization has been reported to be beneficial in reducing the heat-sink effect and the risk of bleeding in select cases (Tacke et al. 2001, 2005).

## 32.5 Complications

Post-ablation complications can occur as a direct injury to the kidney including its vasculature as well as the proximal collecting system, or injury to adjacent structures. Hemorrhage, urine leak, stricture formation and urinary tract infection are examples of urologic complications, while examples of more common non-urologic complications include skin burns, needle track seeding, nerve injury, and pneumothorax (Atwell et al. 2012; Dindo et al. 2004).

In majority of kidney procedures, bleeding is inevitable therefore it is imperative that the optimal coagulation status of the patient is ensured to avoid major complications such as hematoma formation that extends to the retroperitoneum. Hematoma formation risk is estimated at 6% while massive bleeding has been reported in less than 1% of cases. Rarely, post-ablation embolization may be required to control massive hemorrhage (Atwell et al. 2013; Boss et al. 2005; Breen et al. 2007, 2013; Georgiades and Rodriguez 2014; Gervais et al. 2005; Kim et al. 2012; Krokidis et al. 2013; Schmit et al. 2014b; Veltri et al. 2004, 2014; Zagoria et al. 2004b, 2011; Zargar et al. 2016).

Another relatively infrequent complication is hematuria. It has an incidence of 0.5–1% and is usually self-limiting, resolving after 12 to 34 h (Boss et al. 2005; Breen et al. 2013; Georgiades and Rodriguez 2014; Krokidis et al. 2013; Schmit et al. 2014b; Veltri et al. 2004; Zagoria et al. 2004b). Persistent hematuria will raise suspicion for thermal damage to the pelvocalyceal system, which may be supported by imaging studies. Imaging findings may vary from mild ureteritis to urinoma/perinephric hematoma or even hemoretroperitoneum. In these cases, retrograde catheterization and ureteral stent placement for irrigation is necessary (Zorn et al. 2007).

Thermal damage to other adjacent structures such as bowel loops and nerves is also of primary concern. This can be minimized or prevented with the use of fluid or $CO_2$ dissection. Bowel injuries may potentially evolve into perforations and adhesions (Park and Kim 2009).

A multi-institutional review of 271 RFA and cryoablation procedures done intraoperatively and percutaneously, demonstrated an overall complication rate of 11% (Johnson et al. 2004). A meta-analysis comparing percutaneous and surgical renal ablation procedures found a significantly lower major complication rate of 3.1% for percutaneous ablation versus 7.4% for surgical cases (Hui et al. 2008). A large institution review of 573 renal ablation procedures yielded an overall complication rate of 11.3% with a major complication rate of 6.6%. Major complications more commonly occurred with cryoablation 7.7% than with RFA 4.7% (Hinshaw et al. 2014b). Review of several other studies show that renal RFA shows an overall complication rate of 8–13% with major complication rates of 4–6% (Atwell et al. 2008; Gupta et al. 2006; Hegarty et al. 2006; Zagoria et al. 2007) compared to 5–7% major complication rate following percutaneous renal cryoablation (Atwell et al. 2008; Gupta et al. 2006; Silverman et al. 2005).

In general, major complications were found to be much higher in surgical approaches compared with ablative ones as

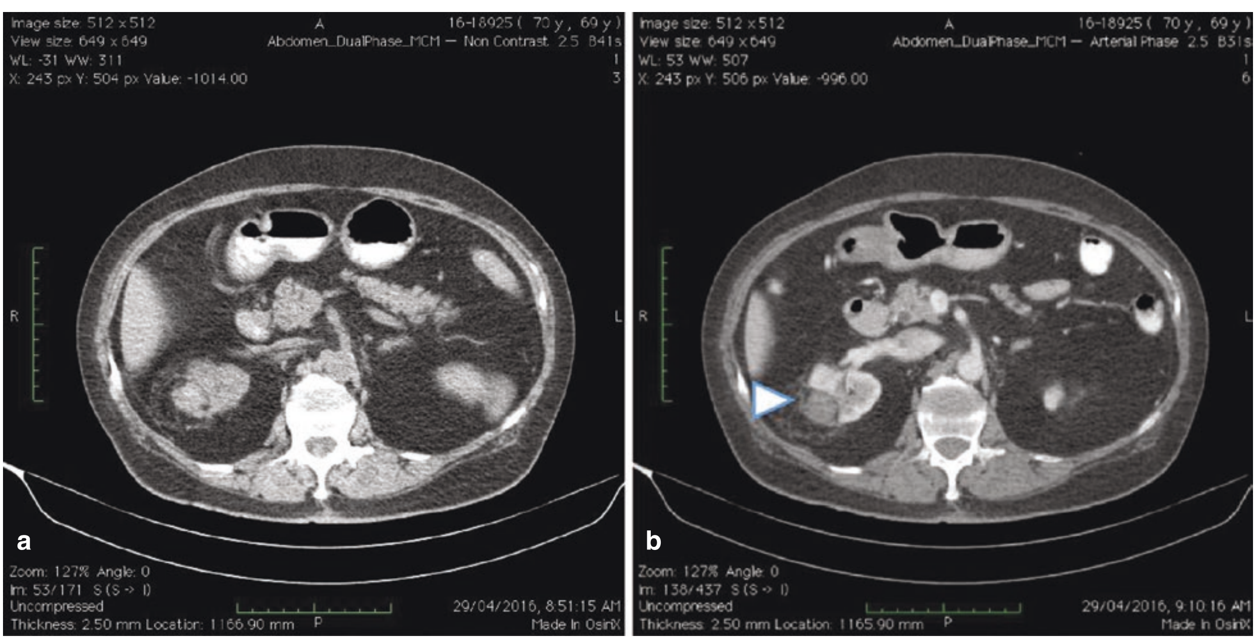


**Fig. 32.6** Follow-up CT scan of 74 year old female with a 2.5 cm renal cell ca, right kidney, 6 months post-radiofrequency ablation (RFA). (**a**) Plain CT scan (**b**) Arterial phase showed no evident enhancement in and around the lesion (arrow). (**c**) The margin between the ablated tissue and the non-ablated renal parenchyma had been replaced gradually by fat, as seen in most cases (halo sign) on venous phase (arrow)

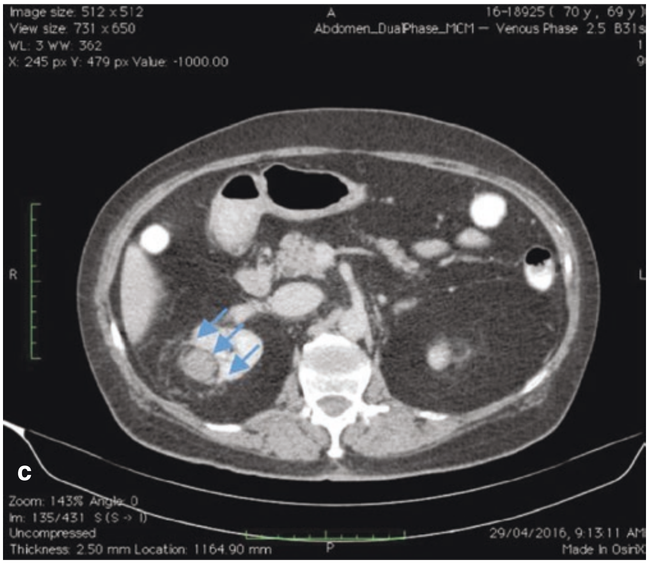


**Fig. 32.6** (continued)

shown in a meta-analysis by Katsanos et al. (2017). In another meta-analysis, patients who underwent microwave ablation were found to have significantly less complications as compared with those who underwent open partial nephrectomy (Kachura et al. 2016).

## 32.6 Patient Follow-Up

Immediately post-ablation, close monitoring of the vital signs of the patient and oxygenation level should be done. Analgesics may be given on demand. Prior to discharge, post-ablation imaging, either ultrasound or CT scan, is performed to exclude complications such as hemorrhage or bowel perforation (Krokidis et al. 2017).

The recommended outpatient follow-up schedule is four weeks post-treatment. Clinical parameters that need to be assessed during the first visit include pain levels and presence of hematuria and/or fever (Krokidis et al. 2017).

A follow-up contrast-enhanced CT or MRI may be done at the third month to evaluate for possible residual tumor and to plan for any re-intervention. A treated lesion will not show enhancement after contrast administration, indicating coagulative necrosis (Smith and Gillams 2008). Nodular enhancement in or around the ablated tumor is indicative of residual disease or disease progression. In the majority of cases, the margin between the ablated tissue and the non-ablated renal parenchyma may be replaced gradually by fat. Repeat CT studies or MRI at 1, 3, and 5 years post-treatment are recommended to check for any recurrent disease (Krokidis et al. 2017) (Fig. 32.6).

## 32.7 Partial Nephrectomy Versus Thermal Ablation

There is very limited evidence available to compare the efficacy and safety of these ablative techniques with the other standards of care. Most of the existing studies are non-randomized, with small sample sizes and with short follow-ups.

A meta-analysis of cohort studies that compared surgeries and ablation for T1 RCCs showed there is no statistically significant difference in the disease-free survival rate. Thermoablative techniques have been shown to have similar outcomes with partial or radical nephrectomy in patients with early stage cancers (Kachura et al. 2016; Krokidis et al. 2017). For small tumors, the cause-specific survival rate and the metastasis-free survival rate are pegged at 95% (75–99% for partial nephrectomy, 71–81% for radical nephrectomy, 83–95% for thermal ablation, 69–94% for active surveillance). Local recurrence-free rates have been shown to be in favor of partial nephrectomy compared with thermal ablation (RR 0.37, 95% CI 0.15–0.89).

Partial nephrectomy was shown to decrease glomerular filtration rate by a larger amount compared with thermal ablation. However, long-term observations have shown that there was no significant difference in the patients' glomerular filtration rate and risk of progression to chronic kidney disease among patients who underwent RFA compared with partial nephrectomy (Kachura et al. 2016).

Complications arising from surgery have also been observed. Although there are higher complication rates for lap partial nephrectomy compared with MWA, these are not statistically significant (Kachura et al. 2016).

## 32.8 Conclusion

With the constantly advancing imaging modalities, early detection of small renal tumors is on the rise. An important emerging treatment option for these, as well as for larger lesions in poor surgical candidates, is thermal ablation, which includes heat- (RFA and microwave) and cold-based (cryotherapy) modalities. These modalities have the distinct advantage, as compared against their surgical counterparts, of carrying less complications while preserving renal function. Their efficacy, however, diminishes with tumor size.

Several guidelines on the use of thermal ablation, although evidence establishing its long-term efficacy and safety as compared with surgery remains to be established.

Pre- and post-procedural patient care are as important as the procedure itself, ensuring patient safety and optimal treatment results. Long-term follow-up includes repeat imaging to detect residual or recurrent tumor.

## References


Andreano A, Brace CL. A comparison of direct heating during radiofrequency and microwave ablation in ex vivo liver. Cardiovasc Intervent Radiol. 2013;36(2):505–11.

Atwell TD, Carter RE, Schmit GD, et al. Complications following 573 percutaneous renal radiofrequency and cryoablation procedures. J Vasc Interv Radiol. 2012;23(1):48–54.

Atwell TD, Farrell MA, Leibovich BC, et al. Percutaneous renal cryoablation: experience treating 115 tumors. J Urol. 2008;179(6):2136–40. discussion 2140-1

Atwell TD, Schmit GD, Boorjian SA, Mandrekar J, Kurup AN, Weisbrod AJ, et al. Percutaneous ablation of renal masses measuring 3.0 cm and smaller: comparative local control and complications after radiofrequency ablation and cryoablation. AJR Am J Roentgenol. 2013;200(2):461–6.

Boss A, Clasen S, Kuczyk M, Anastasiadis A, Schmidt D, Graf H, et al. Magnetic resonance-guided percutaneous radiofrequency ablation of renal cell carcinomas: a pilot clinical study. Investig Radiol. 2005;40:583–90.

Brace CL. Radiofrequency and microwave ablation of the liver, lung, kidney, and bone: what are the differences? Curr Probl Diagn Radiol. 2009;38(3):135–43.

Breen D, Bryant TJ, Abbas A, Shepherd B, McGill N, Anderson JA, et al. Percutaneous cryoablation of renal tumours: outcomes from 171 tumours in 147 patients. BJU Int. 2013;112(6):758–65.

Breen DJ, Railton NJ. Minimally invasive treatment of small renal tumors: trends in renal cancer diagnosis and management. Cardiovasc Interv Radiol. 2010;33(5):896–908.

Breen DJ, Rutherford EE, Stedman B, Roy-Choudhury SH, Cast JEI, Hayes MC, et al. Management of renal tumors by image-guided radiofrequency ablation: experience in 105 tumors. Cardiovasc Interv Radiol. 2007;30(5):936–42.

Campbell SC, Krishnamurthi V, Chow G, Hale J, Myles J, Novick AC. Renal cryosurgery: experimental evaluations of treatment parameters. Urology. 1998;52(1):29–34.

Chiou YY, Hwang JI, Chou YH, Wang JH, Chiang JH, Chang CY. Percutaneous radiofrequency ablation of renal cell carcinoma. J Chin Med Assoc. 2005;68(5):221–5.

Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg. 2004;240(2):205–13.

Fotiadis NI, Sabharwal T, Morales JP, Hodgson DJ, O'Brien TS, Adam A. Combined percutaneous radiofrequency ablation and ethanol injection of renal tumours: midterm results. Eur Urol. 2007;52(3):777–84.

Georgiades C, Rodriguez R. Renal tumor ablation. Tech Vasc Interv Radiol. 2013;16(4):230–8.

Georgiades CS, Rodriguez R. Efficacy and safety of percutaneous cryoablation for stage 1A/B renal cell carcinoma: results of a prospective, single-arm, 5-year study. Cardiovasc Interv Radiol. 2014;37(6):1494–9.

Gervais DA, McGovern FJ, Arellano RS, McDougal WS, Mueller PR. Radiofrequency ablation of renal cell carcinoma. Part 1. Indications, results, and role in patient management over a 6-year period and ablation of 100 tumors. AJR Am J Roentgenol. 2005;185:64–71.

Goldberg SN, Gazelle GS. Radiofrequency tissue ablation: physical principles and techniques for increasing coagulation necrosis. Hepato-Gastroenterology. 2001;48:359–67.

Gupta A, Allaf ME, Kavoussi LR, Jarrett TW, Chan DY, Su LM, et al. Computerized tomography guided percutaneous renal cryoablation with the patient under conscious sedation: initial clinical experience. J Urol. 2006;175:447–52.

Hegarty NJ, Gill IS, Desai MM, Remer EM, O'Malley CM, Kaouk JH. Probe-ablative nephron-sparing surgery: cryoablation versus radiofrequency ablation. Urology. 2006;68(1 Suppl):7–13.

Hindman N, Ngo L, Genega EM, Melamed J, Wei J, Braza JM, et al. Angiomyolipoma with minimal fat: can it be differentiated from clear cell renal cell carcinoma by using standard MR techniques? Radiology. 2012;265(2):468–77.

Hinshaw JL, Lubner MG, Ziemlewicz TJ, Fred T, Lee FT Jr, Brace CL. Percutaneous tumor ablation tools: microwave, radiofrequency, or cryoablation—what should you use and why? Radiographics. 2014a;35:1344–62.

Hinshaw JL, Lubner MG, Ziemlewicz TJ, Fred T, Lee FT Jr, Brace CL. Percutaneous tumor ablation tools: microwave, radiofrequency, or cryoablation—what should you use and why? Radiographics. 2014b;35:1344–62.

Hui GC, Tuncali K, Tatli S, Morrison PR, Silverman SG. Comparison of percutaneous and surgical approaches to renal tumor ablation: metaanalysis of effectiveness and complication rates. J Vasc Interv Radiol. 2008;19(9):1311–20.

Johnson DB, Solomon SB, Su LM, et al. Defining the complications of cryoablation and radio frequency ablation of small renal tumors: a multi-institutional review. J Urol. 2004;172(3):874–7.

Kachura J, Baldassarre F, Kielar A, Baerlocher M. A quality initiative of the Program in Evidence-Based Care (PEBC), Cancer Care Ontario (CCO) focal ablation 3: focal tumour ablation for renal cell carcinoma. 2016.

Kam AW, Littrup PJ, Walther MM, Hvizda J, Wood BJ. Thermal protection during percutaneous thermal ablation of renal cell carcinoma. J Vasc Interv Radiol. 2004;15(7):753–8.

Kim SD, Yoon SG, Sung GT. Radiofrequency ablation of renal tumors: four-year follow-up results in 47 patients. Korean J Radiol. 2012;13(5):625–33.

Krokidis M, Spiliopoulos S, Jarzabek M, Fotiadis N, Sabharwal T, O'Brien T, et al. Percutaneous radiofrequency ablation of small renal tumours in patients with a single functioning kidney: long-term results. Eur Radiol. 2013;23(7):1933–9.

Krokidis ME, et al. CIRSE guidelines on percutaneous ablation of small renal cell carcinoma. Cardiovasc Intervent Radiol. 2017;40(2):177–91.

Liang P, Wang Y. Microwave ablation of hepatocellular carcinoma. Oncology. 2007;72(Suppl 1):124–31.

McGovern FJ, Wood BJ, Goldberg SN, Mueller PR. Radiofrequency ablation of renal cell carcinoma via image guided needle electrodes. J Urol. 1999a;161(2):599–600.

Park BK, Kim CK. Complications of image-guided radiofrequency ablation of renal cell carcinoma: causes, imaging features and prevention methods. Eur Radiol. 2009;19(9):2180–90.

Park BK, Kim SH, Byun JY, Kim YS, Kwon GY, Jang IS. CT-guided instillation of 5% dextrose in water into the anterior pararenal space before renal radiofrequency ablation in a porcine model: positive and negative effects. J Vasc Interv Radiol. 2007;18:1561–9.

Paudice N, Zanazzi M, Agostini S, Bertelli E, Caroti L, Carta P, et al. Contrast-enhanced ultrasound assessment of complex cystic lesions in renal transplant recipients with acquired cystic kidney disease: preliminary experience. Transplant Proc. 2012;44(7):1928–9.

Pedrosa I, Sun MR, Spencer M, Genega EM, Olumi AF, Dewolf WC, et al. MR imaging of renal masses: correlation with findings at surgery. Radiographics. 2008;28(4):985–1003.

Ramanathan R, Leveillee RJ. Ablative therapies for renal tumors. Ther Adv Urol. 2010;2(2):51–68. https://doi.org/10.1177/1756287210366708.

Rosenkrantz AB, Hindman N, Fitzgerald EF, Niver BE, Melamed J, Babb JS. MRI features of renal oncocytoma and chromophobe renal cell carcinoma. AJR Am J Roentgenol. 2010;195(6):W421–7.

Schmit GD, Kurup AN, Weisbrod AJ, Thompson RH, Boorjian SA, Wass CT, et al. ABLATE: a renal ablation planning algorithm. AJR Am J Roentgenol. 2014a;202(4):894–903.

Schmit GD, Schenck LA, Thompson RH, Boorjian SA, Kurup AN, Weisbrod AJ, et al. Predicting renal cryoablation complications: new risk score based on tumor size and location and patient history. Radiology. 2014b;272(3):903–10.

Silverman SG, Tuncali K, van Sonnenberg E, et al. Renal tumors: MR imaging-guided percutaneous cryotherapy—initial experience in 23 patients. Radiology. 2005;236(2):716–24.

Smith S, Gillams A. Imaging appearances following thermal ablation. Clin Radiol. 2008;63:1–11.

Tacke J, Mahnken A, Bucker A, Rohde D, Gunther RW. Nephron-sparing percutaneous ablation of a 5 cm renal cell carcinoma by superselective embolization and percutaneous RF ablation. Rofo. 2001;173:980–3.

Tacke J, Mahnken AH, Gunther RW. Percutaneous thermal ablation of renal neoplasms. Rofo. 2005;177:1631–40.

Takaki H, Yamakado K, Soga N, Arima K, Nakatsuka A, Kashima M, et al. Midterm results of radiofrequency ablation versus nephrectomy for T1a renal cell carcinoma. Jpn J Radiol. 2010;28(6):460–8.

Uppot RN, Silverman SG, Zagoria RJ, Tuncali K, Childs DD, Gervais DA. Imaging-guided percutaneous ablation of renal cell carcinoma: a primer of how we do it. AJR Am J Roentgenol. 2009;192(6):1558–70.

Veltri A, De Fazio G, Malfitana V, Isolato G, Fontana D, Tizzani A, et al. Percutaneous US-guided RF thermal ablation for malignant renal tumors: preliminary results in 13 patients. Eur Radiol. 2004;14:2303–10.

Veltri A, Gazzera C, Busso M, Solitro F, Piccoli GB, Andreetto B, et al. T1a as the sole selection criterion for RFA of renal masses: randomized controlled trials versus surgery should not be postponed. Cardiovasc Interv Radiol. 2014;37(5):1292–8.

Wah TM, Koenig P, Irving HC, Gervais DA, Mueller PR. Radiofrequency ablation of a central renal tumour: protection of the collecting system with a retrograde cold dextrose pyeloperfusion technique. J Vasc Interv Radiol. 2005;16(11):1551–5.

Warshauer DM, McCarthy SM, Street L, Bookbinder MJ, Glickman MG, Richter J, et al. Detection of renal masses: sensitivities and specificities of excretory urography/linear tomography, US, and CT. Radiology. 1988;169(2):363–5.

Weld KJ, Hruby G, Humphrey PA, Ames CD, Landman J. Precise characterization of renal parenchymal response to single and multiple cryoablation probes. J Urol. 2006;176(2):784–6.

Williams SK, de la Rosette J, Landman J, Keely F. Cryoablation of small renal tumors. EAU-EBU Update Series. 2007;5:206–2018.

Zagoria RJ, Hawkins AD, Clark PE, Hall MC, Matlaga BR, Dyer RB, et al. Percutaneous CT-guided radiofrequency ablation of renal neoplasms: factors influencing success. AJR. 2004a;183:201–7.

Zagoria RJ, Hawkins AD, Clark PE, Hall MC, Matlaga BR, Dyer RB, et al. Percutaneous CT-guided radiofrequency ablation of renal neoplasms: factors influencing success. AJR. 2004b;183:201–7.

Zagoria RJ, Pettus JA, Rogers M, Werle DM, Childs D, Leyendecker JR. Long-term outcomes after percutaneous radiofrequency ablation for renal cell carcinoma. Urology. 2011;77(6):1393–7.

Zagoria RJ, Traver MA, Werle DM, Perini M, Hayasaka S, Clark PE. Oncologic efficacy of CT-guided percutaneous radiofrequency ablation of renal cell carcinomas. AJR Am J Roentgenol. 2007;189(2):429–36.

Zargar H, Atwell TD, Cadeddu JA, de la Rosette JJ, Janetschek G, Kaouk JH, et al. Cryoablation for small renal masses:selection criteria, complications, and functional and oncologic results. Eur Urol. 2016;69(1):116–28.

Zorn KC, Orvieto MA, Mikhail AA, Lyon MB, Gerber GS, Steinberg GD, et al. Case report: radiofrequency ablation-induced renal-pelvic obstruction resulting in nephrectomy. J Endourol. 2007;21(9):1059–63.

# 33 Narrow-Band Imaging (NBI)

Seiji Naito

**Abstract**

Cystoscopy and transurethral resection (TUR) using white light (WL) has been used as a standard procedure for diagnosis and treatment of non-muscle invasive bladder cancer (NMIBC). However, WL cystoscopy cannot always effectively identify small tumor or high grade flat lesions, carcinoma in situ (CIS). Small tumors can be frequently missed resulting in a high rate of residual tumors after WL-assisted TUR, and deficient visualization of tumor borders or associated CIS may lead to incomplete resection. Such oversights of small tumors or incomplete resections are considered to be a cause of the high incidence of intravesical recurrence after WL-assisted TUR.

Recently, Narrow-band imaging (NBI) has been developed as a new technology to overcome such shortcomings of WL cystoscopy or WL-assisted TUR. NBI devices filter out the red spectrum from WL, leaving the resultant blue (415 nm) and green (540 nm) spectra. These specific wavelengths penetrate only the surface of the bladder tissue, and are strongly absorbed by hemoglobin. Consequently, high vessel contrast and delicate tissue surface structure can be obtained without any medication. NBI can be used easily and safely in an outpatient clinic for cystoscopy, and in an operating room for TUR. NBI increases the detection of bladder tumors including CIS without any significant increase in false-positive rates that would lead to unnecessary negative biopsies. NBI also may improve the quality of TUR and consequently reduce the subsequent tumor recurrence particularly in low-risk patients.

Thus, NBI is a promising technology that facilitates the diagnosis and treatment of NMIBC.

**Keywords**

Narrow-band imaging · Non-muscle invasive bladder cancer · Transurethral resection

## 33.1 Introduction

Bladder cancer is the seventh most commonly diagnosed cancer in the male population worldwide, while it drops to 11th when both genders are considered (Ferlay et al. 2013). Approximately 75% of patients with bladder cancer present with non-muscle invasive bladder cancer (NMIBC) that is confined to the mucosa or submucosa (Burger et al. 2013). Cystoscopy and transurethral resection (TUR) using white light (WL) has been used as a standard procedure for diagnosis and treatment of such NMIBC cases. However, WL cystoscopy cannot always effectively identify small tumor or high grade flat lesions, carcinoma in situ (CIS). Small tumors can be frequently missed resulting in a high rate of residual tumors after WL-assisted TUR, and deficient visualization of tumor borders or associated CIS may lead to incomplete resection. Such oversights of small tumors or incomplete resections are considered to be a cause of the high incidence of intravesical recurrence after WL-assisted TUR. In fact, the incidence of intravesical tumor recurrence at one year after WL-assisted TUR reaches as high as 50% or more (Sylvester et al. 2006). Therefore, development of a more accurate diagnostic procedure has been required to improve the therapeutic outcome of NMIBC.

Recently, new technologies such as photodynamic diagnosis (PDD) and narrow-band imaging (NBI) have been developed to overcome such shortcomings of WL cystoscopy or WL-assisted TUR. In this article, I present a review of the literature concerning usefulness of NBI for the diagnosis and treatment of NMIBC.

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## 33.2 Principle and Mechanisms

NBI is an optical image enhancement technique designed for endoscopy without the use of dyes. NBI devices filter out the red spectrum from WL, leaving the resultant blue (415 nm) and green (540 nm) spectra. If bladder mucosa is illustrated with such light using an NBI filter, these specific wavelengths penetrate only the surface of the bladder tissue, and are strongly absorbed by hemoglobin. Consequently, the vascular structure appears dark brown or green against a pink or white mucosal background and high vessel contrast and delicate tissue surface structure can be obtained (Bryan et al. 2007). Thus, NBI can highlight a small tumor that may tend to be overlooked by conventional WL cystoscopy. The marginal region of the tumor or CIS can also be identified more clearly as a dark brown enhanced lesion by NBI (Figs. 33.1 and 33.2).

## 33.3 Tumor Detection

Since the first report by Bryan et al. (2007) that NBI flexible cystoscopy could detect a significantly greater number of urothelial cancers than WL cystoscopy, quite a few studies have demonstrated a higher detection rate of bladder cancer by NBI cystoscopy compared to WL cystoscopy. Table 33.1 lists tumor-level and patient-level detection rates and false-positive rates by NBI and WL cystoscopy from six series (Herr and Donat 2008; Cauberg et al. 2010; Tatsugami et al. 2010; Geavlete et al. 2012; Chen et al. 2013; Ye et al. 2015). In these series, the detection rate of NBI cystoscopy is more than 90%, and significantly higher than WL cystoscopy both at tumor-level and patient-level. Differences of detection rates are 11–35% at tumor level and 9–31% at patient level, respectively. Li et al. (2013) conducted a systematic review and meta-analysis using seven studies with prospectively collected data including a total of 1040 patients, and reported a significantly higher detection rate of NBI as compared to WL both at tumor level and patient level settings (rate difference 19%; 95%CI 12–26%; $p < 0.001$; and rate difference 11%; 95%CI 5–17%; $p < 0.001$, respectively).

In cases of CIS, a significantly higher detection rate with NBI cystoscopy compared to WL cystoscopy has been also reported both at tumor-level and patient level (Table 33.2) (Herr and Donat 2008; Tatsugami et al. 2010; Geavlete et al. 2012). A systemic review and meta-analysis by Li et al. (2013) also showed that tumor-level detection rate of CIS by

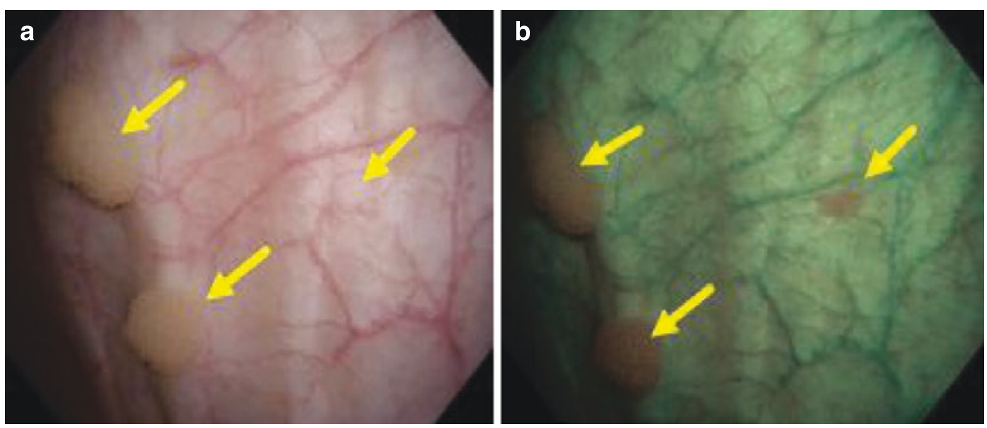


**Fig. 33.1** Small papillary, pTa, low grade urothelial carcinomas. (**a**) WL view. (**b**) NBI view. Three tumors, including a tiny one, are clearly identified by enhanced contrast

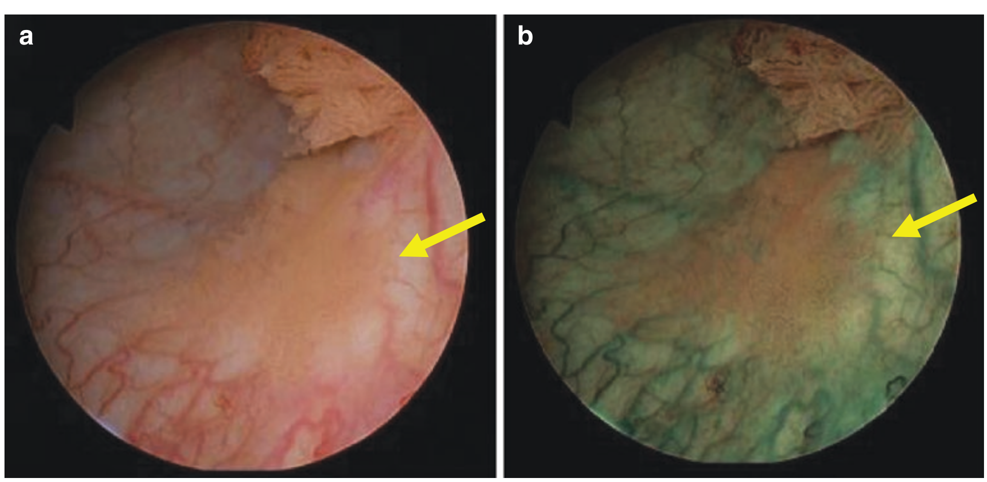


**Fig. 33.2** Papillary, pT1, high grade urothelial carcinoma with CIS. (**a**) WL view. (**b**) NBI view. CIS lesion is more clearly identified by enhanced contrast

NBI cystoscopy was significantly higher than that by WL cystoscopy (rate difference 11%; 95%CI 1–21%; p = 0.03). Tatsugami et al. (2010) emphasized that NBI cystoscopy can be valuable for excluding a diagnosis of NMIBC including CIS because of its high sensitivity, high negative predictive value and low negative likelihood ratio.

One of the concerns of NBI cystoscopy may be a possible higher false-positive rate compared to WL cystoscopy, which may lead to an increased number of unnecessary negative biopsies. Actually, Cauberg et al. (2010) reported a significantly higher tumor-level false positive rate of NBI cystoscopy as compared to WL cystoscopy. However, other authors (Herr and Donat 2008; Tatsugami et al. 2010; Geavlete et al. 2012; Chen et al. 2013; Ye et al. 2015) reported that there was no significant difference in false-positive rates between NBI cystoscopy and WL cystoscopy at patient-level and/or tumor-level (Table 33.2). Furthermore, Li et al. (2013) also showed in his meta-analysis that the tumor level false positive rate of NBI cystoscopy is slightly higher but not significantly different from that of WL cystoscopy.

As to the learning curve of NBI cystoscopy, Herr et al. (2009) evaluated 50 patients subjected to WL cystoscopy and NBI cystoscopy for recurrent bladder tumors. Cystoscopy images in each patient were independently viewed by three experienced urologists and one novice assessing the presence or absence of tumors. As a result, there were no significant differences among urologists in detecting recurrent tumors or in determining the final pathology. Bryan et al. (2010) also investigated whether a new user of NBI cystoscopy, previously unfamiliar with this technique, could reproduce the previous results of an experienced user. They found no significant differences in the excess number of tumors detected by NBI cystoscopy between new users and experienced users.

Thus, NBI cystoscopy can detect NMIBC including CIS more precisely than WL cystoscopy both at patient-level and tumor-level. NBI cystoscopy can be performed without any dyes, which are essential in PDD, and requires a minimal learning curve for its adaptation.

**Table 33.1** Diagnostic accuracy

| (a) Overall detection rate | | | | | | |
|---|---|---|---|---|---|---|
| Authors | Tumor-level detection rate | | | Patient-level detection rate | | |
| | NBI | WLI | p vale | NBI | WLI | p value |
| Herr and Donat (2008) | – | – | – | 100 | 87.4 | 0.05 |
| Cauberg et al. (2010) | 94.7 | 79.2 | <0.001 | 95.9 | 84.9 | – |
| Tatsugami et al. (2010) | 92.7 | 57.3 | <0.01 | – | – | – |
| Geavlete et al. (2012) | 94.8 | 83.9 | <0.0001 | 96.2 | 87.2 | 0.007 |
| Chen et al. (2013) | 96.8 | 79.3 | <0.001 | 97.9 | 88.8 | 0.002 |
| Ye et al. (2015) | 98.8 | 75.5 | <0.0001 | 97.7 | 66.7 | <0.0001 |
| (b) Overall false-positive rate | | | | | | |
| Authors | Tumor-level false-positive rate | | | Patient-level false-positive rate | | |
| | NBI | WLI | p value | NBI | WLI | p value |
| Herr and Donat (2008) | – | – | – | 36.4 | 33.8 | NS |
| Cauberg et al. (2010) | 31.6 | 24.5 | <0.001 | 23.1 | 19 | – |
| Tatsugami et al. (2010) | 36.7 | 30.8 | NS | – | – | – |
| Geavlete et al. (2012) | 13.6 | 11.5 | 0.208 | – | – | – |
| Chen et al. (2013) | – | – | – | 21.8 | 29.1 | 0.12 |
| Ye et al. (2015) | 39.1 | 41.4 | 0.7076 | 50 | 75 | 0.1441 |

## 33.4 Technical Points of NBI-Assisted TURBT

First, the whole bladder wall should be observed carefully with WL cystoscopy and then NBI cystoscopy. The surgeon can switch back and forth between WL and NBI mode by simply pushing a button on a digital flexible cystoscope or camera head attached to the resectoscope. Abnormal-looking mucosa like CIS, which is identified under only NBI cystoscopy, is marked by coagulating the surrounding normal mucosa. Since the bandwidth of the spectral transmittance is narrowed, illumination of NBI is reduced compared to that of WL. Bleeding during a biopsy or resection may decrease the visibility of such target lesions. Therefore, proper maintenance of the resectoscope and light cable is essential for an appropriate biopsy or resection with a good view, and such marking may be helpful to perform a correct target biopsy or subsequent resection. TUR of bladder tumors (TURBT) can

**Table 33.2** Detection rate of CIS

| | Tumor-level detection rate (CIS) | | | Patient-level detection rate (CIS) | | |
|---|---|---|---|---|---|---|
| Authors | NBI | WLI | p value | NBI | WLI | p value |
| Herr and Donat (2008) | – | – | – | 100 | 83 | 0.01 |
| Tatsugami et al. (2010) | 89.7 | 50 | <0.01 | – | – | – |
| Geavlete et al. (2012) | 95.2 | 61.9 | 0.001 | 100 | 66.7 | 0.026 |

be done either under WL or NBI. After completing the biopsy and resection of the tumor, the whole bladder wall should be observed again to confirm the small tumors have not been missed.

## 33.5 Tumor Recurrence After NBI-Assisted TURBT

Since NBI cystoscopy can improve the detection rate of bladder tumors, NBI was expected to reduce the recurrence after TURBT by removing cancers overlooked by WL cystoscopy. Herr and Donat (2010) followed a group of 126 patients with recurrent low-grade bladder tumors treated by fulguration using WL cystoscopy for the first 3 years, and then using NBI cystoscopy for the following 3 years. As a result, NBI cystoscopy was associated with fewer tumor recurrences (94% vs. 62%), fewer mean numbers of recurrent tumors (5.2 vs. 2.8), and longer recurrence-free survival times (13 vs. 29 months, p = 0.001). Cauberg et al. (2011) investigated whether NBI-assisted TUR for NMIBC significantly decreases the residual tumor rate when compared to a matched cohort of WL-assisted TUR, and reported that residual tumor rate was 30.5% in patients treated by WL-assisted TUR and 15.0% in those treated by NBI-assisted TUR (p = 0.04). They concluded that NBI-assisted TUR decreased the residual tumor rate significantly when compared to a matched cohort of WL-assisted TUR. To date, a few randomized studies have been conducted to confirm the benefit of NBI on recurrences after TURBT (Naselli et al. 2012; Naito et al. 2016). Naselli et al. (2012) conducted a randomized prospective trial to assess the impact of NBI-assisted TUR on NMIBC recurrences. A total of 188 patients with NMIBC were randomized to an NBI-assisted TURBT group and WL-assisted TURBT group. The 1-year recurrence-risk was 32.9% in the NBI group and 51.4% in the WL group (OR = 0.62; p = 0.0141). They concluded that NBI can reduce the recurrence risk of NMIBC by at least 10% at 1 year after TUR. As one of the projects of The Clinical Research Office of the Endourological Society (CROES), Naito et al. (2016) conducted a prospective randomized single-blind multicenter trial of NBI-assisted TURBT versus conventional WL-assisted TURBT in primary NMIBC patients. Of the 965 patients enrolled in the study, 481 patients underwent WL-assisted TURBT and 484 patients received NBI-assisted TURBT. Unfortunately, there was no significant difference in overall recurrence rates after TURBT at one year follow-up between the treatment groups: 27.1% in WL-assisted TURBT group and 25.4% in NBI-assisted TURBT group (p = 0.585). However, NBI-assisted TURBT significantly reduced disease recurrences in low-risk patients (pTa, grade 1, <30 mm, and no CIS): 27.3% in WL-assisted TURBT group and 5.6% in NBI-assisted TURBT group (p = 0.002). Although NBI-assisted TURBT took longer as compared to WL-assisted TURBT (38.1 vs 35.0 min, p = 0.039), lesions were significantly more often visible with NBI than with WL (p = 0.033). Intravesical recurrence after TURBT is considered to be caused not only by development of overlooked small tumors but also by regrowth of high-grade tumor cells disseminated during TURBT. NBI may be able to decrease recurrence rates by more precise detection and resection of small tumors in low risk patients, but it is unlikely to prevent regrowth of disseminated high-grade tumor cells. The frequency and severity of adverse events were similar in both treatment groups. Although there are several limitations in this study, such as a lack of uniformity of surgical resections, data on smoking status, central pathology reviews and specific data regarding adjuvant intravesical instillation therapy, the results of this study suggest that use of the NBI technique might provide greater detection of bladder tumors and that subsequent treatment leads to reduced recurrence in low-risk patients. Since small low-grade NMIBC may pose little or no risk of progression to life-threatening disease, early detection and treatment of such tumors may have little value. However, adverse events caused by biopsies are few to none, and improved early detection and subsequent early treatment may reduce the overall number of procedures, both cystoscopy for follow-up and TURBT, in the lifetime, consequently improving the quality of life and reducing the overall cost of surveillance. According to this report, AUA/SUO Joint guidelines 2016 stated that, in patients with NMIBC, a clinician may consider use of NBI to increase detection and decrease recurrence (Conditional Recommendation, Grade C). A prolonged follow-up study up to 3 years after TUR is now ongoing.

## 33.6 Conclusions

NBI is a promising technology that facilitates the diagnosis and treatment of NMIBC. NBI is integrated in a flexible cystoscope or resectoscope and does not require any medication. Therefore, NBI can be used easily and safely in an outpatient clinic for cystoscopy, and in an operating room for TUR. NBI increases the detection of bladder tumors including CIS without any significant increase in false-positive rates that would lead to unnecessary negative biopsies. NBI also may improve the quality of TUR and consequently reduce the subsequent tumor recurrence particularly in low-risk patients.

## References

Bryan RT, Billingham LJ, Wallacet MA. Narrow-band imaging flexible cystoscopy in the detection of recurrent urothelial cancer of the bladder. BJU Int. 2007;191:702–6.

Bryan RT, Shah ZH, Collins SI, et al. Narrowband imaging flexible cystoscopy: a new user's experience. J Endourol. 2010;24:1339–43.

Burger M, Catto JW, Dalbagni G, et al. Epidemiology and risk factors of urothelial bladder cancer. Eur Urol. 2013;63:234–41.

Cauberg ECC, Kloen S, Visser M, et al. Narrow band imaging cystoscopy improves the detection of non-muscle-invasive bladder cancer. Urology. 2010;76:658–63.

Cauberg ECC, Mamoulakis C, de la Rosette JJMCH, et al. Narrow band imaging-assisted transurethral resection for non-muscle invasive bladder cancer significantly reduces residual tumor rate. World J Urol. 2011;29:503–9.

Chen G, Wang B, Li H, et al. Applying narrow-band imaging in complement with white-light imaging cystoscopy in the detection of urothelial carcinoma of the bladder. Urol Oncol. 2013;31:475–9.

Ferlay J, Soerjomataram I, Dikshit R, et al. GLOBOCAN 2012 v.1.0, estimated cancer incidence, mortality and prevalence worldwide in 2012. Lyon: International Agency for Research on Cancer; 2013.

Geavlete B, Jecu M, Multescu R, et al. Narrow-band imaging cystoscopy in non-muscle-invasive bladder cancer: a prospective comparison to the standard approach. Ther Adv Urol. 2012;4:211–7.

Herr HW, Donat SM. A comparison of white-light cystoscopy and narrow-band imaging cystoscopy to detect bladder tumour recurrences. BJU Int. 2008;102:1111–4.

Herr HW, Donat SM. Reduced bladder tumor recurrence rate associated with narrow-band imaging surveillance cystectomy. BJU Int. 2010;107:396–8.

Herr H, Donat M, Dalbagni G, et al. Narrow-band imaging cystoscopy to evaluate bladder tumours—individual surgeon variability. BJU Int. 2009;106:53–5.

Li K, Lin T, Fan X, et al. Diagnosis of narrow-band imaging in non-muscle-invasive bladder cancer: a systematic review and meta-analysis. Int J Urol. 2013;20:602–9.

Naito S, Algaba F, Babjuk M, et al. The clinical research office of endourological society (CROES) multicentre randomized trial of narrow band imaging-assisted transurethral resection of bladder tumor (TURBT) versus conventional white light imaging-assisted TURBT in primary non-muscle-invasive bladder cancer patients: trial protocol and 1-year results. Eur Urol. 2016;70:506–15.

Naselli A, Introini C, Timossi L, et al. A randomized prospective trial to assess the impact of transurethral resection in narrow band imaging modality on non-muscle-invasive bladder cancer recurrence. Eur Urol. 2012;61:908–13.

Sylvester RJ, van der Meiden APM, Oosterlinck W, et al. Predicting recurrence and progression in individual patients with stage Ta T1 bladder cancer using EORTC risk tables: a combined analysis of 2596 patients from seven EORTC trials. Eur Urol. 2006;49(3):466–77.

Tatsugami K, Kuroiwa K, Kamoto T, et al. Evaluation of narrow-band imaging as a complementary method for the detection of bladder cancer. J Endourol. 2010;24:1807–11.

Ye Z, Hu J, Song X, et al. A comparison of NBI and WLI cystoscopy in detecting non-muscle-invasive bladder cancer: a prospective, randomized and multi-center study. Sci Rep. 2015;5:10905.

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# Renal Access for PCNL: The Smaller the Better?

34

Bum Soo Kim and Hyuk Jin Cho

**Abstract**

Although percutaneous nephrolithotomy (PCNL) has been considered as the gold standard for management of large renal stones, several issues such as severe complications and morbidity associated with renal access remain a matter of debate. To overcome these issues, many urologists investigated the risk factors of high morbidity and hypothesized that large tract size for renal access can be one of the major factors related to significant complications. Hence, there have been many endeavors and investigations to reduce the size of renal access tracts and to confirm the effectiveness and safety of smaller tract size for PCNL. Currently, miniaturized PCNL using a smaller nephrostomy tract for renal access has gained wide acceptance for the surgical treatment of small- or medium-sized renal stones; however, the efficacy of mini-PCNL is still controversial. In this chapter, we will review the recent literature related to miniaturized PCNL, such as mini-, ultramini-, and micro-PCNL, and discuss the practical advantages and drawbacks of these procedures compared to those of conventional PCNL.

**Keywords**

Percutaneous nephrolithotomy · Kidney stone · Mini-PCNL · Renal access · Bleeding

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## 34.1 Introduction

Nephrolithiasis is considered an important issue of general health and quality of life, and its overall incidence has increased over the years (Hesse et al. 2003). Percutaneous nephrolithotomy (PCNL) has become a standard procedure for management of large renal stones. Meanwhile, there are several options for smaller stones, such as extracorporeal shock wave lithotripsy (ESWL) and retrograde intrarenal surgery (RIRS) using a flexible ureteroscope, as well as PCNL. With the development of the flexible ureteroscope and lithotripters, most small- or medium-sized renal stones can be effectively managed with RIRS. However, there are still cases for which successful treatment with RIRS is difficult, such as nephrolithiasis of infants, some diverticular stones, and deep calyceal stones with a steep infundibular angle. For these cases, PCNL can be an option, but many urologists still hesitate to perform PCNL due to its associated high morbidity.

During the past two decades, nephroscopes and instruments have been miniaturized in an effort to decrease morbidity associated with PCNL. PCNL using smaller instruments, so-called mini-PCNL or mini-perc, was initially performed in 1997 for the management of pediatric nephrolithiasis (Jackman et al. 1998; Helal et al. 1997). Although there are still no absolute definitions, miniaturized PCNL can be categorized into mini-PCNL (14–22 Fr), ultramini-PCNL (11–13 Fr), and micro-PCNL (4.8–10 Fr), according to the nephrostomy tract size (Desai and Solanki 2013; Desai et al. 2011). It has been reported that nephrostomy tract size is one of the main factors affecting the occurrence of complications (Kukreja et al. 2004). Meanwhile, smaller nephrostomy tract size may negatively affect other procedure-related factors, such as surgical duration and stone-free rate (Giusti et al. 2007). We reviewed recent studies related to miniaturized PCNL to evaluate the advantages and drawbacks of smaller nephrostomy tract size for the treatment of renal stones and have discussed the benefits and harms of miniaturized renal access tracts.


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## 34.2 How to Achieve Renal Access for PCNL

For safe and successful PCNL, proper renal access is one of the most important steps. Fluoroscopic-guided renal access is the traditional approach and has been most commonly performed. However, this approach has several disadvantages, such as increased radiation exposure time for the surgeons and higher risk of possible iatrogenic visceral injury. In addition, if the larger bore for a nephrostomy tract is used, the complications can be more fatal. Moreover, it is difficult to apply this technique to patients with urinary diversions or a transplanted kidney due to the difficulty of retrograde ureteral catheter placement. To overcome these drawbacks of fluoroscopic-guided renal access, alternative techniques, such as ultrasound-guided, computed tomography (CT)-guided, and magnetic resonance imaging (MRI)-guided access, have been tried (Basiri et al. 2008; Ghani et al. 2009; Hagspiel et al. 1998; Hosseini et al. 2009; Karami et al. 2009; Matlaga et al. 2003; Kariniemi et al. 2009) Although several studies have reported satisfactory outcomes and fewer complications with ultrasound-, CT-, and MRI-guided access compared with that of fluoroscopic-guided access, each modality has its limitations. Ultrasound-guided access is operator-dependent and has limited ability to delineate fine details of renal anatomy, especially in obese patients or in patients without definite hydronephrosis (Park and Pearle 2006). CT-guided access is associated with concerns related to ionizing radiation exposure, and MRI-guided access involves the difficulty of visualizing the motion of fine instruments, such as a guidewire. Moreover, both techniques require specially designed equipment for their performance, which can be an obstacle to widespread use of these modalities. To treat nephrolithiasis, many urologists perform renal access with a combined approach using ultrasound and fluoroscopic guidance simultaneously. With fluoroscopic guidance, a targeted calyx can be easily pointed out, and then renal access can be achieved by using ultrasound guidance, resulting in less radiation exposure and reducing the risk of perirenal organ injury.

The development of endoscopy and optical puncture systems has introduced modified renal access techniques. Retrograde access was attempted using a steerable catheter and directing it into the desired calyx in a retrograde fashion, and then advancing a puncture wire out through the catheter to the skin (Lawson et al. 1983; Hunter et al. 1983). The performance of simultaneous fluoroscopic- and retrograde ureteroscopic-guided renal access was also endeavored (Grasso et al. 1995; Kidd and Conlin 2003). In addition, direct renal access using an optical puncture needle called an "all-seeing needle," which motivated the invention of micro-PCNL, was successfully performed (Bader et al. 2011).

## 34.3 Why Do We Need Miniaturized PCNL?

Since Helal et al. performed the first mini-PCNL using an 11 Fr peel-away sheath in 1997 (Helal et al. 1997), we have seen a paradigm shift from conventional PCNL to miniaturized PCNL with a nephrostomy tract size as small as 4.8 Fr. Although PCNL is a minimally invasive procedure with regards to the skin, it is invasive with regards to the kidney and has a risk of various complications. The overall complication rate of PCNL is reported to be 26% (Lang 1987), and it is known to be closely correlated with the surgeon's experience; it decreases from 61% to 3.7% with an increase in the level of surgical experience (Duvdevani et al. 2007). Bleeding is one of the most common and fatal complications of PCNL. Although general transfusion rates after PCNL have been reported as less than 1% (Lang 1987; Duvdevani et al. 2007), the initial series of PCNL outcomes reported an incidence of approximately 11% for postoperative transfusions (Lee et al. 1987). Thoracic complications such as pneumothorax, hydrothorax, hemothorax, and nephropleural fistula, also can occur after PCNL, and the incidence of these complications ranges from 0% to 18%. In particular, the supracostal approach for upper pole renal access is associated with a higher risk of thoracic complications than subcostal puncture (Radecka et al. 2003). Although it is rare, colonic perforation is a possible complication of PCNL, which has been reported in about 1% of cases (Lee et al. 1987).

Several studies demonstrated that the use of a small nephrostomy tract can cause less damage to the kidney, resulting in less hemorrhage and less renal impairment. A small nephrostomy tract also can be correlated with less postoperative patient discomfort. Karakose et al. reported that the use of a small-sized Amplatz sheath significantly decreased the nephrostomy tube size, blood loss, nephrostomy indwelling time, and hospital stay by comparing five groups based on Amplatz sheath size (22, 24, 26, 28, and 30 Fr) (Karakose et al. 2013).

Radiation exposure is a great concern for the procedure of renal access. Desai et al. found an inverse relation between nephrostomy sheath size and radiation exposure time (Desai and Ganpule 2017). In this study, the mean radiation exposure to the surgeon was 0.29 ± 0.12 millisievert (mSv), 0.18 ± 0.1 mSv, 0.16 ± 0.08 mSv, and 0.11 ± 0.04 mSv for the standard PCNL, mini-PCNL, ultramini-PCNL, and micro-PCNL, respectively. These results suggest that smaller nephrostomy tract sizes have a potential to reduce radiation exposure time, although it was not statistically validated.

There is no debate that PCNL is the gold standard modality for management of staghorn renal calculi or large kidney stones (>2 cm). For small- (<1 cm) or medium-sized (1–2 cm) stones, ESWL is the most minimally invasive treatment modality and can be a first-line option if only there are no unfavorable factors, such as shockwave-resistant stones, steep infundibular-pelvic angle, long lower pole calyx, or narrow infundibulum. Meanwhile, for the ESWL-unfavorable medium- or small-sized renal stones (<2 cm), RIRS can be the first choice in most cases. Although new-generation flexible ureteroscopy can provide access to most calyces and effectively remove most calyceal stones, some renal calculi cannot be completely removed by RIRS, which include nephrolithiasis of infants, some diverticular stones, and deep calyceal stones with a steep infundibular-pelvic angle. In addition, the stones in a patient who cannot undergo a retrograde approach due to uncorrectable ureteral stricture, reimplanted ureter, or urinary diversion, cannot be successfully managed with RIRS. In these situations, PCNL can be an alternative, but many urologists still think PCNL is an excessive treatment for small-sized stones, and thus they hesitate to perform PCNL due to its high risk of morbidity. However, mini-PCNL can be a good option, with lower morbidity and high efficacy.

Several studies demonstrated that miniaturized PCNL is as effective and safe as conventional PCNL with tolerable complications (Ruhayel et al. 2017). Generally, stones less than 2 cm in size within a complex collecting system or lower pole, or diverticular stones are considered the best indications for mini-PCNL, but there is no consensus for absolute indications and no credible data to support an upper limit for stone size.

## 34.4 Pros and Cons of Miniaturized PCNL

Proponents of the miniaturized PCNL mention reduced blood loss, decreased postoperative pain and limited hospital stay. The major disadvantage of procedures using small instruments include the limited irrigation flow and more extensive stone fragmentation to fit through a reduced-size sheath leading to prolonged operative times. Although based on the assumption of lower morbidity from reduction in diameter of the tract and less renal trauma, controversy still exists on whether miniaturization leads to such a benefit. There have been several studies to compare the efficacy and safety between miniaturized PCNL and conventional PCNL. Of these studies, randomized controlled trials were performed in two studies (Cheng et al. 2010; Tepeler et al. 2014). Cheng et al. compared the perioperative outcomes of mini-PCNL using tract size 16 Fr with conventional PCNL (24 Fr) (Cheng et al. 2010). In their study, blood loss and transfusion rates were significantly lower in the mini-PCNL group, although the types of stone were not comparable. Hospital stay, postoperative pain, dose of postoperative analgesics, and ratio of positive fever were comparable between the two groups. The stone-free rates of the staghorn stone and the simple renal pelvis stone were also similar, whereas the mini-PCNL group achieved a significantly higher stone-free rate for multiple calyceal stones (85.2%) than the conventional PCNL group (70.0%). The surgical duration was significantly longer in the mini-PCNL group for all stone types. Additionally, Tepeler et al. compared intrarenal pelvic pressure as well as perioperative outcomes between micro-PCNL (4.8 Fr) using an all-seeing needle and conventional PCNL (30 Fr) (Tepeler et al. 2014). This study showed that the surgical duration and hospital stay were significantly longer in the conventional PCNL group. Stone-free and complication rates were comparable between both groups. Although blood loss was significantly lower, intrarenal pelvic pressure was significantly higher in the micro-PCNL group.

Additionally, several nonrandomized comparative studies have been conducted, which compared perioperative outcomes between mini-PCNL and conventional PCNL (Knoll et al. 2010; Mishra et al. 2011; Xu et al. 2014; Yamaguchi et al. 2011). Yamaguchi et al. analyzed the PCNL global study database of the Clinical Research Office of the Endourological Society (CROES), and divided the patients into four groups (≤18, 24–26, 27–30, and ≥32 Fr) according to the nephrostomy tract size. They reported that blood loss and transfusion rates significantly increased with tract size (Yamaguchi et al. 2011). Mishra et al. compared the outcomes of mini-PCNL (15–20 Fr) with those of conventional PCNL (24–30 Fr) for the treatment of 1–2 cm-sized renal stones (Mishra et al. 2011). Although it is a limitation that they used different energy sources for lithotripsy (holmium laser in the mini-PCNL group and pneumatic lithotripter in the conventional PCNL group), they reported less blood loss, shorter hospital stay, and longer surgical duration in the mini-PCNL group, while stone-free rates and analgesic use were similar in both groups. Xu et al. also reported less blood loss and comparable surgical duration, hospital stay, stone-free and complication rates in the mini-PCNL group compared to those of the conventional PCNL group, although the mean stone size was smaller in the mini-PCNL group (Xu et al. 2014). Giusti et al. observed a smaller hematocrit drop, lower transfusion rate, shorter duration of hospitalization, and similar use of analgesics in the mini-PCNL group, but significantly longer surgical duration and lower stone-free rate were found in the mini-PCNL group than in the conventional PCNL group (Giusti et al. 2007).

Likewise, several studies demonstrated that mini-PCNL has some advantages in terms of less blood loss and comparable stone-free and complication rates compared with that of conventional PCNL. However, there are a few studies that showed no advantages of mini-PCNL in terms of blood loss. Knoll et al. observed similar blood loss, surgical duration, analgesic requirements, stone-free and complication rates between the mini-PCNL and standard PCNL groups; even the mean stone size was significantly larger in the standard PCNL group (Knoll et al. 2010). Nevertheless, there are no reports that mini-PCNL is associated with more blood loss compared to that of conventional PCNL. There have been concerns about poor visibility of mini-PCNL due to the small-sized endoscope and weak irrigation flow, but most urologists who have performed mini-PCNL found almost no differences in visibility between conventional and mini-PCNL.

Miniaturized PCNL may have additional advantages over not only conventional PCNL, but also RIRS, using flexible ureteroscopy. For example, one chief advantage is patient positioning. Currently, PCNL is being performed in a supine or modified supine position at many centers, but less flank exposure and subsequent limited movement of instrumentation are well-known drawbacks of supine PCNL (Liu et al. 2010; Yuan et al. 2016). Miniaturized PCNL also can be performed in the supine and prone positions, and limitation of instrument movement can be theoretically and practically less affected, even in the supine position. Likewise, mini-PCNL can be performed in various positions, even when compared to positioning of RIRS; RIRS typically can only be performed in limited positions, such as the lithotomy or supine positions.

Another advantage of miniaturized PCNL is the straightforward creation of renal access. For conventional PCNL, several steps are required for renal access; even a balloon dilator is used. In contrast, only a single puncture is required for micro-PCNL using an all-seeing needle. In the case of mini- or ultramini-PCNL, fewer steps are required for the creation of a nephrostomy tract, which may induce reduced renal parenchymal damage, radiation exposure, and overall surgical duration. For these reasons, miniaturized PCNL may also be more advantageous than conventional PCNL for single-session cases requiring multiple punctures due to multicalyceal stones.

Many cases require a supracostal puncture technique for effective and successful stone removal, but supracostal renal access and dilatation is more challenging and problematic than that of the subcostal approach. One of the reasons for the difficulty of the supracostal approach is that the diameters of the dilator and nephrostomy sheath are wider than the intercostal space. In this scenario, an Amplatz sheath can be difficult to manage, and even can be bent during surgery. However, miniaturized PCNL requires a much narrower nephrostomy tract and smaller instruments; thus, the nephrostomy sheath can pass through the intercostal space smoothly and can angle downward easily without bending. Therefore, miniaturized PCNL can be considered advantageous for supracostal renal access.

Although many studies showed several advantages of miniaturized PCNL and demonstrated that the use of miniaturized PCNL systems is safe and effective, there are also several disadvantages of miniaturized PCNL. Compared to conventional PCNL, the major disadvantage of miniaturized PCNL is that it requires the fragmentation of stones into smaller pieces so that the stone fragments can be removed through the narrower sheath. It can also cause longer surgical duration, especially for larger stones. To overcome these time-consuming procedures, several surgeons recently used modified Amplatz sheaths, which can be connected to a vacuum suction system, and stone fragments can be simultaneously removed via vacuum suctioning during stone fragmentation (Mager et al. 2016; Nicklas et al. 2015; Nagele and Nicklas 2016).

In terms of renal damage, miniaturized PCNL is generally assumed to be associated with lower morbidity and less renal damage than conventional PCNL because less blood loss has been reported by several studies. However, Li et al. investigated the systemic response to conventional and mini-PCNL by assessing the levels of acute-phase proteins such as tumor necrosis factor-alpha, interleukin-6, interleukin-10, C-reactive protein, and serum amyloid A, and found no significant differences between the two groups (Li et al. 2010). In addition, Traxer et al. compared the extent of renal injury in pigs undergoing 11 or 30 Fr-percutaneous nephrostomy (Traxer et al. 2001). They observed that the mean scar volume and fractional loss of parenchyma was not significantly different between the groups.

Intrarenal pelvic pressure during surgery and hemodynamic, electrolyte, and metabolic changes have been compared between conventional and miniaturized PCNL. Tepeler et al. measured intrarenal pelvic pressure during procedures, comparing conventional and micro-PCNL (Tepeler et al. 2014). Intrarenal pelvic pressure was significantly higher in the micro-PCNL group during all steps of the procedure, although the complication and success rates were not significantly different. The increased intrarenal pelvic pressure may lead to pyelovenous, pyelolymphatic, and pyelotubular backflow, as well as forniceal rupture. Moreover, systemic absorption of bacteria and endotoxins from the irrigation fluid can be a risk factor for postoperative fever and urinary tract infection (Tepeler et al. 2014). Therefore, surgeons should be aware of higher intrarenal pelvic pressure during miniaturized PCNL, and placement of a ureteral catheter intraoperatively can be helpful for the drainage of irrigation fluid and reducing the pressure. Xu et al. compared hemodynamic, electrolyte, and metabolic changes between conventional and mini-PCNL (Xu et al. 2014). In their study, although no significant hemodynamic and electrolyte changes were found in both groups, a trend toward metabolic acidosis was observed as the irrigation time progressed in the mini-PCNL group.

## 34.5 Summary

While the clear indications of miniaturized PCNL are still under investigation, data in literature suggests miniaturized PCNL is as efficacious and safe as conventional PCNL with acceptable complications. Based on current literature and recent experiences, miniaturized PCNL can be used for the removal of renal stones in all calyces accessible to conventional PCNL. The best indications for miniaturized PCNL seem to be small- or medium-sized stones of up to 2 cm, although there is no definite evidence to support the establishment of an upper size limit. In general, patients with small collecting systems and narrow infundibulae may benefit from the use of miniaturized PCNL systems. Moreover, the presence of calyceal diverticular stones can be a good potential indication for miniaturized PCNL. Although it is suitable to perform conventional PCNL using a large- bore Amplatz sheath for larger (>2 cm) or staghorn renal stones, for smaller stones (<2 cm), miniaturized PCNL is associated with a similar stone-free rate when compared to conventional PCNL, with less bleeding, tolerable renal damage, shorter hospital stay, and less postoperative discomfort. Additional advantages of miniaturized PCNL include improved safety with the supracostal puncture approach, excellent access to almost all calyces and the upper ureter, and effective performance in both the supine and prone positions. However, surgeons must always keep in mind possible complications related to higher intrarenal pelvic pressure, as well as the trend towards the development of metabolic acidosis during PCNL using a smaller nephrostomy tract. Moreover, it should be noted that comparison of the miniaturized PCNL with the conventional techniques may be related to biases due to poor quality of evidence with small sample sizes and variable inclusion criteria. Thus, well-designed, randomized, multi-institutional studies are needed before considering them a standardized procedure with potential for replacing conventional PCNL or as an alternative to ESWL or RIRS.

## References


Bader MJ, Gratzke C, Seitz M, et al. The "all-seeing needle": initial results of an optical puncture system confirming access in percutaneous nephrolithotomy. Eur Urol. 2011;59:1054–9.

Basiri A, Ziaee AM, Kianian HR, et al. Ultrasonographic versus fluoroscopic access for percutaneous nephrolithotomy: a randomized clinical trial. J Endourol. 2008;22:281–4.

Cheng F, Yu W, Zhang X, et al. Minimally invasive tract in percutaneous nephrolithotomy for renal stones. J Endourol. 2010;24:1579–82.

Desai MR, Ganpule AP. Miniaturized percutaneous nephrolithotomy: a decade of paradigm shift in percutaneous renal access. Eur Urol. 2017;72(2):236–7.

Desai MR, Sharma R, Mishra S, et al. Single-step percutaneous nephrolithotomy (microperc): the initial clinical report. J Urol. 2011;186:140–5.

Desai J, Solanki R. Ultra-mini percutaneous nephrolithotomy (UMP): one more armamentarium. BJU Int. 2013;112:1046–9.

Duvdevani M, Razvi H, Sofer M, et al. Third prize: contemporary percutaneous nephrolithotripsy: 1585 procedures in 1338 consecutive patients. J Endourol. 2007;21:824–9.

Ghani KR, Patel U, Anson K. Computed tomography for percutaneous renal access. J Endourol. 2009;23:1633–9.

Giusti G, Piccinelli A, Taverna G, et al. Miniperc? No, thank you! Eur Urol. 2007;51:810–4. discussion 815.

Grasso M, Lang G, Taylor FC. Flexible ureteroscopically assisted percutaneous renal access. Tech Urol. 1995;1:39–43.

Hagspiel KD, Kandarpa K, Silverman SG. Interactive MR-guided percutaneous nephrostomy. J Magn Reson Imaging. 1998;8:1319–22.

Helal M, Black T, Lockhart J, et al. The Hickman peel-away sheath: alternative for pediatric percutaneous nephrolithotomy. J Endourol. 1997;11:171–2.

Hesse A, Brandle E, Wilbert D, et al. Study on the prevalence and incidence of urolithiasis in Germany comparing the years 1979 vs. 2000. Eur Urol. 2003;44:709–13.

Hosseini MM, Hassanpour A, Farzan R, et al. Ultrasonography-guided percutaneous nephrolithotomy. J Endourol. 2009;23:603–7.

Hunter PT, Hawkins IF, Finlayson B, et al. Hawkins-Hunter retrograde transcutaneous nephrostomy: a new technique. Urology. 1983;22:583–7.

Jackman SV, Docimo SG, Cadeddu JA, et al. The "mini-perc" technique: a less invasive alternative to percutaneous nephrolithotomy. World J Urol. 1998;16:371–4.

Karakose A, Aydogdu O, Atesci YZ. The use of the amplatz sheath in percutaneous nephrolithotomy: does amplatz sheath size matter? Curr Urol. 2013;7:127–31.

Karami H, Arbab AH, Rezaei A, et al. Percutaneous nephrolithotomy with ultrasonography-guided renal access in the lateral decubitus flank position. J Endourol. 2009;23:33–5.

Kariniemi J, Sequeiros RB, Ojala R, et al. MRI-guided percutaneous nephrostomy: a feasibility study. Eur Radiol. 2009;19:1296–301.

Kidd CF, Conlin MJ. Ureteroscopically assisted percutaneous renal access. Urology. 2003;61:1244–5.

Knoll T, Wezel F, Michel MS, et al. Do patients benefit from miniaturized tubeless percutaneous nephrolithotomy? A comparative prospective study. J Endourol. 2010;24:1075–9.

Kukreja R, Desai M, Patel S, et al. Factors affecting blood loss during percutaneous nephrolithotomy: prospective study. J Endourol. 2004;18:715–22.

Lang EK. Percutaneous nephrostolithotomy and lithotripsy: a multi-institutional survey of complications. Radiology. 1987;162:25–30.

Lawson RK, Murphy JB, Taylor AJ, et al. Retrograde method for percutaneous access to kidney. Urology. 1983;22:580–2.

Lee WJ, Smith AD, Cubelli V, et al. Complications of percutaneous nephrolithotomy. AJR Am J Roentgenol. 1987;148:177–80.

Li LY, Gao X, Yang M, et al. Does a smaller tract in percutaneous nephrolithotomy contribute to less invasiveness? A prospective comparative study. Urology. 2010;75:56–61.

Liu L, Zheng S, Xu Y, et al. Systematic review and meta-analysis of percutaneous nephrolithotomy for patients in the supine versus prone position. J Endourol. 2010;24:1941–6.

Mager R, Balzereit C, Gust K, et al. The hydrodynamic basis of the vacuum cleaner effect in continuous-flow PCNL instruments: an empiric approach and mathematical model. World J Urol. 2016;34:717–24.

Matlaga BR, Shah OD, Zagoria RJ, et al. Computerized tomography guided access for percutaneous nephrostolithotomy. J Urol. 2003;170:45–7.

Mishra S, Sharma R, Garg C, et al. Prospective comparative study of miniperc and standard PNL for treatment of 1 to 2 cm size renal stone. BJU Int. 2011;108:896–9. discussion 899-900.

Nagele U, Nicklas A. Vacuum cleaner effect, purging effect, active and passive wash out: a new terminology in hydrodynamic stone retrival is arising—does it affect our endourologic routine? World J Urol. 2016;34:143–4.

Nicklas AP, Schilling D, Bader MJ, et al. The vacuum cleaner effect in minimally invasive percutaneous nephrolitholapaxy. World J Urol. 2015;33:1847–53.

Park S, Pearle MS. Imaging for percutaneous renal access and management of renal calculi. Urol Clin North Am. 2006;33:353–64.

Radecka E, Brehmer M, Holmgren K, et al. Complications associated with percutaneous nephrolithotripsy: supra- versus subcostal access. A retrospective study. Acta Radiol. 2003;44:447–51.

Ruhayel Y, Tepeler A, Dabestani S, et al. Tract sizes in miniaturized percutaneous nephrolithotomy: a systematic review from the European Association of Urology Urolithiasis Guidelines Panel. Eur Urol. 2017;72(2):220–35.

Tepeler A, Akman T, Silay MS, et al. Comparison of intrarenal pelvic pressure during micro-percutaneous nephrolithotomy and conventional percutaneous nephrolithotomy. Urolithiasis. 2014;42:275–9.

Traxer O, Smith TG 3rd, Pearle MS, et al. Renal parenchymal injury after standard and mini percutaneous nephrostolithotomy. J Urol. 2001;165:1693–5.

Xu S, Shi H, Zhu J, et al. A prospective comparative study of haemodynamic, electrolyte, and metabolic changes during percutaneous nephrolithotomy and minimally invasive percutaneous nephrolithotomy. World J Urol. 2014;32:1275–80.

Yamaguchi A, Skolarikos A, Buchholz NP, et al. Operating times and bleeding complications in percutaneous nephrolithotomy: a comparison of tract dilation methods in 5,537 patients in the Clinical Research Office of the Endourological Society Percutaneous Nephrolithotomy Global Study. J Endourol. 2011;25:933–9.

Yuan D, Liu Y, Rao H, et al. Supine versus prone position in percutaneous nephrolithotomy for kidney calculi: a meta-analysis. J Endourol. 2016;30:754–63.

# Extracorporeal Shock Wave Lithotripsy: What All Urologists Should Know

35

Timothy C. K. Ng and Anthony C. F. Ng

**Abstract**

Despite having been used in urology for more than 30 years, there is continuous modification in the application of extracorporeal shock wave lithotripsy (ESWL) to improve its performance. For machine design, the increase in the understanding of coupling in shock wave transmission has led to the incorporation of semi-water basin or the use of camera to improve coupling during lithotripsy. The increase in usage of computerized tomography for stone diagnosis has also allowed us to collect more stone information, including stone density, skin to stone distance, etc., for the prediction of treatment outcomes. As older patients have poorer treatment outcome, and alternate treatment for senior patients should be consider if there are also other unfavorable factors. The use of better analgesic protocol, slower shock wave delivery rate, careful application of coupling gel, and closer monitoring of treatment with imaging will all contribute to improvement in treatment outcome.

**Keywords**

Extracorporeal shock wave lithotripsy · Urolithiasis Treatment protocol · Outcomes · Complications

Extracorporeal shock wave lithotripsy (ESWL) is the use of focused, high-intensity, external shock wave in fragmentation of urinary calculi into smaller fragments that can be passed spontaneously. The use of this technology in stone management has been more than 30 years. The first successful shock wave treatment of kidney stones in a human using Dornier's Lithotripter HM1 was performed by Professor Christian Chaussy in Munich on February 9, 1980 (Chaussy et al. 1980). Since then ESWL has rapidly become one of the most commonly used treatment approaches for urinary calculi. There were also a lot of changes in the machine design and also treatment protocol to try to further improve the efficiency and safety of ESWL. However, there was a general observation that newer generations of lithotripters had lower treatment successful rate than the first clinical used lithotripter, HM3 (Gerber et al. 2005). Together with the rapid improvement in endoscopic and intracorporeal lithotripsy technologies, there were increasing challenges about the role of ESWL on stone management.

However, the minimal invasiveness of ESWL with reasonable treatment result is still the advantage over other endoscopic treatments. Therefore, in recent years, there were many developments to try to improve the performance of ESWL. In this review, we would like to summarize some of these new developments, in machine design, patient selection, and treatment protocols and hope to help to improve the daily management of our patients.

## 35.1 Machine Design

A lithotripter is composed of four components, a shock wave generator, a focusing system, a coupling mechanism, and a localization system. The shock wave generator was considered as the heart of a lithotripter. Electrohydraulic generator was the first type of shock wave generation technique used (Chaussy et al. 1980). However, the gradual erosion of the spark gap tips of the generator would result in variation in shock wave focus, larger focal zone, and also requirement of regular electrode replacement. Therefore, electromagnetic generator and piezoelectric generator gradually emerged and had largely replaced the former technology. In particular, electromagnetic generator was the most

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commonly used technology in current lithotripters. The advantages of this included consistency of shock wave generated, allowance of fine adjustment of energy levels, smaller focal zone, etc. The provision of smaller focal zone was believed to help decrease potential damage to surrounding tissues due to the larger focal zone generated by electrohydraulic generator. Unfortunately, in recent years, the smaller focal zone of new generation lithotripters was believed to be one of the reasons for the decrease in performance of ESWL (Elmansy and Lingeman 2016). Since renal stone will move during respiration, therefore, targeted stones would easily move out of the small focal zone during treatment, decreasing the overall efficacy (Cleveland et al. 2004). Therefore, currently, there are lithotripters that could provide different focal zone sizes (Elmansy and Lingeman 2016). According to the recommendation, larger focal zone would be used for renal stones, as it is more mobile during treatment, while smaller focal zone would be used for ureteric stones. However, this proposed benefit of focal zone needs prospective studies to confirm.

A shock wave will lose its energy during its passage across media of different densities (impedance). Therefore, we need a good media for the effective transmission of shock wave into the patient's body. Coupling system is the mechanism used for each machine for the transmission of shock wave. In HM3 machine, the patient was put in a large water tank for the coupling of shock wave, which was believed to be the most effective mechanism. However, the use of water tank was inconvenient and may not be suited for all patients. Therefore, currently, most of the machines are using other means for shock wave transmission. Some lithotripters still use a small water basin for the contact between the treatment head (generator) and patients, e.g., Storz SLX-F2 lithotripter. But most of the other lithotripters will use gel, as the media for shock wave transmission. However, air pockets might be trapped within the gel, and these would greatly affect the shock wave transmission (details would be discussed in the later section). Therefore, in new lithotripters, some have incorporated camera system within the generator system for the assessment of the quality of gel application. This would help to improve the coupling effectiveness and help to improve the performance of lithotripsy.

## 35.2 Patient Selection

The initial successfulness of ESWL has made some urologists believe that all stones could be treated by this technology. However, with the increase in understanding the nature of ESWL, we now understand that there are certain limitations for its usage. In general, ESWL is the preferred treatment option for stones smaller than 2 cm (European Association of Urology 2017). As the stone size increases, ESWL success rate decreases. Also for certain hard stone compositions, such as cysteine and calcium oxidate monohydrate, ESWL might not be effective. Therefore, these provided us some selection criteria for choosing ESWL to patients.

Stone location will also affect the treatment outcome. Stones in the upper-pole calyx, renal pelvis, and pelviureteric junction are associated with better stone-free rate. Stones in the lower-pole calyx are associated with lower stone clearance rate (European Association of Urology 2017; Lingeman et al. 1994). There is a number of lower-pole anatomic features that reduce stone passage, including a steep infundibular-pelvic angle, narrow infundibulum, and long infundibular length/calicopelvic height (Ng et al. 2008).

Computerized tomography (CT) is currently the most commonly performed imaging for stone diagnosis and treatment planning. Besides the high accuracy in diagnosis of ureteric stone in patients suffering from ureteric colic, there are many CT parameters that we could measure to help the prediction of ESWL successfulness. Stone volume, mean stone density, and skin-to-stone distance were potential predictors of successful treatment with ESWL (Ng et al. 2009).

Mean stone density, by measuring the average Hounsfield unit of the stone, provided a parameter to assess the density of the targeted stone and is the most consistently positive parameter used for the prediction of treatment outcome (Ng et al. 2009). Pareek and colleagues performed the first study to evaluate skin-to-stone distance as an independent predictor of stone-free rate after ESWL, in 64 patients with 0.5–1.5 cm lower-pole stones (Pareek et al. 2005). The average skin-to-stone distance was calculated by measuring three distances from the center of the stone to the skin (0°, 45°, 90° angles). They have demonstrated that a skin-to-stone distance greater than 10 cm predicted ESWL treatment failure.

Ng et al. studied 94 patients with proximal ureteric stones (Ng et al. 2009). In this study, stone volume less than 0.2 cc, stone density less than 593 Hounsfield unit, and skin-to-stone distance less than 9.2 cm were significant predictors of successful stone passage after ESWL. A scoring system was constructed based on these three factors. The ESWL success rate at 3 months for scores 0, 1, 2, and 3 was 17.9%, 48.4%, 73.3%, and 100%, respectively. Similarly, Tran described a scoring system, Triple D score, which was calculated based on ellipsoid stone volume of less than 150 μl, stone density less than 600 Hounsfield unit, and skin-to-stone distance of less than 12 cm (Tran et al. 2015). The ESWL success rates for Triple D Score of 0, 1, 2, and 3 was 21.4%, 41.3%, 78.7%, and 96.1%, respectively.

Besides stone parameters, patient factor could also affect stone treatment outcome. In a multivariate analysis of 120 patients, with a 0.5–2.5 cm solitary renal stone, El-Nahas and colleagues illustrated that obesity (BMI ≥ 30) and increased stone density (>1000 HU) are significant predictors of failure rate after ESWL (El Nahas et al. 2007).

Interestingly, patient age has been demonstrated to influence stone-free rate after ESWL. Abdel-Khalek's study on 2954 patients and Abe's study on 3023 patients illustrated that age is one of the prognostic factors that determine stone-free rate (Abdel-Khalek et al. 2004; Abe et al. 2005). In a multivariate analysis of 2192 patients, Ng demonstrated that stone clearance after ESWL for renal stones, but not ureteric stones, was significantly lower in older patients age > 60 years (Ng et al. 2007). This might be related to the effectiveness of transmission of shock-wave energy through the renal parenchymal tissue to the targeted stone. A possible explanation he proposed is that aging causes sclerotic changes in the kidney, which affects the acoustic impedance of the kidney. As shock wave did not need to transmit through the renal parenchyma, therefore this aging effect did not affect the treatment outcome of ureteric stones. In order to have further studies on the effect of the renal parenchyma on ESWL outcome, Ng et al. performed another study on 206 patients, with renal stones sized 0.5–2 cm, and concluded that a thinner renal cortex was an unfavorable factor for successful ESWL after adjustment for stone volume, mean stone density, and the shock wave delivery rate (Ng et al. 2015). The thinning of parenchyma was probably related to renal scarring. Therefore, this indirectly supports the effect of renal scarring on the treatment outcome of ESWL.

## 35.3 Treatment Protocol

In the original HM3 machine, patients were put under general anesthesia for ESWL. However, in the later development of ESWL, sedoanalgesic approach, or even analgesics free, was the common pain control practice during ESWL. However, as stone could move up and down for 5 cm during respiration, therefore, the targeted stones could easily fall out of the focal zone of the lithotripters. Cleveland et al. had illustrated that stone motion for 1 cm could already lead to a significant reduction in comminution (Cleveland et al. 2004). If the stones moved for more than 2 cm, 75% of shock wave would be missed during treatment. As patients could have more irregular breathing and movement if they experience pain, therefore, the current pain-relieving protocol might be one of the reasons for the decreased treatment outcome in modern ESWL.

Sorensen had compared the impact of intravenous sedation to general anesthesia on 259 patients, with a single renal or upper ureteric stone of less than 2 cm (Sorensen et al. 2002). He concluded that the stone-free rate was significantly higher in patients who received general anesthesia at 3 months' time (87% vs 55%). Ng performed a retrospective study on 520 patients, with SWL for solitary urinary stone of less than 1 cm, who received either oral analgesic (diclofenac) or intravenous analgesic (alfentanil) in addition to oral analgesic (Ng et al. 2007). The additional use of intravenous analgesic has a significant higher stone-free rate (44.9% vs 38.2%) compared to those with only single dose of oral analgesics at the beginning of ESWL. Therefore, more liberal usage of analgesic would also help to improve the treatment outcome of ESWL.

As discussed in previous sections, many modern lithotripters used the water cushion for the coupling of shock wave into patients. As 99.9% of lithotripter shock waves are reflected in a water-air interface, hence, it is very important to eliminate air between the lithotripter head and the body. Pishchalnikov performed a study to investigate how air pocket at coupling interface can affect the shock wave transmission (Pishchalnikov et al. 2006). He photographed air pockets trapped at the coupling interface between a Dornier DoLi-50 electromagnetic lithotripter and a test tank shielded by a sheet of polyester membrane. LithoClear, a commercial coupling gel, was used as the coupling medium. He demonstrated that the quality of coupling is variable and produced air pockets ranging from 1.5% to 19%, resulting in a mean decrease in shock wave amplitude of around 20%. The presence of only 2% air pockets at the coupling interface can reduce stone fragmentation by 20–40%. De-coupling and re-coupling, which simulates the reposition of a patient, reduce the transmission of acoustic energy by 75%. Neucks has studied further on the effect of gel application on treatment outcome (Neucks et al. 2008). He discovered that the best way was to deliver lithotripsy gel as a bolus from a stock jug onto the lithotripter cushion. The gel was allowed to spread as the cushion automatically inflated. This results in less coupling defects compared to gel application by hand.

Boris performed continuous monitoring of air pockets with a video camera integrated into a DoLi SII lithotripter during SWL (Bohris et al. 2012). He illustrated that at a higher air ratio, there was an increase in number of shock waves needed for complete stone fragmentation. Therefore, continuous monitoring for coupling defects can reduce the number of shock wave applied, energy required, and treatment time and hence improve the SWL outcome. This optical monitoring system was currently incorporated in some newer generation of lithotripters.

The rate of shock wave delivery can also affect the outcome of stone fragmentation. Originally, the rate of shock wave is synchronized with heart rate to prevent ectopic. However, later studies had proved that shock wave-related arrhythmia was clinically insignificant in normal population. Therefore, faster shock wave delivery rate, typically 2 Hz, was used to shorten the treatment time for the patient. Unfortunately, in recent years, many studies observed that a faster shock wave delivery rate actually would decrease the treatment effectiveness. In a meta-analysis of nine studies including 1572 patients, who had different frequencies (60, 90, and 120 shock waves per minute) of shock wave lithotripsy, Li reported that the overall success rate was significantly lower in patients who received high frequency (120 vs 90 and 120 vs 60) (Li et al. 2013). He demonstrated that reducing the frequency from 120 to 60 shock waves per minute increased the overall success rate for stones greater than 1 cm. However, this would also lengthen the treatment duration. Success rate for stones smaller than 1 cm had no significant difference among patients with different shock wave frequencies. A frequency of 120 shock waves per minute was suggested for stones less than 1 cm, as treatment duration would be reduced as well.

Ng et al. performed a prospective randomized study on 206 patients, with unilateral renal stones, who received shock waves delivered at 60 or 120 shocks per minute (Ng et al. 2012). They concluded that slower shock wave frequency results in better treatment outcome in patients with stones greater than 1 cm. However, he also demonstrated that at a slower shock wave delivery, there was a statistically significant increase in acute kidney injury markers. The clinical implication of such an increase in urinary markers was yet to be defined.

Logarakis compared the ESWL outcomes by 12 urologists in one shock wave center to determine the inter-operator variation and operator-specific success rates of SWL (Logarakis et al. 2000). In this study, the treatment result of 5769 renal and ureteric stones by Dornier MFL 5000 lithotripter was reviewed. The urologist has more treatment performed, delivered more total number of shocks, had longer fluoroscopy time during treatment, and had higher stone-free and lower re-treatment rate. Therefore, Logarakis et al. demonstrated the importance of completion of full treatment and frequent fluoroscopic guided targeting of stones. The latter point might be particularly relevant in the modern lithotripter, as the focal zone size was narrower than previous machines.

While the use of α(1)-blocker, as medical expulsive therapy, for ureteric stone is still controversial (Hollingsworth et al. 2006; Pickard et al. 2015), there was a meta-analysis of 15 studies, with 1326 patients included, suggesting that patients receiving tamsulosin had a 24% improvement in stone clearance, shorter expulsion time, and lower analgesic requirement, compared to the placebo group (Zheng et al. 2010). Therefore, a short course of alpha-blocker could be prescribed to patients after SWL to renal stones to improve stone fragment clearance.

## References


Abdel-Khalek M, Sheir KZ, Mokhtar AA, Eraky I, Kenawy M, Bazeed M. Prediction of success rate after extracorporeal shock-wave lithotripsy of renal stones—a multivariate analysis model. Scand J Urol Nephrol. 2004;38(2):161–7.

Abe T, Akakura K, Kawaguchi M, Ueda T, Ichikawa T, Ito H, et al. Outcomes of shockwave lithotripsy for upper urinary-tract stones: a large-scale study at a single institution. J Endourol. 2005;19(7):768–73.

Bohris C, Roosen A, Dickmann M, Hocaoglu Y, Sandner S, Bader M, Stief CG, Walther S. Monitoring the coupling of the lithotripter therapy head with skin during routine shock wave lithotripsy with a surveillance camera. J Urol. 2012;187:157–63.

Chaussy C, Brendel W, Schmiedt E. Extracorporeally induced destruction of kidney stones by shock waves. Lancet. 1980;2(8207):1265–8.

Cleveland RO, Anglade R, Babayan RK. Effect of stone motion on in vitro comminution efficiency of Storz Modulith SLX. J Endourol. 2004;18:629–33.

El Nahas AR, El Assmy AM, Mansour O, Sheir KZ. A prospective multivariate analysis of factors predicting stone disintegration by extracorporeal shock wave lithotripsy: the value of high-resolution noncontrast computed tomography. Eur Urol. 2007;51(6):1688–93.

Elmansy HE, Lingeman JE. Recent advances in lithotripsy technology and treatment strategies: a systematic review update. Int J Surg. 2016;36:676–80.

European Association of Urology. Guidelines on urolithiasis. 2017.

Gerber R, Studer UE, Danuser H. Is newer always better? A comparative study of 3 lithotriptor generations. J Urol. 2005;173(6):2013–6.

Hollingsworth JM, Rogers MA, Kaufman SR, et al. Medical therapy to facilitate urinary stone passage: a meta-analysis. Lancet. 2006;368:1171–9.

Li K, Lin T, Zhang C, et al. Optimal frequency of shock wave lithotripsy in urolithiasis treatment: a systematic review and meta-analysis of randomized controlled trials. J Urol. 2013;190:1260–7.

Lingeman JE, Siegel YI, Steele B, Nyhuis AW, Woods JR. Management of lower pole nephrolithiasis: a critical analysis. J Urol. 1994;151(3):663–7.

Logarakis NF, Jewett MA, Luymes J, et al. Variation in clinical outcome following shock wave lithotripsy. J Urol. 2000;163:721–5.

Neucks JS, Pishchalnikov YA, Zancanaro AJ, et al. Improved acoustic coupling for shock wave lithotripsy. Urol Res. 2008;36:61–6.

Ng CF, Lo A, Lee K, Wong KT, Chung WY, Gohel D. A prospective randomized study on the clinical effects of shockwave delivery for unilateral kidney stone: 60 versus 120 shocks per minute. J Urol. 2012;188(3):837–42.

Ng CF, Luke S, Chiu PK, Teoh JY, Wong KT, Hou SS. The effect of renal cortical thickness on the treatment outcomes of kidney stones treated with shockwave lithotripsy. Korean J Urol. 2015;56(5):379–85.

Ng CF, Siu WYD, Wong A, Goggins W, Chan E, Wong 364 KT. Development of a scoring system from non-contrast comput- 365 erized tomogram measurements to improve the selection of upper 366 ureteral stone for extracorporeal shock wave lithotripsy. J Urol. 367 2009;181(3):1151–7.

Ng CF, Thompson T, Tolley DA. Characteristics and treatment outcome of patients requiring additional intravenous analgesia during extracorporeal shockwave lithotripsy with Dornier Compact Delta lithotriptor. Int Urol Nephrol. 2007;39:731–5.

Ng CF, Wong A, Tolley DA. Is extracorporeal shock wave lithotripsy the preferred treatment option for elderly patients with urinary stone? A multivariate analysis of the effect of patient age on treatment outcome. BJU Int. 2007;100:392–5.

Ng CF, Wong A, Tolley DA. Assessment of caliceal pelvic height is an unreliable predictor of outcome following shock wave lithotripsy. J Endourol. 2008;22(7):1409–15.

Pareek G, Hedican SP, Lee FT Jr, Nakada SY. Shock wave lithotripsy success determined by skin-to-stone distance on computed tomography. Urology. 2005;66(5):941–4.

Pickard R, Starr K, MacLennan G, Lam T, Thomas R, Burr J, McPherson G, McDonald A, Anson K, N'Dow J, Burgess N, Clark T, Kilonzo M, Gillies K, Shearer K, Boachie C, Cameron S, Norrie J, McClinton S. Medical expulsive therapy in adults with ureteric colic: a multicentre, randomised, placebo-controlled trial. Lancet. 2015;386(9991):341–9.

Pishchalnikov YA, Neucks JS, VonDerHaar RJ, Pishchalnikova IV, Williams JC Jr, McAteer JA. Air pockets trapped during routine coupling in dry head lithotripsy can significantly decrease the delivery of shock wave energy. J Urol. 2006;176:2706–10.

Sorensen C, Chandhoke P, Moore M, et al. Comparison of intravenous sedation versus general anesthesia on the efficacy of the Doli 50 lithotriptor. JUrol. 2002;168:35–7.

Tran TY, McGillen K, Cone EB, Pareek G. Triple D Score is a reportable predictor of shockwave lithotripsy stone-free rates. J Endourol. 2015;29:226.

Zheng S, Liu LR, Yuan HC, Wei Q. Tamsulosin as adjunctive treatment after shockwave lithotripsy in patients with upper urinary tract stones: a systematic review and meta-analysis. Scand J Urol Nephrol. 2010;44(6):425–32.

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# 36 Endoscopic Management of Renal Stone: Retrograde, Antegrade, and Combined Approaches

Sung Yong Cho, Woo Jin Bang, and Hyung Joon Kim

**Abstract**

Owing to its technical development, tailored management for renal stones has become available to reduce mortality rates and increase surgical outcomes. In the era of flexible ureteroscopic surgery and miniaturized nephroscopy, urologists have embraced expanded minimally invasive options for managing and collecting symptomatic renal stones. The renal and ureteral surgery can be classified into three categories of retrograde, antegrade, and bidirectional approaches to target lesions. In cases that are expected to be difficult with the percutaneous or retrograde approach, a bidirectional approach can be considered according to the status of the targeted lesions.

**Keywords**

Urolithiasis · Urinary calculi · Nephrolithotomy · Percutaneous · Ureteroscopy · Minimally invasive surgical procedures

## 36.1 Introduction

Nephrolithiasis represents an expensive and growing worldwide health burden. The appropriate type of surgery should be chosen based on the patient's status and needs, prioritizing preservation of renal function, patient quality of life, and time required to complete the procedure. Urologists have been performing endourological procedures such as percutaneous nephrolithotomy (PCNL) with 30-Fr large-bore balloon dilatation catheters and ureteroscopic surgery (URS) for a long time. In the era of expended minimal invasive procedures, urologists have embraced alternative options for managing and collecting symptomatic renal stones when noninvasive treatments, such as extracorporeal shock wave lithotripsy (ESWL), are ineffective. These include transurethral lithotripsy, flexible ureteroscopic surgery (fURS), retrograde intrarenal surgery (RIRS), percutaneous antegrade stone surgery, antegrade intrarenal surgery, miniaturized percutaneous nephrolithotomy, and endoscopic combined intrarenal surgery, which can be classified into three categories of retrograde, antegrade, and bidirectional approaches to target lesions (Fig. 36.1).

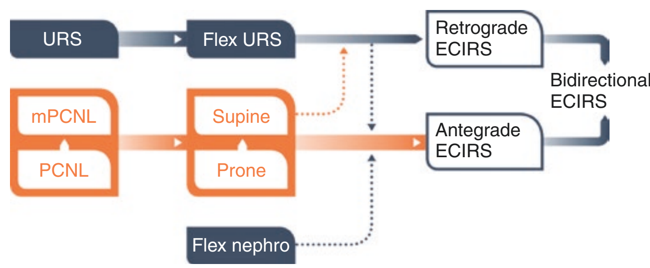


**Fig. 36.1** Paradigm shift of renal and ureteral stone surgery

## 36.2 Indication for Retrograde, Antegrade, and Bidirectional Approaches

In an antegrade approach, a good percutaneous tract must be established. PCNL is a more invasive procedure, it has some undeniable advantages over the retrograde approach, such as shorter distance to the stone and availability of large track sizes (from 8 Fr up to 30 Fr). For these reasons, an antegrade approach remains the gold standard treatment for large renal stones.

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There are ongoing debates on the preferred treatment option for lower calyceal stones, the primary choice would be PCNL when the lower calyx has an acute infundibulopelvic angle or narrow infundibulum. Such conditions may affect the surgical outcome, defined by the stone-free rate, and may also cause more damage to the flexible ureteroscope because of excessive stress on the scope.

The antegrade approach also can be considered when the retrograde approach is not applicable. Specific conditions that preclude a retrograde approach to the renal pelvis are musculoskeletal deformities and congenital/acquired urinary tract abnormities. If the patient cannot be placed in the lithotomy position due to pelvic bone abnormalities or stiffness, the retrograde approach would not be simple. Congenital conditions may include high insertion of the ureter or malrotation of the kidney, as in a horseshoe or pelvic kidney. Acquired conditions include: (1) severe ureteral stenosis caused by either infection or previous ureteral surgeries or (2) alteration in location of the ureteral orifice caused by formation of a neobladder or conduit after radical bladder surgery, antireflux surgery, or kidney transplantation. Preinsertion of a PCN tube to relieve pain or to control infection may affect the approach type as well.

Selection of the combined, bidirectional approach is also a viable option, depends on the location and size of the renal stones.

### 36.2.1 Possible Indications for Surgery with a Retrograde Approach Using fURS

- Renal stone not exceeding 2 cm in maximum diameter
- Combine operation with low/mid ureteral stone
- When patients cannot be in the prone position because of anesthetic considerations (preexisting compromised cardiopulmonary status, morbid obesity, or an impossible prone position because of bone deformities)
- Residual renal pelvic and calyceal stones after ESWL
- Calyceal diverticular stones and nephrocalcinosis
- Not suitable for percutaneous puncture because of coagulopathy or antiplatelet agent use
- Difficulty in performing surgery using an antegrade approach (retroperitoneal colon and huge renal cyst)

### 36.2.2 Possible Indications for Surgery Using an Antegrade

- When the lower calyx has an acute infundibulopelvic angle or narrow infundibulum
- When the retrograde approach is not applicable
- Specific conditions, including musculoskeletal deformities and congenital/acquired urinary tract abnormities
- When the patients cannot be placed in the lithotomy position because of pelvic bone abnormalities or stiffness
- Congenital conditions with high insertion of the ureter
- Malrotation of the kidney, as in a horseshoe or pelvic kidney
- Acquired conditions, including severe ureteral stenosis caused by either infection or previous ureteral surgeries or alteration in location of the ureteral orifice caused by formation of a neobladder or conduit after radical bladder surgery, antireflux surgery, or kidney transplantation
- Preinsertion of a percutaneous nephrostomy (PCN) tube to relieve pain or control infection

### 36.2.3 Possible Indications for Combined Approaches to the Kidney or Ureter

- Staghorn stone
- Large renal and concomitant ureteral stones or strictures
- Ipsilateral medium-to-large renal stones and contralateral small renal stones
- Diverticular stones with a difficult angle to the infundibulum or a narrow infundibulum
- Difficult angle to approach from the calyx of the percutaneous puncture to other calyces to avoid multiple tracts
- Impacted ureteropelvic junction (UPJ) stones with complete obstruction
- Ureteral strictures that need an antegrade incisional procedure

## 36.3 Retrograde Approach

### 36.3.1 Position

A retrograde approach is performed in most URS and RIRS procedures by gaining access through the natural orifice. In most cases, the patient is placed in the lithotomy position, but the supine position may be considered in patients with an ileal conduit along with the percutaneous approach due to technical difficulty in identifying the orifice. Using well-padded stirrups for the lower extremity, limiting the duration of surgery with the patient in the lithotomy position, and repositioning and mobilizing the knees and legs if procedures extend beyond 2 h should be considered to prevent postoperative complications due to the lithotomy position, such as nerve injury and acute compartment syndrome.

### 36.3.2 Advancement Techniques

It is possible to gain access through the ureter by dilating the ureter with a ureteral balloon (12 Fr) or serial dilator in cases of a narrow ureterovesical junction (UVJ) and severely tortuous ureter, which make it difficult to use a rigid ureteroscope or introduce an access sheath. Passive ureteral dilation by ureteral stent insertion only and attempting a delayed consecutive procedure may prevent ureteral injury, reduce operative time, and enhance the stone-free rate. In cases that are expected to be difficult with the retrograde approach, a bidirectional approach can be considered by combining with the antegrade approach.

#### 36.3.2.1 Access Sheath

Using ureteral access sheaths facilitates expeditious and atraumatic entry and re-entry to the upper collecting system with the flexible ureteroscope. Advantages include decreasing intrarenal pressure, enhancing the stone-free rate, and reducing the damage rate of fURS. Because the outer diameter of the access sheath is approximately 9.5–17.5 Fr and is larger than the inner diameter of the ureter, which spans approximately 8 Fr, approximately 50% of the patients experience grades 1–3 injury. However, long-term follow-up results are lacking on what problems these ureteral injuries may cause in the future. The larger the size of the access sheath, the easier it is to irrigate and to remove relatively larger stones using a basket, but the higher the risk of ureteral injury. The 12/14-Fr access sheath was used most widely for adults, but the size recently has become thinner as the flexible ureteroscope has become thinner.

#### 36.3.2.2 Irrigation Method

Most flexible ureteroscopes have a very small internal diameter of 3.6 Fr. When the stone retrieval basket or laser fiber is inserted, the irrigation flow rate is further reduced to approximately 1/4. Therefore, it is better to use a pressure- and/or flow-controlled automated pump, pressure bag, and manual bulb irrigator rather than gravity irrigation to achieve clearer vision. Using the ureteral access sheath, it is possible to maintain intrapelvic pressure below 20 cm$H_2O$ under 200 mmHg pressure with an automated pump, as it allows efflux of irrigant through the sheath and around the ureteroscope (Fig. 36.2).

| | Gravity (mL/min) | 60mL syringe (mL/min) | Roller pump (200mmHg) (mL/min) |
|---|---|---|---|
| Empty channel | 32-35 | 110 | 104 |
| 2.5F instrument | 5-7 | 24-55 | 26 |
| 0.038-inch wire | 2 | 21 | N/A |

**Fig. 36.2** Irrigation flow rates for 3.6-Fr working channels

#### 36.3.2.3 Fragmentation, Dusting, or Pop-Dusting

When removing a renal stone using a flexible ureteroscope, a holmium:YAG laser usually is used as an intracorporeal lithotripter. The laser setting differs in the case of fragmentation and dusting. Holmium:YAG laser energy setting: dusting (0.2–0.6 J; 30–50 Hz), fragmentation (0.8–1.5 J, 5–10 Hz), pop-dusting (0.8–1.5 J, 10–30 Hz). Hounsfield units of the preoperative computed tomography scan can be used to analyze the Stone Heterogeneity Index and other factors to determine the status of stones. The surgeon's preference can be an important factor in performing fragmentation and dusting.

#### 36.3.2.4 Stone Removal Techniques: Lasering, Basketing, and Retrieval

To remove stones, the nitinol tip-less stone basket mainly is used. The stone basket can be used in 1.1–2.4-Fr flexible ureteroscopes, but a small diameter laser fiber is recommended to preserve deflection function of the flexible ureteroscope and smooth irrigation flow. Mostly, 4-wire nitinol tip-less baskets are used and mesh types can be used to remove small fragments.

### 36.3.3 Difficult Situations and Complications

A stone size more than 2 cm, located at the lower calyx, and a steep infundibulopelvic angle may result in a long operation time and low stone-free rate. The complication rates, such as urinary tract infection, can be higher along with the longer operation time. Excessive manipulation of the delicate flexible ureterscope may cause endoscopic damage.

In case of a diverticular stone, access to the dorsal or ventral calyx is difficult, especially in the lower pole. Kidney movement due to respiration can make stone fragmentation retrieveal more difficult. Therefore, collaboration with anesthesiologist is necessary with controlled ventilation. Furthermore, the bidirectional, combined antegrade/retrograde approaches can improve the stone-free rate, reduce postoperative complications, and prevent damage to the flexible scope.

## 36.4 Antegrade Approach

### 36.4.1 Positions: Modified Supine or Prone Position

The prone position was first described in 1976 (Fernstrom and Johansson 1976). It was believed to guarantee a safe way to avoid organ damage. Over the years, the positioning has evolved from a classic prone position without supporting equipment developed into various modifications including the classic prone position with supporting equipment (Papatsoris et al. 2009; Turner et al. 2000; Addla et al. 2008), modified reverse lithotomy (Lehman and Bagley 1988), split-leg prone (Grasso et al. 1993), and prone-flexed positions (Ray et al. 2009). These modifications have created more working space, less interference with nephroscopy movement, and the possibility of performing a combined retrograde approach to the kidney. However, controversy has remained about interference with the patients' respiration and cardiovascular circulation. The patient is padded thoroughly under the thorax to facilitate ventilation to avoid such an event. To situate an open-end or occlusion catheter with the patient in the classic prone position, the patient must be placed in the lithotomy position and then flipped over to prone. With the modified prone position, a flexible cystoscope or ureteroscope can be used to engage the guidewire into the ureter without repositioning the patient.

PCNL in prone position provides a larger field with various access routes and instrument manipulation and easier upper pole access. Drawbacks are a longer operation time due to patient repositioning and higher respiratory/cardiovascular risk compared to the supine position. Access to the upper posterior calyx has been facilitated with the prone position because the medial side is close to the posterior abdominal wall and the nephroscope can pass straight from the upper pole calyx to the ureter. It is especially helpful when the percutaneous antegrade approach is performed to the deep area of the isthmus for patients with horseshoe kidneys. The flexible ureteroscope can be used to approach the stones in the mid or lower pole calyx when we consider the bidirectional combined approach.

In case of morbid obesity patient, PCNL at a lateral position can be considered. It can be feasible because urologists are familiar with this position when laparoscopic renal surgeries are performed. However, this position is not used widely because the fluoroscopy-guided percutaneous access can be challenging. Flexible ureteroscopic procedures can be challenging as well because of the unusual fluoroscopic view of the kidney.

The supine position has been spotlighted because of easier anesthesiologic management, easier patient positioning, low pressure into the collecting system, and an easy antegrade or bidirectional combined approach. Valdivia reported the first percutaneous access to the kidney performed with patients supine, and this position developed into the modified Valvidia (for allowing simultaneous rigid ureteroscopic procedures) (Turner et al. 2000), modified flank roll (Brehmer et al. 2008), Galdakao-modified Valvidia (Scoffone et al. 2008), flank-free supine (with two towels under the shoulder and hip), and Barts flank-free modified (with a saline bag under the rib cage and a gel pad under the pelvis) (Bach et al. 2012) positions. The supine position has been modified to achieve more working space, less stress to the spine, less rotation of the torso, and less mobility of the ipsilateral kidney. Usually, an air bag or saline bag is situated under the lumber fossa to create even more space. To have space for facilitating movement of the nephroscope, the patient's side-end, edge of the bag, and table edge should be in the same line. Advantages of supine PCNL are that it is better tolerated in high-risk patients, especially in elderly, obese patients. For the anesthesiologist, prompt management can be done during unexpected events. One of the most important advantages of the supine position for the surgeon is that the direction of the percutaneous tract would help maintain a low intrarenal pressure and thereby reduce the risk of backflow of the irrigants and allow spontaneous washout of fragmented stones. The disadvantage of supine PCNL would be hyper mobility of the kidney during tract formation and low intrarenal pressure causing less room for the surgery.

### 36.4.2 Puncture Techniques

Puncture is determined by three key factors; "point," "direction," and "depth." These factors are affected by the anatomy of the kidney and location of the stone, but mostly by the position of the patient. In the case of supine PCNL, the point of the puncture is located at two fingerbreadths below the posterior axillary line. The direction of the puncture is parallel or slightly upward to the operation table. Access tracks usually are made at the low- or mid-calyx. In the supine position, approach to the calyx can be achieved by the triangular method. The C-arm is turned 90° to perform accurate puncture (Fig. 36.3).

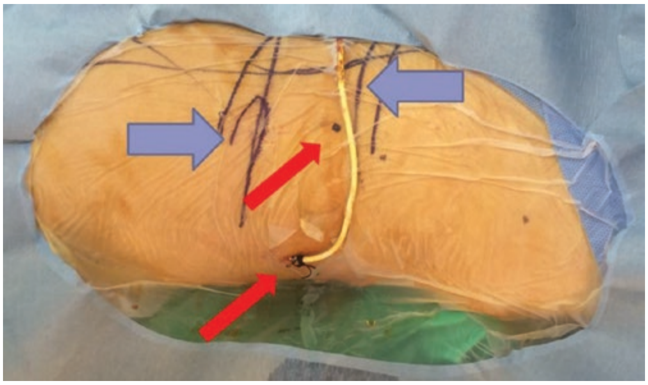

**Fig. 36.3** Differences in percutaneous punctures between supine and prone PCNL

Percutaneous puncture to the kidney can be established under fluoroscopic or ultrasonographic guidance. A recent trend is to use fluoroscopy and ultrasonography in combination for a puncture to take advantage of both techniques. Insertion of an occlusion catheter or open-end catheter before the puncture is required, especially when performing fluoroscopy-guided puncture only. It also would be useful even in ultrasonography-guided puncture by creating hydronephrosis in non-obstructive stone cases.

When using ultrasound, real-time monitoring of the kidney and its surrounding structures is possible avoiding the chance of visceral organ injury. With more experience, the anterior and posterior calyx can be distinguished easily. If the small sized convex probe is available, puncture at the narrow space between the lower margin of the rib and pelvic bone becomes possible. Another advantage of ultrasonographic puncture is that there is no need for radiation or contrast agents.

Fluoroscopy-guided puncture is useful to insert a guidewire through the access needle after ultrasonography-guided puncture or to determine whether the renal collecting system is intact. The target calyx can be approached using either a bull's eye or triangular technique when the patient is in the prone position. The puncture line passes through the posterior abdominal wall and sometimes runs through the sacrospinalis or latissimus dorsi muscle.

### 36.4.3 Advancement Techniques

After successful puncture has been made, it is important not to lose the tract. For initial access via the puncture needle, a floppy-tip nitinol type guidewire is inserted into the needle sheath. For impacted stones, the hairy guidewire can be useful. The guidewire should be changed to a stiffer one before dilating the tract and inserting the access sheath. The safety guidewire is not mandatory but preferred in cases there is a high possibility of losing the tract.

For dilation of the nephrostomy tract, either a serial dilator (fascial dilator system, Amplatz dilator system) or balloon dilator system can be used. Dilation must be performed under fluoroscopic guidance. For a scarred tract caused by previous surgery or infection, the serial dilator may be more beneficial. However, serial dilation relies on guidewire stability. Careful manipulation is mandatory to prevent slippage or buckling of the guidewire. Balloon dilation can be a faster and easier way to form an access tract. One must be sure that the stiff portion of the guidewire is placed beyond the parenchyma and the floppy portion at least is tangled in the calyx/renal pelvis for safe insertion.

### 36.4.4 Classification of PCNL

PCNL can be classified into several types based on the size of the tract: conventional, mini, ultra-mini, super-mini, and more. The size of the tract affects the outcome and complications of the surgery. Larger bore tracts may lead to a better stone-free rate and shorter operation time, but, at the same time, more bleeding and more damage to the nephrons causing potential reduction of renal function. If available, the size of the tract should be selected based on the stone burden, location, and sometimes hardness of the stone. In some cases, an access sheath for retrograde intrarenal stone surgery can be adopted instead to manage renal and ureteral stones at the same time.

### 36.4.5 Visualization and Approach to the Target

In most PCNL cases, a rigid nephroscope is enough to manage renal stones. However, if the stone burden is large, involving multiple calyxes as in staghorn stones, it would be difficult to achieve a stone-free status with the single tract. Excessive torque with the rigid nephroscope may cause massive damage to the kidney. To avoid such complications, performing multiple punctures is an option. If available, a flexible cystonephroscope can be used as well. For currently available flexible cystonephroscopes to pass through the tract, the sheath size must exceed 18-Fr access or a minimally invasive percutaneous large (24–26 Fr) sheath or above should be prepared. In cases with a narrow calyx or infundibulum, fURS also can be combined either from above or below.

### 36.4.6 Fragmentation Methods

Currently, ultrasonic, pneumatic, electrohydraulic, and laser lithotripters are available for intracorporeal lithotripsy. Devices that combine ultrasonic and pneumatic techniques with suction incorporated have been developed and applied at many centers.

Each lithotripsy device has its inherent benefits and limitations to their use. For laser lithotripsy, the holmium:YAG laser is widely accepted. The main advantage of laser lithotripsy includes effective breakage of stones regardless of its composition. The laser also can be used for flexible scopes. Forceful deflection always should be avoided.

### 36.4.7 Techniques: Lasering, Basketing, and Retrieval

When the laser lithotriptor is used, 200–550 nm fibers can be applied depending on the PCNL types. If a flexible nephrocystoscope is used to approach other calyces, 275–365 nm fibers are appropriate. Whether to dust or fragment the stone depends mainly on the tract size and hardness of the stone. In conventional PCNL, the operation time can be reduced by fragmenting the stone into large pieces. If the tract size is small, dusting might be an only option.

Stone baskets or stone forceps are used to retrieve stone fragments. Intrarenal pressure could be used to achieve Hoover lithopaxy (vacuum cleaner effect) especially when supine PCNL is performed due to the direction of the tract.

### 36.4.8 Tubeless vs. Totally Tubeless

Percutaneous nephrostomy catheters (Malecot, pigtail, re-entry catheters) may be left postoperatively when considering staged PCNL or to control tract bleeding. Despite its advantages, patients complain of pain and discomfort. Along with the trend of reducing the tract size, tubeless or totally tubeless PCNL is being performed more often. In most cases, a double-J stent is left in situ by either the antegrade or retrograde approach (tubeless). If there was no bleeding or mucosal injury during operation and a low chance of obstruction by the fragments, even double-J stents are not inserted (totally tubeless).

## 36.5 Combined Approach

### 36.5.1 Optimal Room Set-up

Development of the prone position has focused on more working space, less interference with nephroscopic movement, and the possibility of performing a combined retrograde approach to the kidney. Modification of the supine position has focused on achieving more working space, less stress to the spine, less rotation of the torso, and less mobility of the ipsilateral kidney. Monitors should be located close to the cephalic area to avoid rotation of the torso of the surgeon who performs simultaneous flexible ureteroscopic surgery. Some monitors and the C-arm device should be located in the opposite area of the main surgeon who performs percutaneous surgery. It is desirable that the C-arm device is located in the center of the patient near to the kidney. If the main surgical table is located between the main and second surgeons next to the patient's left leg, both surgeons can share it without difficulty (Fig. 36.4).

### 36.5.2 Puncture Technique

When surgeons consider a combined approach to the target lesion, the guidance for percutaneous puncture can be performed by an occlusion catheter, ureteral catheter, dual-lumen catheter, or flexible ureteroscope. Use of the occlusion catheter is helpful when hydronephrosis is created in the target kidney, the catheter is fixed, and the ureter is obstructed to avoid passage of fragmented small stones, or to differentiate the posterior from the anterior calyx.

Access for percutaneous puncture using an antegrade or retrograde air pyelogram can be acceptable with decreased access time (Jangid et al. 2017). However, the risk of air embolism always should be monitored carefully. Experienced surgeons can perform percutaneous puncture without hydronephrosis in the target kidney and the accurate puncture can be confirmed by indigo carmine- or methylene blue-stained

**Fig. 36.4** (Left) View from the patients' legs. (Right) View from the back of the main operator

saline or contrast dye. fURS can be used as guidance for puncture and the guidewire can be drawn to the ureter by the flexible ureteroscope. This through-and-through technique guarantees the stability of the percutaneous tract.

### 36.5.3 Advancement

The upper pole calyx has been facilitated for the bidirectional approach because the nephroscope can pass straight from the upper pole calyx to the ureter. The mid pole calyx can be used when there is risk of injury in the diaphragm, spleen, or liver during upper pole puncture. However, advancement of the flexible ureteroscope through the mid pole puncture into the level of the mid ureter or below sometimes can be challenging. When a flexible nephroscopic approach to the target lesion is not feasible, the flexible ureteroscope can be used for a simultaneous retrograde approach to the stones in the mid or lower pole calyx.

Surgeons should know the differences of the deflection mechanism between flexible nephroscopes and ureteroscopes. The length of the tip related to deflection is approximately 6 and 15 cm for flexible ureteroscope and nephroscope, respectively. Gentle manipulation is necessary because of the risk of damage to the external surface of the flexible nephroscope when it is used through the percutaneous puncture. The bidirectional approach can be feasible when we guarantee continuous irrigation with the pressure- and flow-controlled automated irrigation device because the intrarenal pressure is low with pressure leakage through the percutaneous tract and resultant collapse of the renal collecting system. The irrigation device is effective to avoid a poor visual field with hematuria as well. Forceful manipulation of flexible nephroscopes or ureteroscopes can cause mucosal injury without appropriate security of the intrarenal space.

When we consider a bidirectional approach for incision of a ureteral stricture, an antegrade approach is recommendable if the stricture segment is longer than 5 mm because a retrograde approach can cause distortion of the distal ureter and the direction can be deviated. A simultaneous retrograde approach has a role of guidance for the antegrade incision to increase accuracy.

### 36.5.4 A Case Study: Difficult Double-J Stenting: A Severely Kinked Ureter and a Hydronephrotic Kidney

A 50-year-old woman presented to my hospital with a diagnosis of a left hydronephrotic kidney. She already underwent a ureteroscopic exam at the regional hospital, which revealed a pathologic lesion in the left ureter, but the physician could not identify anything distal to the severely kinked ureteral site. He could not see the proximal portion. He reported on the referral sheet that there must be obstruction in the left ureter. At presentation to my hospital, I performed PCN first to relieve the hydronephrosis in the left kidney. Then, I decided to perform simultaneous antegrade and retrograde approaches.

There was no obstruction because the blue indigo carmine dye could be seen in the ureter. Instead, a narrowed ureteral lesion was noted at the L3 level on the left side with a severely kinked distal ureter. First, I attempted to insert a double-J catheter via flexible cystoscopy. However, the double-J catheter stuck at the level of the kinked ureter and could not be moved anymore (Fig. 36.5). Then, I attempted an antegrade approach. Using an access sheath and flexible

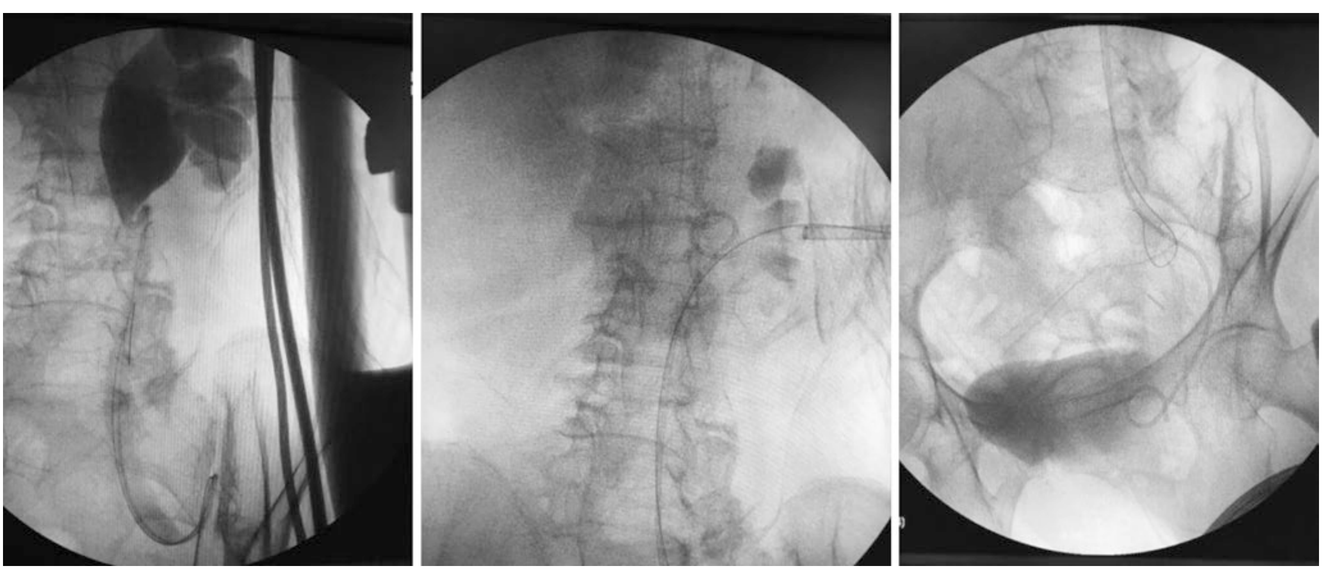

**Fig. 36.5** (Left) Distorted ureter. (Middle) Antegrade approach to draw the double-J catheter. (Right) Straightened ureter with double-J catheter

URS, I pulled the stuck ureter to the renal pelvis with a stone basket.

## 36.6 Summary

Because of its technical development, tailored management for renal stones has become available to reduce mortality rates and increase surgical outcomes. In the era of fURS and miniaturized PCNL, urologists have embraced expanded minimally invasive options to advance urologic health. Three categories of retrograde, antegrade, and bidirectional approaches to target lesions always should be considered in daily practice.

**Remark** Permission is obtained to show the human images in this article according to local regulation.

## References

Addla SK, Rajpal S, Sutcliffe N, et al. A simple aid to improve patient positioning during percutaneous nephrolithotomy. Ann R Coll Surg Engl. 2008;90:433.

Bach C, Goyal A, Kumar P, et al. The Barts 'flank-free' modified supine position for percutaneous nephrolithotomy. Urol Int. 2012;89:365.

Brehmer B, Moll C, Makris A, et al. Endosew: new device for laparoscopic running sutures. J Endourol. 2008;22:307.

Fernstrom I, Johansson B. Percutaneous pyelolithotomy. A new extraction technique. Scand J Urol Nephrol. 1976;10:257.

Grasso M, Nord R, Bagley DH. Prone split leg and flank roll positioning: simultaneous antegrade and retrograde access to the upper urinary tract. J Endourol. 1993;7:307.

Jangid DK, Sharma G, Yadav SS, et al. A comparative study of antegrade air pyelogram and retrograde air pyelogram for initial puncture access during percutaneous nephrolithotomy. J Clin Diagn Res. 2017;11:PC01.

Lehman T, Bagley DH. Reverse lithotomy: modified prone position for simultaneous nephroscopic and ureteroscopic procedures in women. Urology. 1988;32:529.

Papatsoris A, Masood J, El-Husseiny T, et al. Improving patient positioning to reduce complications in prone percutaneous nephrolithotomy. J Endourol. 2009;23:831.

Ray AA, Chung DG, Honey RJ. Percutaneous nephrolithotomy in the prone and prone-flexed positions: anatomic considerations. J Endourol. 2009;23:1607.

Scoffone CM, Cracco CM, Cossu M, et al. Endoscopic combined intrarenal surgery in Galdakao-modified supine Valdivia position: a new standard for percutaneous nephrolithotomy? Eur Urol. 2008;54:1393.

Turner CD, Anderson J, Gerber GS. Improved patient positioning for percutaneous nephroscopic procedures using a surgical saddle. J Urol. 2000;163:199.

# 37 Navigation in Endourology, Ureteroscopy

Kenji Yoshida, Seiji Naito, and Tadashi Matsuda

**Abstract**

Novice urologists sometimes lose their orientation in patients with complicated pyelocaliceal shapes. Controlling a flexible ureteroscope with skill requires a great deal of time and effort and also requires a certain level of expertise. With recent engineering technological advances, there are few reports of real-time navigation system for accurate access to the upper urinary collecting system via percutaneous approach. In this section, we introduce our experimental ureteroscopic navigation system that uses a magnetic tracking device and evaluate the accuracy of ureteroscopic maneuvers in a three-dimensional (3D) pyelocaliceal system model. Our system could help surgeons with different levels to observe all renal papillaethereby by showing surgeons the real-time tip position of ureteroscope on the navigation image. In this section, we introduce our experimental model of ureteroscopic navigation system (ex vivo) using a magnetic tracking device. This concept may lead to increase the detection rate of upper urinary pathologies and the accuracy of surgical procedures. However, there are several challenges to overcome before clinical use, such as adding a built-in magnetic sensor at the tip of the flexible ureteroscope, overcoming pyelocaliceal intraoperative deformation (expansion and contraction) caused during saline irrigation and movements in kidney position with respiration.

**Keywords**

Ureteroscopy · Navigation system · Skill analysis

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## 37.1 Introduction

Flexible ureteroscopes have become an important tool in minimally invasive urological treatment of upper urinary tract pathologies. The active deflection, small outer diameters, large working channels, and high-resolution images (Buscarini and Conlin 2008; Chow et al. 2003; Humphreys et al. 2008) of these scopes permit efficient access and treatment of upper urinary tract pathology. However, novice urologists sometimes lose their orientation in patients with complicated pyelocaliceal shapes. Controlling a flexible ureteroscope with skill requires a great deal of time and effort and also requires a certain level of expertise. Uncertain examination may overlook a pathology that is difficult to identify and lead to suboptimal documentation regarding the position of the pathology.

With recent engineering technological advances, several navigation approaches can be used to help surgeons perform accurate surgical procedures. In urology, image-guided surgery for partial nephrectomy, laparoscopic radical prostatectomy, and prostate biopsy are possible (Hamacher et al. 2016; Hughes-Hallet et al. 2014; Lanchon et al. 2016; Matsuda 2013; Simpfendorfer et al. 2011; Ukimura and Gill 2008; Ukimura et al. 2015a, b). Almost all approaches use preoperative computed tomography (CT) data for augmented reality, which superimposes a reconstructed three-dimensional (3D) image of target organs over the endoscopic image. Although augmented reality, which uses a template of surface reconstructive data, cannot describe depth perception during soft tissue deformation, it can provide accurate information about the current target position and its relationship to the surrounding structures (Simpfendorfer et al. 2016). In contrast, there are few reports of real-time navigation system use in urinary tract surgery. In percutaneous nephrolithotomy, accurate access to the collecting system is very important for a successful operation. Rassweiler et al. (2012) reported that an iPad-assisted puncture system was helpful in decision-making for optimal percutaneous access to the kidney. 3D-augmented reality can display the position of the kidney, stones, and surrounding organs, such as the liver,


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spleen, and colon. This system also can help surgeons determine the best puncture site and to avoid surrounding organ damage. Lima et al. (2017) discussed a ureteroscopic-assisted navigation system for percutaneous kidney puncture using electromagnetic systems in a prospective proof-of-concept phase 1 study. During percutaneous puncture, surgeons viewed a display with a four-view 3D trajectory and position of the needle next to the ureteroendoscopic monitor. This technique had a high success rate (83.3%) for the first attempt. Other systems include a bladder registration and navigation system using infrared cameras for rigid cystoscopic examination (Agenant et al. 2013). The system includes optical markers attached to the external end of a cystoscope and could be helpful for increasing reproducibility and improving documentation for bladder tumor location.

In this section, we introduce our experimental model of ureteroscopic navigation system (ex vivo) that uses a magnetic tracking device and evaluate our system by analyzing evaluate the accuracy of maneuvers in a 3D pyelocaliceal phantom model. We also evaluated the potential for reduced radiation exposure using this navigation system (Yoshida et al. 2014, 2015).

## 37.2 System Overview

### 37.2.1 Ureteroscopic Navigation System (Fig. 37.1a)

#### 37.2.1.1 Phantom Model

Digital Imaging and Communications in Medicine (DICOM) CT data (1 mm slice thickness) obtained from a patient with a normal pyelocaliceal system was used to create a 3D image of a pyelocaliceal system. The phantom with an inner cavity for endoscopy was made from polyvinyl alcohol (JMC Corp., Yokohama, Japan). Fiducial markers were placed at the four corners of the cuboid phantom.

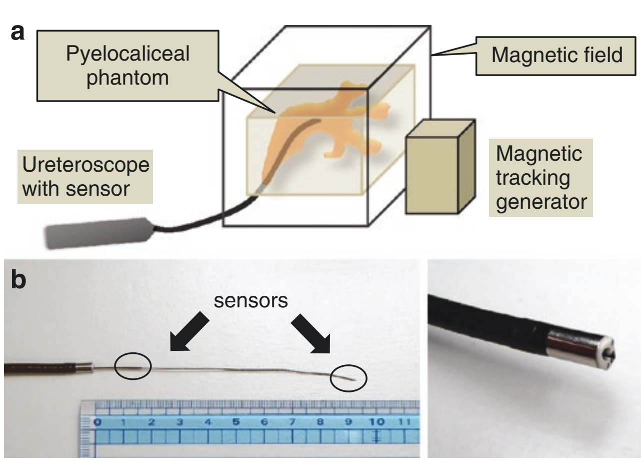


**Fig. 37.1** (**a**) Schema of our ureteroscopic navigation system. (**b**) Two sensors were attached to a cord which passed through the ureteroscope channel. One sensor was located at the tip of ureteroscope and the other was about 8 cm from the tip

### 37.2.2 Position Tracking System (Fig. 37.1b)

A magnetic measurement device (3D-Guidance medSAFE; Ascension Technology Corp., Shelburne, VT) was used to provide a magnetic field. A working volume of a magnetic field is 400 × 400 × 400 mm at a height of 10 cm from the generator. A cord with two magnetic sensors was passed through the ureteroscopic channel (URF Type-V; Olympus, Tokyo, Japan) to track the tip position of the ureteroscope. The pyelocaliceal phantom was placed in the magnetic field.

#### 37.2.2.1 Display of the Navigation Image

The four fiducial markers were placed to align the position of the markers on the 3D image. After calibration and image registration, the tip position of the ureteroscope was superimposed on the pyelocaliceal 3D image. The endoscopic image was displayed next to this 3D navigation image on a single screen (Fig. 37.2a).

A point 8 cm from the of the ureteroscope and the tip position of the ureteroscope were displayed in real time with two dots in yellow on the navigation image, and these two dots were connected by a yellow line to describe the movements of the ureteroscope. Using a foot pedal, the surgeons could view the depth and current tip position of the scope while rotating the 3D navigation image and could also mark the real-time tip position with a blue dot (Fig. 37.2b).

### 37.2.3 Simulated Fluoroscopy (Fig. 37.3)

To measure the time using fluoroscopy during ureteroscopic procedure, we developed a simulated fluoroscopy system by referring to the DICOM CT data. This image included a rib bone, vertebral body, iliac bone, as a C-arm two-dimensional image, and showed the real-time position of the ureteroscope on a second monitor. Injecting the simulated inject contrast medium, the surgeons could confirm the shape of pyelocaliceal system and the tip position of ureteroscope. The simulated contrast image was automatically disappeared after 60 s.

## 37.3 Evaluation of Ureteroscopic Performance

### 37.3.1 Participants and Tasks

Thirty-one urologists were divided into two groups: 15 junior residents (14 men and 1 woman, post-graduate years <10, Group A) and 16 senior residents (all men, post-graduate years ≥10, Group B). Participants were asked to perform two

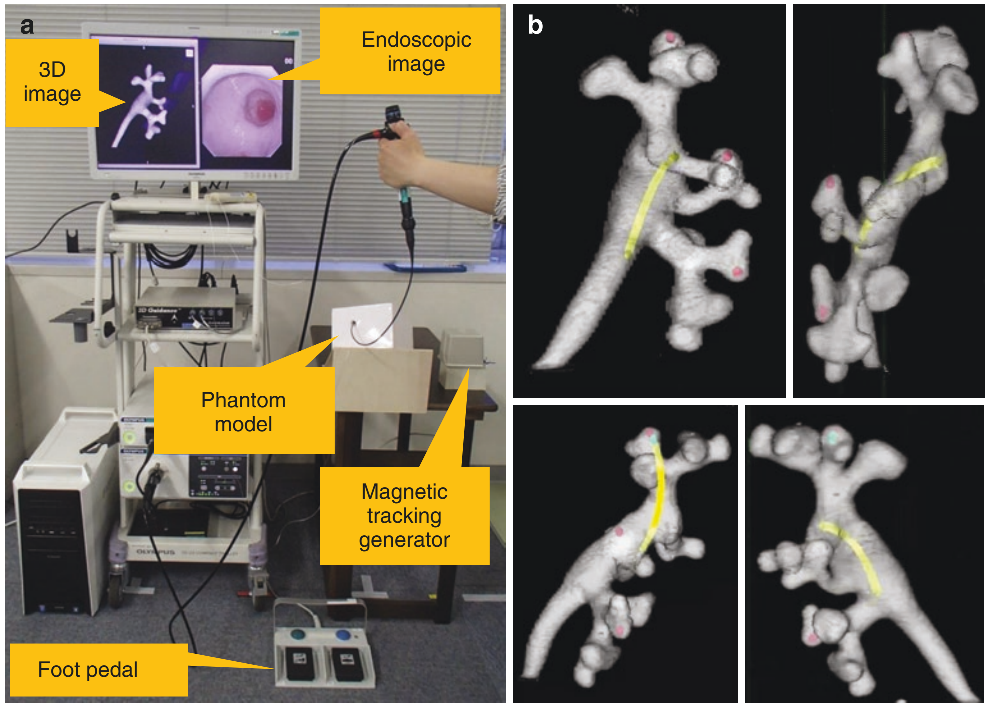


**Fig. 37.2** Navigation system over view during examination of the phantom. (**a**) The tip position of the ureteroscope is indicated in real-time on a 3D image of a pyelocaliceal system, (**b**) 3D navigation image can be rotated using the foot pedal

**Fig. 37.3** Simulated fluoroscopic image

tasks examining the inside of the phantom. Before performing the tasks, participants confirmed the 3D shape of the pyelocaliceal system and the location of three designated calices.

In Task 1, three designated calyces (antero-superior, antero-middle, and antero-inferior) were marked with dots in blue that represented pathologies. First, the surgeons were asked to advance the scope using only simulated fluoroscopy and to record the tip position when they thought to reach the blue markings. In this task, the surgeons could not confirm the recorded positions on the 3D image. Next, surgeons performed the same task using the navigation system. They could detect the current tip position of the ureteroscope while rotating the 3D image using the foot pedal. Then, they were asked to record the tip position when reaching the scope to the blue markings.

In Task 2, surgeons examined all 15 calices and marked their position when reaching each papilla. First with simulated fluoroscopy and then with navigation.

### 37.3.2 Evaluation Parameters

We recorded the accuracy rate (AR) of detecting the marked calyces, migration length (ML) of the ureteroscope, time taken to complete the task (T), and time exposed to simulated fluoroscopy (sFT). The AR for both tasks were calculated as follows:

$$\mathrm{AR}(\text{Task}\,1) = \frac{\text{number of correctly identified calyces}}{\text{number of marked calyces}(\text{three})} \times 100\%$$

$$\mathrm{AR}(\text{Task}\,2) = \frac{\text{number of correctly identified calyces}}{\text{all calyces}(\text{fifteen})} \times 100\%$$

In this study, we defined that the beginning of the task was the moment of ureteroscope insertion into the phantom, and the end was the moment of ureteroscope removal from the phantom. To clarify the percentage of time the participants use fluoroscopy, we defined the sFT percentages which were calculated by dividing sFT by T.

ML was calculated as follows:

$$\Delta ML = \sqrt{\Delta x^2 + \Delta y^2 + \Delta z^2}\,(\mathrm{mm})$$

$$\mathrm{ML} = \sum_{0}^{T} \Delta ML\,(\mathrm{mm})$$

### 37.3.3 Results

#### 37.3.3.1 AR, ML, and T for Task 1 and Task 2 (Fig. 37.4)

AR, ML, and T for both Task 1 and Task 2 with the navigation system were significantly better than with simulated fluoroscopy, and indicated that using the navigation system improved ureteroscopic performance by navigating the endoscope tip to the designated position.

#### 37.3.3.2 Subgroup Analysis for AR, ML, and T in Group A and B (Fig. 37.5)

AR, ML, and T for Task 1 were significantly better with the navigation system in both Group A and B. AR in both groups for Task 2 and ML in Group A for Task 2 were significantly better with the navigation system.

### 37.3.4 Duration of Simulated Radiation Exposure

Mean sFT was 71 s in Task 1 and 57 s in Task 2. The mean percentage of sFT was 18.3% and 17.9% for Task 1 and Task 2, respectively.

## 37.4 Future Work

Our novel navigation system could help surgeons to observe all renal papillae with a wide range of experience by showing surgeons the real-time tip position of ureteroscope on the navigation image. This concept may lead to increase the detection rate of upper urinary pathologies and the accuracy of surgical procedures. However, our system is still under development, because there are several challenges to be overcome before clinical use is possible. These include adding a built-in magnetic sensor at the tip of flexible ureteroscope and overcoming the deformation of pyelocaliceal system (expansion and contraction) caused by intraoperative saline irrigation and movements in kidney position with respiration.

In brain surgery, Atsumi et al. (2011) reported a neuroendoscopic navigation system that uses a magnetic tracking system. The authors developed a prototype scope with a built-in magnetic sensor (1.8 mm in diameter and 9 mm in length) in the tip while only increasing the scope diameter by 1.5 mm compared with a commercially available scope. However, there are technical challenges in decreasing scope diameter; the actual insertion diameter of the scope in Atsumi et al.'s study was 6.3 mm (approximately 18 French). To prevent increasing the ureteroscopic insertion diameter, we inserted the sensor into the working channels. However, this prevented the insertion of guidewires or ureteroscopic instruments. New technology to minimize the endoscopic diameter is needed to realize our ureteroscopic system for clinical use.

Agenant et al. (2013) reported a real-time bladder navigation system to improve patient follow-up and increase the reproducibility of the cystoscopy. The authors discussed two problems with examination using the cystoscope: complete inspection of the bladder may not be possible, and a lack of documentation accuracy for tumor location and size. Although their system uses a rigid cystoscopic navigation system with infrared camera (optical tracking system), a flexible cystoscopic navigation system might be developed by applying the techniques that Atsumi et al. reported (Atsumi et al. 2011).

Soft tissue deformation is one of the most difficult barriers to overcome in image-guided surgery. In image-guided partial nephrectomy, a preoperative CT image is reconstructed to create 3D models that are overlaid on intraoperative images. However, almost all studies have suffered from soft tissue deformation caused by surgical manipulation, patient positioning, and movement secondary to respiration (Simpfendorfer et al. 2016). Simpfendorfer et al. reported the feasibility of intraoperative CT imaging for navigated laparoscopic partial nephrectomy (Simpfendorfer et al. 2016). The combination of marker-based augmented reality

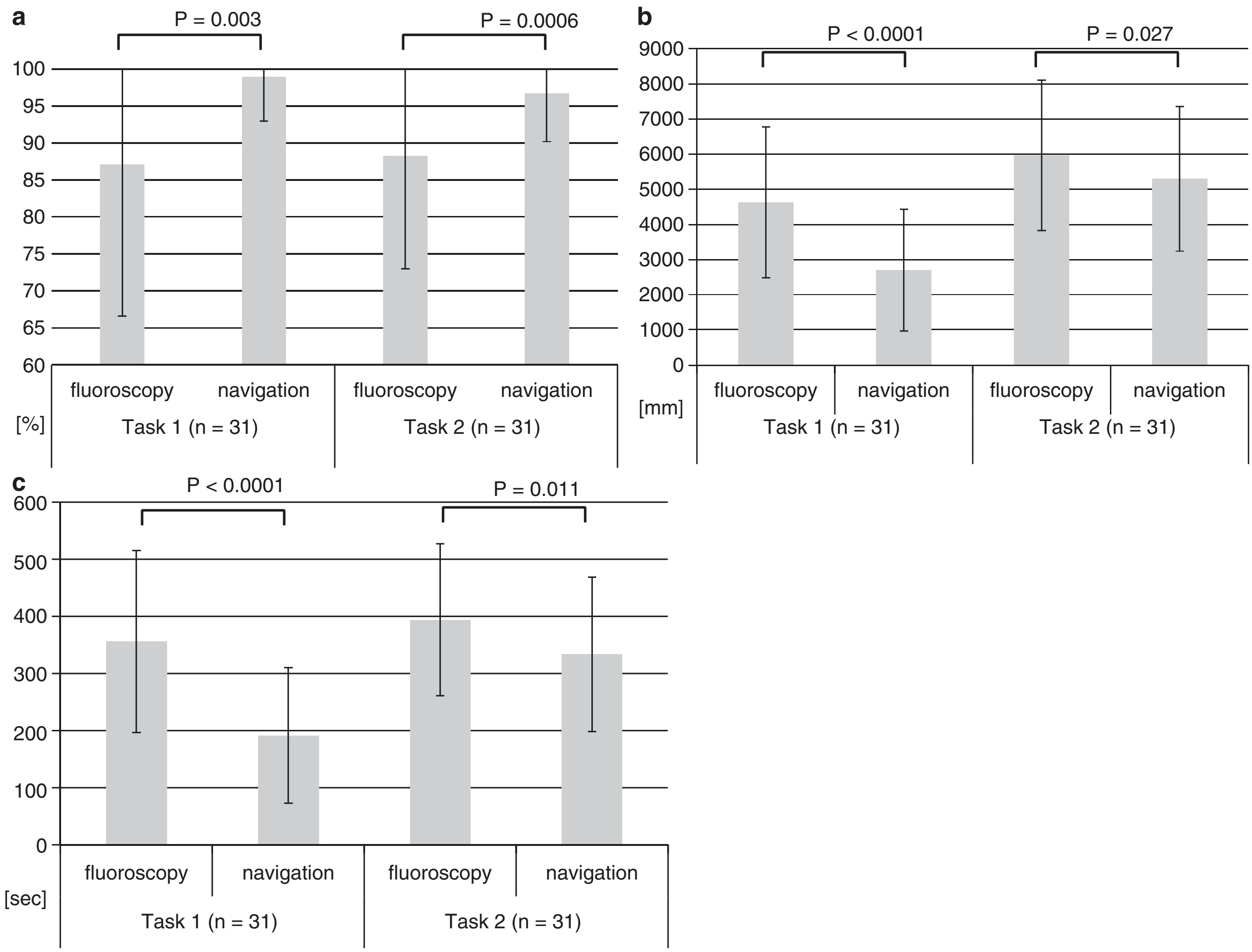


**Fig. 37.4** AR, ML, and T for Task 1 and Task 2. (**a**) AR, (**b**) ML, (**c**) T

with low target registration error (0.5 mm) and fluoroscopy can permit accurate tumor dissection for challenging endophytic tumor locations. The augmented reality fluoroscopic image shows the determining spatial relationship between the laparoscopic instrument and tumor locations. This technique has the potential to overcome intraoperative organ deformations caused during saline irrigation and by movements in kidney position with respiration.

A technique of stitching and surface reconstruction from endoscopic images also overcomes temporary organ deformation of the urinary tract. This technique has been applied in various endoscopic procedures, such as urology, retinal surgery, tubular organs, laparoscopy, otorhinolaryngology, neurosurgery, colonoscopy, and endomicroscopy (Bergen and Wittenberg 2016). In urology, this procedure has been used to create a panoramic view or a planar projection surface of the endoscopic image during bladder inspection. The technique also can provide a map of the documentation procedure and a real-time view for navigation. Although it is not easy to reconstruct images in situations with poor visibility because of macroscopic hematuria or debris in the urine, this technique could be applied to inspection of the upper urinary tract. Real-time navigation systems from reconstructed 3D upper urinary tract images could be realized by advancements in stitching and surface reconstruction technology.

With increased use of endoscopic surgery for pathology of pyelocaliceal system, the use of fluoroscopy has increased. Urologists should adhere to the "as low as reasonably achievable (ALARA)" principle to prevent harmful effects to both themselves and their patients (Andonian and Atalla 2009). Weld et al. (2015) reported a correlation between increasing the ureteroscopic experience and decreasing the fluoroscopy time. Furthermore, Novice surgeons tend to use fluoroscopy more often because they sometimes lose the spatial orientation. Some studies have described a radiation reduction protocol to reduce fluoroscopy time while using ureteroscopy (Greene et al. 2011; Hsi and Harper 2013; Kokorowski et al. 2013; Weld et al. 2014). Despite these reports, extensive time

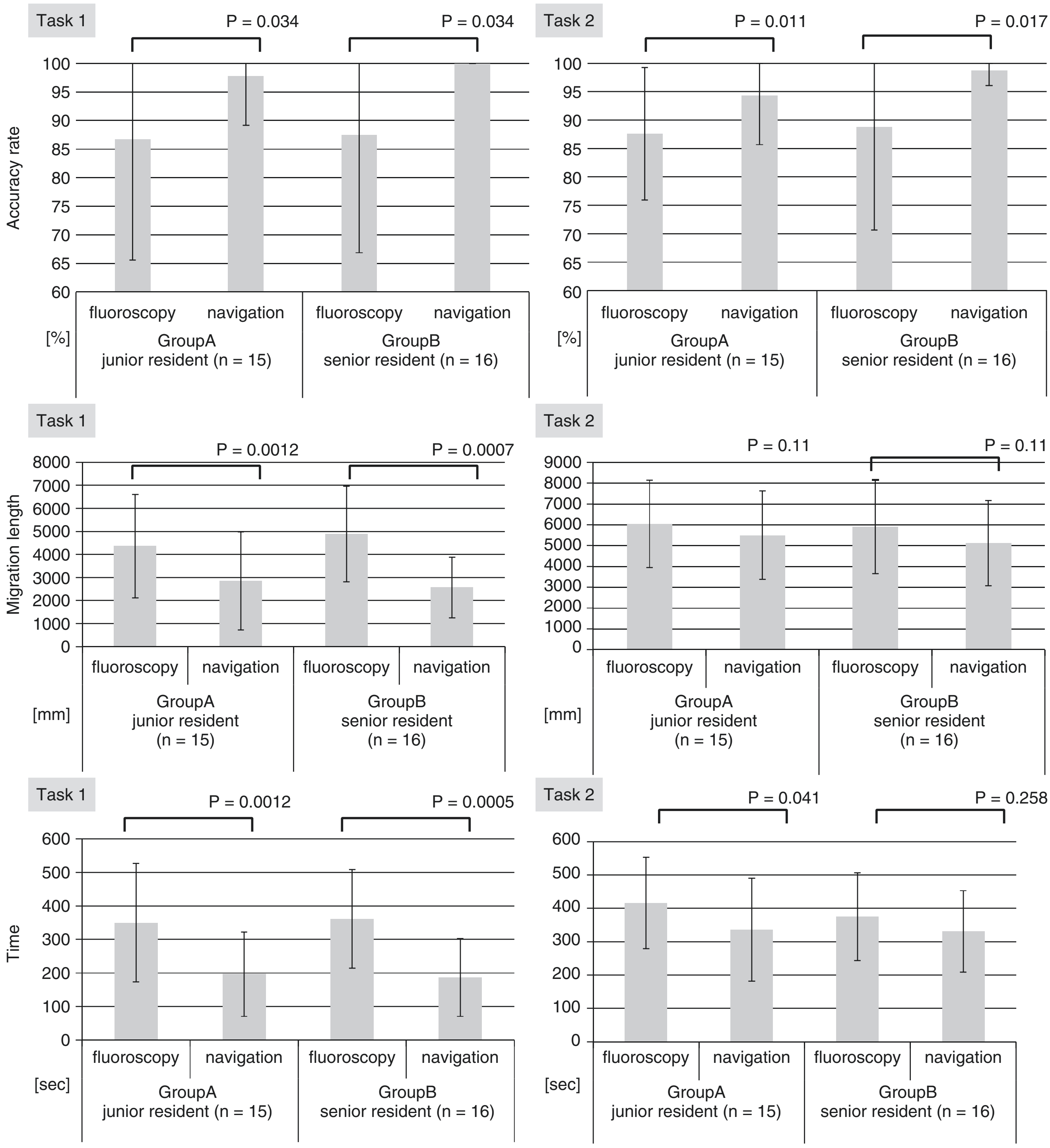


**Fig. 37.5** AR, ML, and T for Task 1 and Task 2 in Group A and B

and effort are required to minimize fluoroscopy time. Since our system can show the current tip position of ureteroscope at real-time, it could be helpful for decreasing the fluoroscopy time.

Use of our ureteroscopic navigation system could improve ureteroscopic performance among surgeons with a wide range of experience. Our system has the potential to reduce fluoroscopy time by showing surgeons the tip position of the ureteroscope on the 3D image. However, to enable the future clinical application of this system, we must overcome the problems of respiratory-related kidney movement, registration of the ureteroscope, and deformation of the pyelocaliceal system by intraoperative saline irrigation.

## References


Agenant M, Noordmans HJ, Koomen W, et al. Real-time bladder lesion registration and navigation: a phantom study. PLoS One. 2013;8:e54348.

Andonian S, Atalla MA. Radiation safety in urology. AUA Update Series. 2009;28:lesson 26.

Atsumi H, Matsumae M, Hirayama A, et al. Newly developed electromagnetic tracked flexible neuroendoscpe—technical note. Neurol Med Chir. 2011;51:611–6.

Bergen T, Wittenberg T. Stitching and surface reconstruction from endoscopic image sequences: a review of applications and methods. IEEE J Biomed Health Inform. 2016;20:304–21.

Buscarini M, Conlin M. Update on flexible ureteroscopy. Urol Int. 2008;80:1–7.

Chow GK, Patterson DE, Blute ML, JW S. Ureteroscopy: effect of technology and technique on clinical practice. J Urol. 2003;170:99–102.

Greene DJ, Tenggadjaja CF, Bowman RJ, et al. Comparison of a reduced radiation fluoroscopy protocol to conventional fluoroscopy during uncomplicated ureteroscopy. Urology. 2011;78:286–90.

Hamacher A, Kim SJ, Cho ST, et al. Application of virtual, augmented, and mixed reality to urology. Int Neurourol J. 2016;20:172–81.

Hsi RS, Harper JD. Fluoroless ureteroscopy: zero-dose fluoroscopy during ureteroscopic treatment of urinary-tract calculi. J Endourol. 2013;27:432–7.

Hughes-Hallet A, Mayer EK, Marcus HJ, et al. Augmented reality partial nephrectomy: examining the current status and future perspective. Urology. 2014;83:266–73.

Humphreys MR, Miller NL, Williams JC Jr, et al. A new world revealed: early experience with digital ureteroscopy. J Urol. 2008;179:970–5.

Kokorowski PJ, Chow JS, Strauss KJ, et al. Prospective systematic intervention to reduce patient exposure to radiation during pediatric ureteroscopy. J Urol. 2013;190(suppl4):1474–8.

Lanchon C, Custillon G, Moreau-Gaudry A, et al. Augmented reality using transurethral ultrasound for laparoscopic radical prostatectomy: preclinical evaluation. J Urol. 2016;196:244–50.

Lima E, Rodrigues P, Mota P, et al. Ureteroscopy-assisted percutaneous kidney access made easy: first clinical experience with a novel navigation system using electromagnetic guidance (IDEAL stage 1). Eur Urol. 2017;72(4):610–6.

Matsuda T. Recent advances in urologic laparoscopic surgeries: laparoendoscopic single-site surgery, natural orifice transluminal endoscopic surgery, robotics and navigation. Asian J Endosc Surg. 2013;6(2):68–77.

Rassweilera J, Mullerb M, Fangeraub M, et al. iPad-assisted percutaneous access to the kidney using marker-based navigation: initial clinical experience. Eur Urol. 2012;61:627–31.

Simpfendorfer T, Baumhauer M, Muller M, et al. Augmented reality visualization during laparoscopic radical prostatectomy. J Endourol. 2011;25:1841–5.

Simpfendorfer T, Gasch C, Hatiboglu G, et al. Intraoperative computed tomography imaging for navigated laparoscopic renal surgery: first clinical experience. J Endourol. 2016;30:1105–11.

Ukimura O, Gill IS. Imaging-assisted endoscopic surgery: Cleveland Clinic experience. J Endourol. 2008;22:803–10.

Ukimura O, Gross ME, de C, Abreu AL, et al. A novel technique using three-dimensionally documented biopsy mapping allows precise revisiting of prostate cancer foci with serial surveillance of cell cycle progression gene panel. Prostate. 2015a;75:863–71.

Ukimura O, Marien A, Palmer S, et al. Trans-rectal ultrasound visibility of prostate lesions identified by magnetic resonance imaging increases accuracy of image-fusion targeted biopsies. World J Urol. 2015b;33:1669–76.

Weld LR, Nwoye UO, Knight RB, et al. Safety, minimization and awareness radiation training reduces fluoroscopy time during unilateral ureteroscopy. Urology. 2014;84:520–5.

Weld LR, Nwoye UO, Knight RB, et al. Fluoroscopy time during uncomplicated unilateral ureteroscopy for urolithiasis decreases with urology resident experience. World J Urol. 2015;33:119–24.

Yoshida K, Kawa G, Taniguchi H, et al. Novel ureteroscopic navigation system with a magnetic tracking device: a preliminary ex vivo evaluation. J Endourol. 2014;28:1053–7.

Yoshida K, Yokomizo A, Matsuda T, et al. The advantage of a ureteroscopic navigation system with magnetic tracking in comparison with simulated fluoroscopy in a phantom study. J Endourol. 2015;29:1059–64.

# 38 Navigation in Laparoscopic and Robotic Urologic Surgery

Fumiya Hongo and Osamu Ukimura

**Abstract**

Augmented reality for surgical navigation is considered to visually recognize organs in the surgical field, for example, additional information not perceptible in reality is presented in real time on the endoscope screen by superimposing information not directly visible macroscopically or endoscopically. It is a surgical assistance technology aiming at improvement of the objective of surgery.

In surgery navigation, it is necessary to prepare an organ tracking system to acquire information on the spatial position of the target in real time similar to the spatial position tracking system, like a satellite GPS.

In future, application for hologram display using a laser light, commentary characters and sound up-dating the target condition in real time, a system informing of the safety and risk to the operator through color codes and alarm sound will be expected. Also, complementation and improvement of judgment ability will be possible by introducing Artificial Intelligence (AI).

**Keywords**

Kidney cancer · Prostate cancer · Augmented reality Three-dimensional · Medical imaging

## 38.1 Introduction

Robot-assisted surgery is a treatment method utilizing a surgery support system enabling safe and low-invasive surgery using 3D vision and forceps with 7 freedom degrees of joint. Robot-assisted radical prostatectomy (RARP) is performed in more than about 80% of radical prostatectomy (RP)-treated prostate cancer cases in the US. Surgery aiming at functional preservation including curability and urinary continence has been performed compared with the conventional surgical method, but complications, such as bleeding and anastomotic failure, occur during the learning curve early after introduction, being problematic. In addition, accurate conservation of nerves around the prostate is desired to retain the functions (urinary continence and sexual function) after surgery. On the other hand, for small kidney cancer, the importance of not only curability but also conservation of the renal function has been pointed out and partial nephrectomy has spread, but robot-assisted partial nephrectomy (RAPN) minimizing invasiveness of treatment and shortening the ischemic time has also spread. In these robot-assisted surgeries in the urology field, navigation may be a very important surgery support technique to increase the surgical accuracy.

## 38.2 Augmented Reality for Surgical Navigation

The technology to additionally present information in a reality environment perceptible for humans using a computer is termed Augmented Reality (AR). In the medical field, to visually recognize organs in the surgical field, for example, additional information not perceptible in reality is presented in real time on the endoscope screen by superimposing information not directly visible macroscopically or endoscopically, such as ‘the degree of tumor expansion in the organ’ and ‘tumor-feeding blood vessel distributing in the organ’, and this is considered a surgery support technique aiming at improvement of the objective of surgery (Marescaux et al. 2004). For the method to present additional information, new 3-dimensional images matching spatial arrangement are generally used, but commentary characters or sound related to the target may be used, and any means to augment information perceptible in reality may be used (Ukimura and Gill 2009a).

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In surgery navigation, real-time superimposed display on the endoscope screen of additional information of the target as an object acquired by computer processing is required, for which real-time acquisition of spatial positional information of the target is necessary. For example, in car navigation, the present car position on the earth is identified utilizing an artificial satellite global-scale position measurement system termed Global Positioning System (GPS). Car movement is traced by the satellite in real time and the current reach and estimated time of arrival to several options of route to the destination set beforehand are displayed as additional information. For surgery navigation, it is necessary to prepare an organ tracking system to acquire information on the spatial position of the target in real time similar to the spatial position tracking system, satellite GPS.

## 38.3 Intraoperative Navigation in Robot-Assisted Urological Surgery

Transrectal ultrasound (TRUS) navigation is used in open and laparoscopic total prostatectomy, and its usefulness has been reported (Ukimura et al. 2006; Okihara et al. 2009). The Da Vinci system for RARP has a function to display ultrasound and CT/MRI images in the surgical field on the 3D endoscope screen, termed Tile Pro, and real-time ultrasound images can be easily provided to the surgical field through cable connection. Using this function, information on the accurate transected surface and posterior surface of the organ are provided (Fig. 38.1), facilitating navigation for safe and reliable surgery.

Laparoscopic partial nephrectomy (LPN) has spread aiming at preservation of the renal function and low invasiveness, but LPN is a difficult surgical procedure because it requires rapidly applying laparoscopic resection, hemostasis, and suture within a limited ischemic time. Thus, robot-assisted partial nephrectomy (RPN) has spread expecting to overcome this technical difficulty of LPN, reducing invasiveness, and shortening the ischemic time. Three-dimensional images of the tumor localization and renal arterial and venous distributions are prepared before partial nephrectomy using software, such as OsiriX (Pixmeo, Swiss) and Synapse Vincent System (FUJIFILM, Japan) (Fig. 38.2), and projected in a console using TilePro™ during surgery. In its standard procedure, before tumor resection during surgery, an ultrasound probe is placed in the body cavity and a resection line is marked around the tumor by coagulation using Monopolar curved scissors held by the right hand while ultrasound images are displayed on the console screen using TilePro™ Multi-Display (Fig. 38.3).

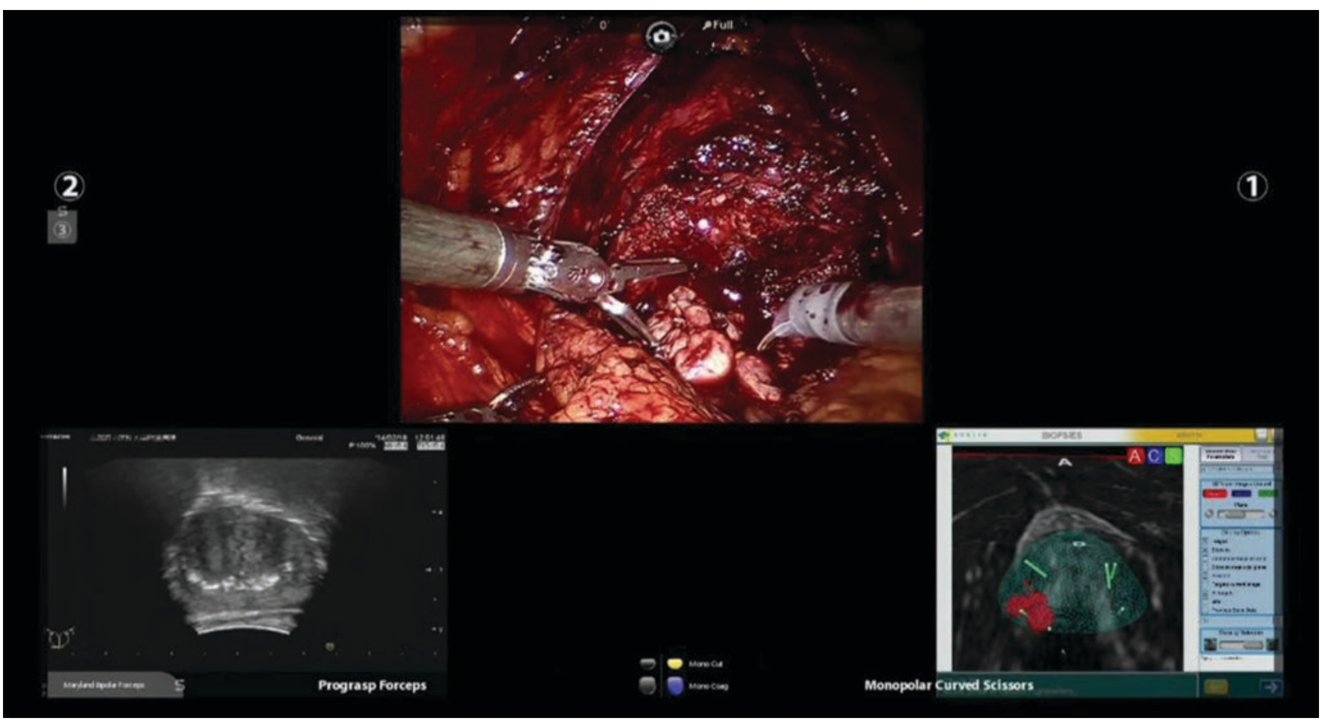


**Fig. 38.1** Intraoperative transrectal ultrasound (TRUS) images of a prostate in RARP

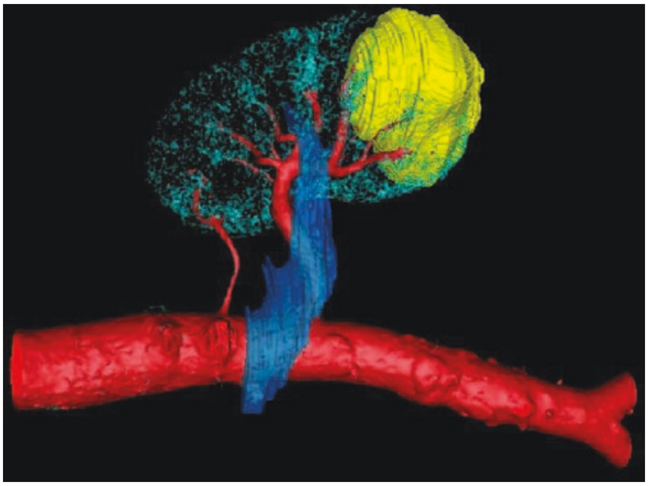

**Fig. 38.2** 3D constructed CT images by OsiriX®

## 38.4 Development of AR Navigation by Urology Department

To our knowledge, the world's initial execution of AR navigation in the urology field transmitted at a public place is the live operation of laparoscopic partial nephrectomy performed by our team in the 2006 World Congress of Endourology annual meeting held in Cleveland (Ukimura and Gill 2008). Our AR system is comprised of a computerized workstation and surgical instruments (a rigid laparoscope and laparoscopic surgical instruments) equipped with an infrared optical position tracking camera (Polaris, Northern Digital, Waterloo, Canada) (Fig. 38.4). Firstly, we developed AR navigation for total prostatectomy using cancer and neurovascular bundle models visualized by transrectal ultrasound imaging immediately before surgery at an

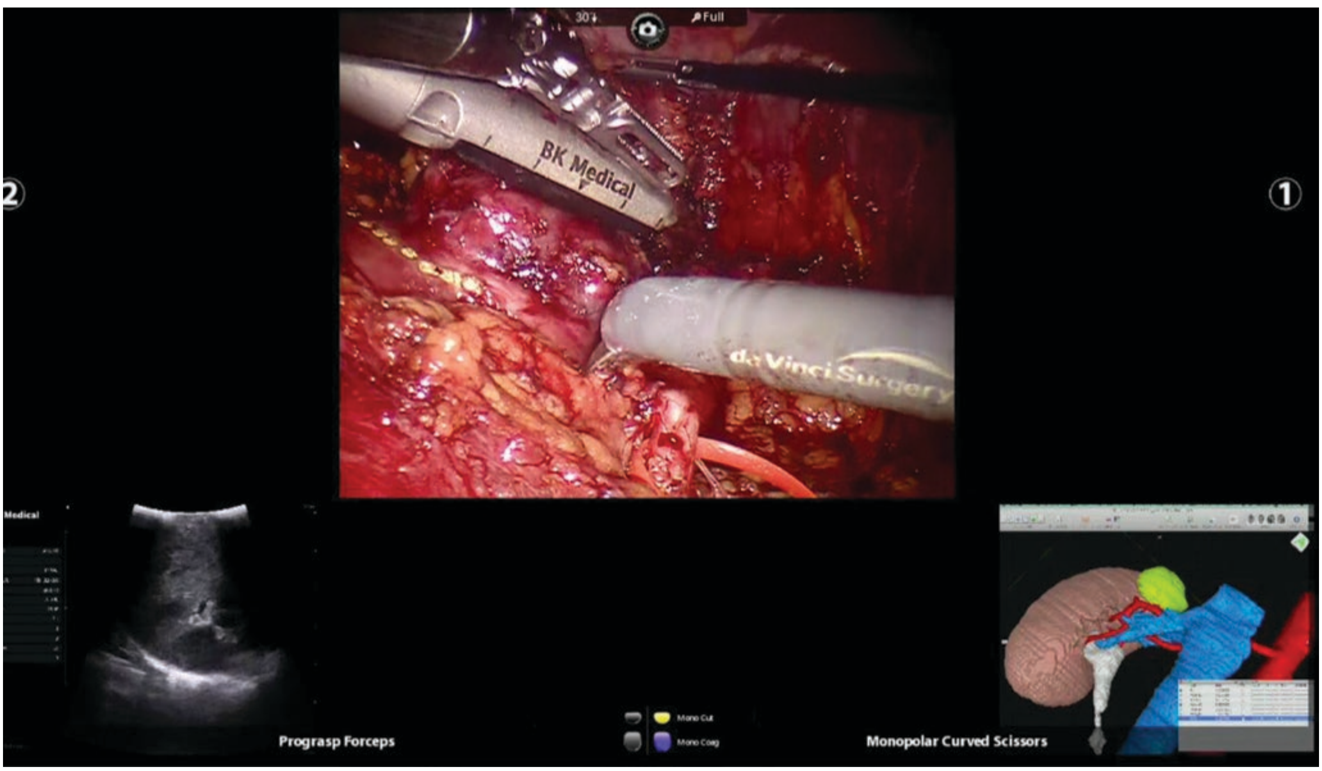


**Fig. 38.3** Intraoperative ultrasound and 3D constructed CT images on TilePro™ multi-input display in RAPN

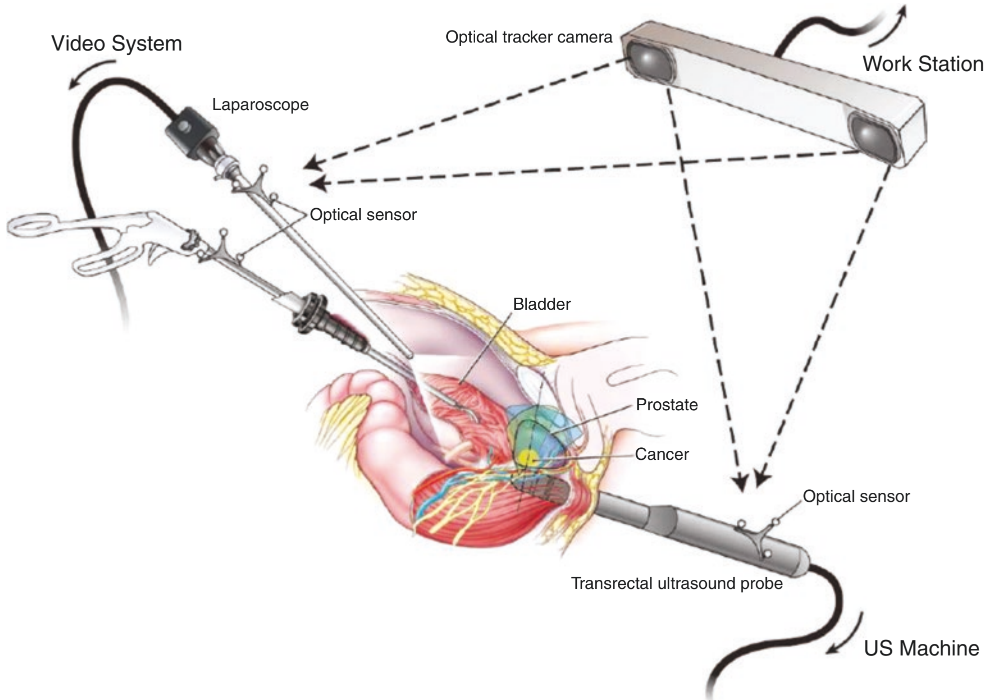


**Fig. 38.4** Augmented reality system using optical tracking camera and 3-markers-attached instruments (Modified from figure form reference Ukimura and Gill (2009a))

operation site. For partial nephrectomy, a 3-dimensional model of the kidney and renal tumor (and tumor blood vessels currently) was prepared from contrast-enhanced CT information acquired at a slice width of 1 mm or smaller on the day before surgery. The properties of the blood vessels in the renal hilum and curved kidney surface in the surgical field were identified using a positional sensor probe employing the Iterative Closest Point method, and registration with the corresponding points and curved surface in the 3-dimensional model was performed to realize AR by superimposed display. The renal tumor expansion pattern in the organ not-visible in the conventional endoscopic visual field could be observed as if it were see-through in the organ, which contributes to support for surgery. In the development for partial nephrectomy, we also developed a system which tracks the tip and direction of scissors for laparoscopic surgery using the optical tracking system and calculates the distance between the tumor and the tip of the surgical tool applying the AR function. Using this system, we proposed a concept, "Surgical Radar", correcting the ideal direction of resection in real time to achieve negative resected margins (Ukimura and Gill 2009b). To define the spatial position and direction of scissors, we designed a color map method displaying the direction pointed by scissors and distance from the tumor in real time ("Surgical Radar" capable of displaying regions 5- and 10-mm distant from the outer margin of the tumor), like a weather forecast map (such as presenting a distance up to 5 mm in yellow and within 5–10 mm in green) (Fig. 38.5). Subsequently, we developed a result-predictive AR function aiming at correcting the current state through

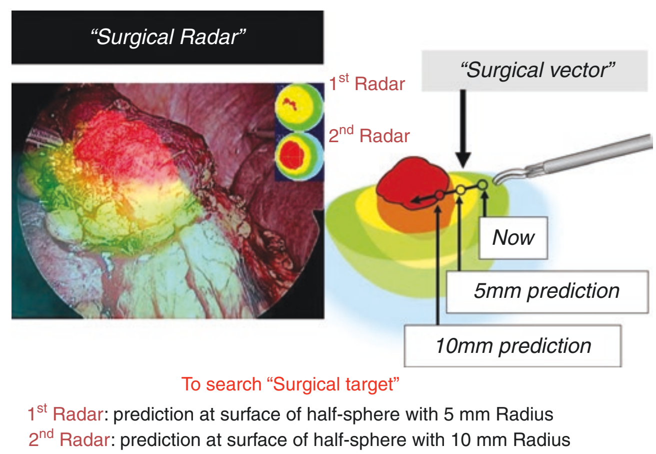


**Fig. 38.5** Augmented reality with predictive "Surgical Radar" function (Modified from figure form reference Ukimura and Gill (2009b))

which the operator can explore the distance between the current resection site and tumor and direction to cut thereafter in real time by observing "Surgical Radar", and reported a concept leading to automation of robot surgery in the future, which corresponds to a recent popular topic, autonomous cars (Ukimura and Gill 2008). We also newly designed a 3D reno-vascular tumor model in which kidney tumors and the distribution of blood vessels in the kidney can be recognized as if the internal region of the organ is see-through, aiming at non-ischemic partial nephrectomy, and realized AR using this new model (Fig. 38.6) (Ukimura et al. 2012; Nakamoto et al. 2012).

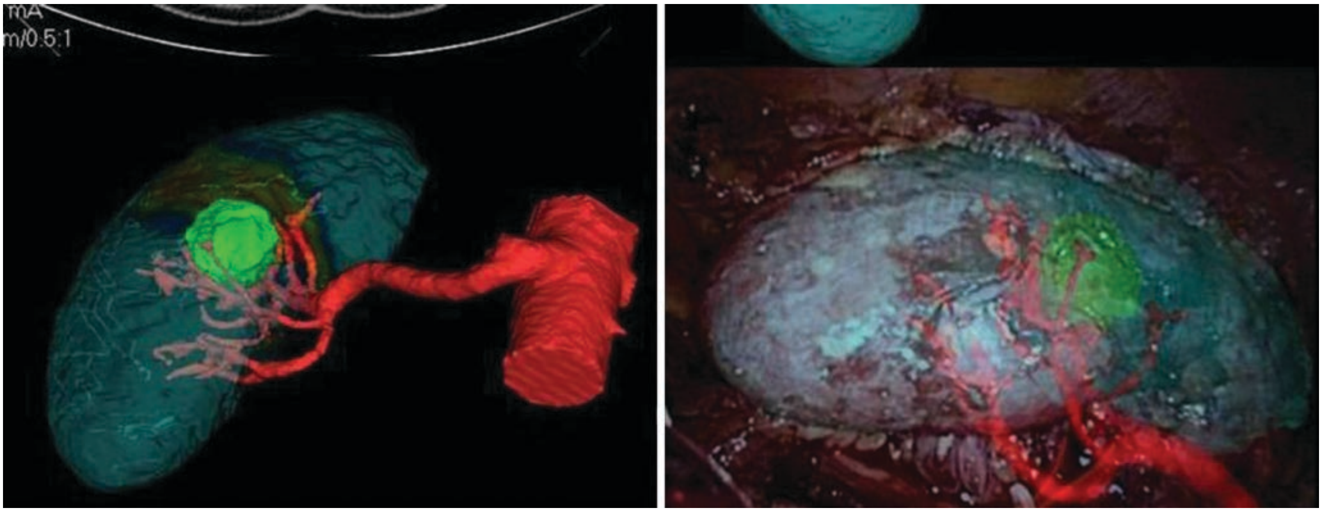


**Fig. 38.6** Augmented reality in "zero-ischemia" partial nephrectomy for completely intra-renal hilar tumor (Modified from figure form reference Nakamoto et al. (2012))

Unlike neurosurgery and orthopedic surgery, in urological surgery, it is difficult to match the surgical field to the position information of acquired images because the surgical field alters with deformation, respiratory movement, and posture change-induced shift of the target organ. However, with recent progresses in computer and medical engineering technologies, techniques to trace or correct deformity and respiratory movement of the organ in real time during surgery have been introduced. To track spatial movement and distortion of the organ in real time, three wireless magnetic markers used in radiotherapy (Calypso 4D localization system) were applied surrounding the kidney tumor as Body-GPS. CT images of the kidney including the markers were acquired, and a 3-dimensional model of the kidney tumor was prepared before surgery. We clarified that dynamic AR (4-dimensional AR) can be realized: In the surgical field placed in the magnetic field, Body-GPS automatically transmits the spatial coordinates to the magnetic position tracking system in real time, and based on this information, even though the organ is dynamically moved by the surgical operation, information of the 3-dimensional tumor model is superimposed and displayed following the moving organ on the endoscopic screen (Nakamoto et al. 2008). We recently reported that the postoperative renal function corresponding to the resection line can be predicted before surgery (Isotani et al. 2015).

In 2009, Teber et al. in Germany reported that AR is feasible for laparoscopic partial nephrectomy and total prostatectomy by puncturing the organ with needles with a needlepoint and using many needlepoints as visual markers for coordinate recognition (Teber et al. 2009; Simpfendörfer et al. 2011). In the same year, Su et al. in Florida introduced a 3-dimensional camera and identified the spatial positional information by acquiring the characteristics of the target curved kidney surface, and AR was possible using the technique to superimpose the information on the preoperative kidney tumor model (Su et al. 2009). The method calculating the spatial coordinates from image information collected by a 3-dimensional camera appears a simple ideal system because it does not use an external organ tracking system, but unfortunately, the accuracy of AR prepared by calculation for registration from image-based calculation materials collected using a single 3-dimensional camera is insufficient compared with that of AR prepared by the current registration method using external markers, and improvements in various directions are being discussed. In 2013, Müller et al. of Germany developed an AR application system capable of iPad tablet display for PCNL (Müller et al. 2013), and Schneider et al. of Switzerland reported in 2014 that they increased the accuracy of AR to an error range of 2.1 ± 1.2 mm in a pig model (Schneider et al. 2014). In 2015, Edgcumbe et al. of Canada reported that registration of the kidney with only an about 1.5-mm error is possible even though an imaging technique-based position tracking system is used by placing a light source capable of projecting a grid-pattern checker board through a laparoscope and acquiring images of the 3-dimensional structure of the organ with a curved surface (Edgcumbe et al. 2015). In 2016, Lanchon et al. of France constructed a 3-dimensional image of the prostate by transurethral ultrasonography and AR could be realized in laparoscopic total prostatectomy (Lanchon et al. 2016). Therefore, although the risk of errors in the registration process decreases in AR utilizing ultrasound images acquired in the surgical field, but preoperative CT and MRI with high resolution are appropriate for preparing a model of cancers and nerves, which are the targets of visualization, in many cases, leaving many problems to be solved. In the same year, Teber's group of Germany proposed a system in which the entire procedure can be performed during surgery without preoperative CT data acquisition by puncturing markers: Using cone-beam CT applicable during surgery, they acquired CT 3D-volume data by puncturing many needlepoint needles during surgery, and realized AR using the needlepoints as visual markers for coordinate recognition since 2009 (Simpfendörfer et al. 2016).

## 38.5 Future Prospects of Intraoperative Navigation

Curability is the highest priority in surgery for cancer, but low-invasiveness and functional preservation are also considered important, leading to the current procedures including robot-assisted surgery. Functional preservation after total prostatectomy represents conservation of urinary continence and the erectile function and that after partial nephrectomy represents conservation of the renal function. To achieve both cancer cure and functional preservation, elaborate control of the resected stumps and nerve conservation are necessary, for which appropriate navigation and monitoring may be very useful.

With improvement of imaging software, preoperative construction of a detailed 3-dimensional model has become possible (Komai et al. 2016; Shin et al. 2016), and whether the surgeon prepared it having a sense of purpose is questioned as a true value of the 3-dimensional model. Calculation software for organ deformation models has also progressed. Deformation of organs depends on the shape, properties, and hardness of the organ, condition of adjacent organs, and position of fixation support tissue, and studies using various calculation models are progressing. It has also recently become possible to prepare a soft 3-dimensional model using a 3D-printer and a model with materials reflecting the properties of the constituting organ. Furthermore, application for hologram display using a laser light is expected (Hartl et al. 2016). Progression of these simulation techniques may be returned to AR. Realization of new medical AR by combining with a sensor detecting the characteristics and physical properties of the target is expected for the future in which not only superimposed image display but also commentary characters and sound up-dating the target condition in real time and a system informing of the safety and risk to the operator through color codes and alarm sound are introduced, and complementation and improvement of judgment ability will be possible by introducing Artificial Intelligence (AI) (Epp et al. 1988).

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## References


Edgcumbe P, Pratt P, Yang GZ, Nguan C, Rohling R. Pico Lantern: surface reconstruction and augmented reality in laparoscopic surgery using a pick-up laser projector. Med Image Anal. 2015;25(1):95–102.

Epp H, Kalin M, Miller D. PC software for artificial intelligence applications. Science. 1988;240(4853):824–30.

Hartl AD, Arth C, Grubert J, Schmalstieg D. Efficient verification of holograms using mobile augmented reality. IEEE Trans Vis Comput Graph. 2016;22(7):1843–51.

Isotani S, Shimoyama H, Yokota I, China T, Hisasue S, Ide H, Muto S, Yamaguchi R, Ukimura O, Horie S, et al. Feasibility and accuracy of computational robot-assisted partial nephrectomy planning by virtual partial nephrectomy analysis. Int J Urol. 2015;22(5):439–46. https://doi.org/10.1111/iju.12714. Epub 2015 Mar 17.

Komai Y, Sugimoto M, Gotohda N, Matsubara N, Kobayashi T, Sakai Y, et al. Patient-specific 3-dimensional printed kidney designed for “4D” surgical navigation: a novel aid to facilitate minimally invasive off-clamp partial nephrectomy in complex tumor cases. Urology. 2016;91:226–33.

Lanchon C, Custillon G, Moreau-Gaudry A, Descotes JL, Long JA, Fiard G, Voros S. Augmented reality using transurethral ultrasound for laparoscopic radical prostatectomy: preclinical evaluation. J Urol. 2016;196(1):244–50.

Marescaux J, Rubino F, Arenas M, Mutter D, Soler L. Augmented-reality-assisted laparoscopic adrenalectomy. JAMA. 2004;292(18):2214–5.

Müller M, Rassweiler MC, Klein J, Seitel A, Gondan M, Baumhauer M, Teber D, Rassweiler JJ, Meinzer HP, Maier-Hein L. Mobile augmented reality for computer-assisted percutaneous nephrolithotomy. Int J Comput Assist Radiol Surg. 2013;8(4):663–75.

Nakamoto M, Ukimura O, Faber K, Gill IS. Current progress on augmented reality visualization in endoscopic surgery. Curr Opin Urol. 2012;22:121–6.

Nakamoto M, Ukimura O, Gill IS, et al. Realtime organ tracking for endoscopic augmented reality visualization using miniature wireless magnetic tracker. In: Dohi T, Sakura I, Liao H, editors. Medical imaging and augmented reality, (MIAR) 2008. New York: Springer; 2008. p. 359–66.

Okihara K, Kamoi K, Kanazawa M, Yamada T, Ukimura O, Kawauchi A, Miki T. Transrectal ultrasound navigation during minilaparotomy retropubic radical prostatectomy: impact on positive margin rates and prediction of earlier return to urinary continence. Int J Urol. 2009;16:820–5.

Schneider A, Pezold S, Saner A, Ebbing J, Wyler S, Rosenthal R, Cattin PC. Augmented reality assisted laparoscopic partial nephrectomy. Med Image Comput Comput Assist Interv. 2014;17(Pt 2):357–64.

Shin T, Ukimura O, Gill IS. Three-dimensional printed model of prostate anatomy and targeted biopsy-proven index tumor to facilitate nerve-sparing prostatectomy. Eur Urol. 2016;69(2):377–9.

Simpfendörfer T, Baumhauer M, Müller M, Gutt CN, Meinzer HP, Rassweiler JJ, Guven S, Teber D. Augmented reality visualization during laparoscopic radical prostatectomy. J Endourol. 2011;25(12):1841–5.

Simpfendörfer T, Gasch C, Hatiboglu G, Müller M, Maier-Hein L, Hohenfellner M, Teber D. Intraoperative computed tomography imaging for navigated laparoscopic renal surgery: first clinical experience. J Endourol. 2016;30(10):1105–11.

Su LM, Vagvolgyi BP, Agarwal R, et al. Augmented reality during robot assisted laparoscopic partial nephrectomy: toward real-time three-dimensional-CT to stereoscopic video registration. Urology. 2009;73:896–900.

Teber D, Guven S, Simpfendörfer T, et al. Augmented reality: a new tool to improve surgical accuracy during laparoscopic partial nephrectomy? Preliminary in vitro and in vivo results. Eur Urol. 2009;56:332–8.

Ukimura O, Gill IS. Imaging assisted endoscopic surgery—Cleveland Clinic experience. J Endourol. 2008;22(4):803–10.

Ukimura O, Gill IS. Augmented reality. In: Ukimura O, Gill IS, editors. Contemporary interventional ultrasonography in urology. New York: Springer; 2009a.

Ukimura O, Gill IS. Image-fusion, augmented reality and predictive surgical navigation. Urol Clin North Am. 2009b;36:115–23.

Ukimura O, Magi-Galluzzi C, Gill IS. Real-time transrectal ultrasound guidance during laparoscopic radical prostatectomy: impact on surgical margins. J Urol. 2006;175:1304–10.

Ukimura O, Nakamoto M, Gill IS. 3D reconstruction of renovascular-tumor anatomy to facilitate zero-ischemia laparoscopic and robotic partial nephrectomy. Eur Urol. 2012;61:211–7.

# 39 MRI-Ultrasound Fusion Prostate Biopsy

Wai-Kit Ma and Peter Ka-Fung Chiu

**Abstract**

MRI prostate has emerged as the most accurate imaging available for detection of significant prostate cancer. Standardized reporting using the *The Prostate Imaging Reporting and Data System (PI-RADS)* system for MRI prostate is important for clinical management and for professional communication. Besides diagnosis of prostate cancer, MRI prostate also enabled targeted prostate biopsy, and MRI-Ultrasound fusion biopsy has been increasingly utilized for targeting of suspicious MRI lesions during real-time ultrasound scanning of prostate. The elements of a successful MRI-Ultrasound fusion biopsy program include high quality MRI imaging and reporting, and the proper usage of fusion biopsy machines in achieving an accurate targeted biopsy.

**Keywords**

MRI · Prostate biopsy · Fusion biopsy

## 39.1 Introduction

Prostate biopsy, the current standard for prostate cancer diagnosis, was performed nearly one million times annually a decade ago in the United States, most frequently as a result of an elevated PSA (Welch et al. 2007). Following the US Preventive Services Task Force (USPSTF) recommendation against prostate-specific antigen (PSA) screening in 2012, biopsy volume has decreased by 28.7% by 2016 (Halpern et al. 2017). The trend in Asia, on the contrary, is on the rise as reflected by a steady increase in prostate cancer incidences in Asian countries during the past few decades (Chen and Ren 2014). Despite the use of a 12-core systematic biopsy instead of traditional sextant sampling methods, it relies on sampling efficiency for cancer detection and is consequently subject to sampling error (Bjurlin et al. 2014). Up to 35% of clinically significant cancers can be missed, but at the same time overdiagnosis and overtreatment of indolent cancers can be a more apparent problem in Asia where the overall prostate cancer incidence is still low compared with Caucasian countries.

With the advancement in the magnetic resonance imaging (MRI) techniques, notably the multiparametric (mp) MRI, it is considered the most sensitive and specific imaging tool for localizing clinically significant prostate cancer. Targeted prostate biopsy can be performed in the forms of MRI in-bore-guided biopsy, MRI visual estimation-guided biopsy (also known as cognitive fusion biopsy), and MRI-ultrasound (US) fusion-guided biopsy making use of commercially available image fusion systems. This chapter will focus on the MRI-US fusion prostate biopsy development and current status in Asia, and discussion on the key tips for a successful operational workflow in the fusion prostate biopsy.

## 39.2 Multiparametric Magnetic Resonance Imaging (mpMRI) and Prostate Imaging Reporting and Data System (PIRADS)

Multi-parametric MRI (mpMRI) is a non-invasive imaging method that is now increasingly used in prostate cancer diagnosis, staging as well as in active surveillance setting (Moore et al. 2013). It utilizes a combination of sequences which provide anatomical information (T1 and T2 weighted images) and functional information which is provided by diffusion weighted MRI (DWI), Dynamic Contrast Enhanced MRI (DCE) and/or proton MR Spectroscopic Imaging (MRSI).

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T2 weighted MRI is the basis for anatomic imaging as it provides superior soft-tissue resolution for detection and also staging of prostate carcinoma. Addition of DWI and DCE improves the ability of detection and predicts the tumour behaviour. MR spectroscopy is an optional sequence which is less commonly performed (Dickinson et al. 2011). A systematic review found mpMRI had sensitivity of 58–96% and negative predictive value of 63–98% with specificity 23–87% (Futterer et al. 2015). The results of the latest PROMIS trial in the United Kingdom showed that mpMRI could be used as a triage test before first biopsy to allow 27% of men with elevated serum PSA to avoid biopsy (Ahmed et al. 2017).

### 39.2.1 Typical Sequences in mpMRI

**Anatomical MRI (T1 and T2 w MRI):** T1 weighted and T2 weighted images form the basis for anatomical information that can be obtained in mpMRI. Both T1 and T2 weighted sequences should include the prostate, seminal vesicles and the external sphincter. A slice thickness of 3 mm and an in plane resolution of 0.7 mm or better is recommended (Barentsz et al. 2012).

T1 weighted images are used mainly for identification of post-biopsy haemorrhage which can lead to artefacts and decrease the accuracy of mpMRI. It is recommended that MR examination of the prostate should be delayed for 6 weeks after the biopsy due to decreased accuracy in detection of focal prostate carcinoma and also confounding findings which may affect the accurate staging of prostate carcinoma (Ikonen et al. 2001).

T2 weighted MRI allows anatomical visualization of transitional and peripheral zones. The normal peripheral zone demonstrates uniform high signal intensity due to increased water content of glandular structures. Tumors are typically low in signal intensity compared with the high signal intensity of the background glandular peripheral zone. Other benign conditions such as prostatitis, hemorrhage, benign prostatic hyperplasia may also result in low signal intensity in the peripheral zone.

Detection of tumor in the transitional zone of the prostate can be challenging due to the heterogeneous appearance of the benign prostate hyperplasia which is common in middle-aged and elderly individuals. Tumors in this area generally are seen as irregular lesions with homogenous hypo intensity on T2 weighted images. Benign prostatic hyperplasia and nodules, on the other hand are usually well circumscribed with distinct capsule. Multiplanar T2 weighted images are useful in determining extra prostatic extension of disease. In addition, involvement of the neurovascular bundle and the sphincter can be assessed on T2 weighted images.

**Diffusion weighted MRI:** A Series of magnetic gradients known as ‘b’ values are applied to quantify the Brownian motion of free water in a tissue. Relative to the glandular prostate, water molecules in malignant tissue demonstrate restricted diffusion at high b values. The values of 50 and 800 s/mm$^2$ are typically used for detection of prostate carcinoma. However, significant technological advances have allowed assessment and use of higher b values (1000–2000 s/mm$^2$) which have improved the accuracy of mpMRI in detection of lesions. This is particularly useful in the transitional zone where benign conditions such as BPH can be associated with restricted diffusion (Katahira et al. 2011). Diffusion weighted MRI is displayed as a parent diffusion coefficient map. Lower ADC values are associated with higher rate of malignancy. Application of diffusion weighted MRI has been shown to significantly improve detection of significant prostate carcinoma.

**Dynamic contrast-enhanced MRI:** Ultrafast T1 weighted MRI scanning sequences before, during and after rapid administration of gadolinium based MRI contrast agents demonstrates vascularity of tissues. Tumors typically exhibit early and rapid enhancement as well as early washout due to neo angiogenesis. A bolus injection of 3 mm/s, a minimum slice thickness of 4 mm is recommended. The easiest method of evaluating DCE MRI images is to qualitatively detect focal early enhancement compared to normal prostate tissue. A negative result is defined as no early enhancement, or diffuse enhancement not corresponding to a focal finding on T2 and/or DWI or focal enhancement corresponding to a lesion demonstrating features of BPH on T2; a positive result is focal enhancement earlier than or contemporaneously with that of adjacent normal prostatic tissues, and corresponds to suspicious finding on T2 and/or DWI. Significant overlap in enhancement properties between benign and malignant regions in the transitional zone such as a benign prostatic hyperplasia is noted which can limit the interpretation of DCE MRI.

**MR spectroscopic imaging:** MR spectroscopic imaging is a functional method which assesses the biochemical characteristics of tissue, specifically the intracellular concentrations of choline and citrate. Tumors typically display reversal of choline to citrate ratio compared to normal tissues. However, benign prostatic hyperplasia can also demonstrate reversal of calling to citrate ratio which can be confounding. In addition, MRSI leads to longer acquisition times and places significant burden on technical skills and on post processing technique. Hence, MRSI is not commonly performed in routine clinical practice.

### 39.2.2 The Prostate Imaging: Reporting and Data System (PI-RADS):

The need for a global standardization and to assist the rapid growth in the use of multiparametric MRI (mpMRI) for imaging prostate carcinoma led to the development of The Prostate Imaging Reporting and Data System (PI-RADS) by

AdMeTech Foundation's International Prostate MRI Working group. The first iteration of this system was developed by the European Society of Uro-Radiology (PI-RADS version 1) (Barentsz et al. 2012). PIRADS version 1 provided a framework for structured assessment of lesions on mpMRI using the BI-RADS model (Breast Imaging and Reporting Archiving Data system). Indications, minimum and optimum imaging protocols and interpretation were elaborated. Several studies validated the PI-RADS v1 and its value in detecting significant cancer. The adoption of PIRADS v1 was limited due to its potential weakness of combining scores for each sequences derived.

PIRADS v2 which was released online in December 2014 improved upon the previous version by providing an algorithm for deriving an overall assessment using T2 weighted, DWI and DCE MRI. PIRADS version 2 simplified the interpretation of mpMRI. Interpretation of lesions on T2 and DWI were defined. Dominant sequences were defined for peripheral and transitional zones which would supersede the findings in other sequences. In addition, the interpretation of DCE MRI was greatly simplified into a binary assessment of presence or absence of focal early enhancement. A size threshold of 15 mm is suggested for differentiating between T2 weighted and DWI scores of four and five. MRSI which was an optional power meter in PI-RADS version 1 is no longer included in the assessment of lesions in version 2. This has resulted in increased adaptation of PI-RADS v2 by the radiology community. Moderate inter reader agreement has been demonstrated in interpretation with the newer version.

PI-RADS Assessment Categories (Weinreb et al. 2016)

- PI-RADS 1—Very low (clinically significant cancer is highly unlikely to be present)
- PI-RADS 2—Low (clinically significant cancer is unlikely to be present)
- PI-RADS 3—Intermediate (the presence of clinically significant cancer is equivocal)
- PI-RADS 4—High (clinically significant cancer is likely to be present)
- PI-RADS 5—Very high (clinically significant cancer is highly likely to be present)

### 39.2.3 PIRADS Assessment for T2W for Peripheral Zone and Transition Zone

#### 39.2.3.1 Peripheral Zone

1. Uniform high signal intensity
2. Linear or wedge-shaped hypointensity or diffuse mild hypointensity, usually indistinct margin
3. Heterogeneous signal intensity or non-circumscribed, rounded, moderate hypointensity; includes others that do not qualify as 2, 4, or 5
4. Circumscribed, homogenous moderately hypointense focus or mass confined to prostate and <1.5 cm in the greatest dimension
5. Same as 4 but ≥1.5 cm in greatest dimension or definite extraprostatic extension/invasive behaviour

#### 39.2.3.2 Transitional Zone

1. Homogenous intermediate signal intensity
2. Circumscribed hypointense or heterogeneous encapsulated nodule(s) (BPH)
3. Heterogeneous signal intensity with obscured margins. Includes others that do no qualify as 2, 4, or 5
4. Lenticular or non-circumscribed, homogenous moderately hypointense, and <1.5 cm in greatest dimension
5. Same as 4, but ≥1.5 cm in greatest dimension or definite extraprostatic extension/invasive behavior

### 39.2.4 PIRADS Assessment for DWI

Peripheral Zone/Transitional zone

1. No abnormality on ADC or high b-value DWI
2. Indistinct hypo intense on ADC
3. Focal mildly/moderately hypo intense on ADC and isointense/mildly hyper intense on high b-value DWI
4. Focal markedly hypo intense on ADC hyper intense on high b-value DWI; <1.5 cm in greatest dimension
5. Same as 4 but ≥1.5 cm in greatest dimension or definite extra prostatic extension/invasive behavior

**PI-RADS Assessment Category for the peripheral zone (PZ):**

| DWI | T2W | DCE | PI-RADS |
|---|---|---|---|
| 1 | **Any** | **Any** | **1** |
| 2 | **Any** | **Any** | **2** |
| 3 | **Any** | **–**<br>**+** | **3**<br>**4** |
| 4 | **Any** | **Any** | **4** |
| 5 | **Any** | **Any** | **5** |

**PI-RADS Assessment Category for the transition zone (TZ):**

| T2W | DWI | DCE | PI-RADS |
|---|---|---|---|
| 1 | **Any** | **Any** | **1** |
| 2 | **Any** | **Any** | **2** |
| 3 | **≤4**<br>**5** | **Any** | **3**<br>**4** |
| 4 | **Any** | **Any** | **4** |
| 5 | **Any** | **Any** | **5** |

## 39.3 MRI-USG Fusion Prostate Biopsy: Available Platforms and Principles

Targeted biopsy of the prostate can be performed by cognitive fusion, MRI in-bore biopsy, or MRI-Ultrasound fusion. Cognitive fusion involves least resources and personnel, but is highly operator dependent and accuracy may be limited at extremes of prostate (apex, base, far lateral). MRI in-bore biopsy was the first targeted prostate biopsy method described, and was shown to be highly accurate in detecting cancer (Hoeks et al. 2012). However, it has not gained widespread popularity due to cost, long procedure time in MRI suite, and requirement of specialized MRI equipment.

MRI-Ultrasound fusion involves software assisted fusion platform to co-register MRI and Ultrasound images with suspicious MRI lesions shown on real-time ultrasound for targeted biopsy. The biopsy needle track can be detected and stored in the fusion machine for future use, including re-sampling of same lesion in case of active surveillance, or focal therapy in areas with prior positive biopsies. It is more accurate than cognitive fusion, and more user-friendly as transrectal ultrasound guided biopsy (either transrectal or transperineal) is familiar to all Urologists. The disadvantages include high cost of the fusion biopsy machine and the need to familiarize with the hardware and software in fusion biopsy. MRI-Ultrasound fusion biopsy is rapidly gaining popularity worldwide. Many different fusion biopsy machines have appeared in recent years, each with their unique features and mechanisms (Kongnyuy et al. 2016). They differ in terms of needle tracking mechanism, MRI and Ultrasound image registration (rigid or elastic or both), route of biopsy (transrectal, transperineal, or both), and presentation of image and lesion to the operator during biopsy (Table 39.1).

**Table 39.1** A comparison of commonly used MRI-Ultrasound fusion biopsy systems

| System, Manufacturer (No. of systems worldwide)[a] | Ultrasound image acquisition | Tracking mechanism | Image registration method | Biopsy route | Publications | Patient number | Key messages |
|---|---|---|---|---|---|---|---|
| Artemis, Eigen (155) | Manual rotation along a fixed axis on robotic arm | Robotic arm with sensor encoded joints | Elastic | TR | Meng et al. (2016)<br>Sonn et al. (2013) | 601<br>171 | TB diagnosed 35% more Gleason ≥7 and 38% less Gleason 6 cancer<br>TB is 3 times more likely to diagnose cancer, and 38% Gleason ≥7 cancer only diagnosed on TB |
| Urostation or Trinity, Koelis (200) | Automatic scanning at 3 positions | Image based tracking | Elastic | TR | Baco et al. (2016)<br>de Gorski et al. (2015)<br>Portalez et al. (2012) | 175<br>232<br>129 | Cancer detection by 2-core TB is similar to 12-core SB<br>TB detected more cancer than SB in prostate size >40ml<br>Cancer detection per core for TB is 36%, SB is 5% |
| Uronav, Invivo/Philips | Manual freehand sweep | Electromagnetic tracking | Elastic | TR | Siddiqui et al. (2015)<br>Salami et al. (2015a, b) | 1003<br>140 | TB diagnosed 30% more high risk and 17% less low risk prostate cancers<br>TB diagnosed 17.2% more clinically significant cancer |
| Virtual Navigator (Esaote) | Manual freehand sweep | Electromagnetic tracking | Rigid | TR | Delongchamps et al. (2013) | 258 | TB diagnosed 9% more clinically significant cancer, and 18% less insignificant cancer |
| Real-time Virtual Sonography RVS (Hitachi) | Real-time biplanar ultrasound | Electromagnetic tracking | Rigid | TR/TP | Miyagawa et al. (2010)<br>Zhang et al. (2015) | 85<br>62 | 35% cancer only diagnosed on TB<br>TB diagnosed 28% more clinically significant cancer |
| Biojet (D&K) | Automatic scanning with probe on robotic arm | Robotic arm with sensor encoded joints | Rigid | TR/TP | Borkowetz et al. (2015)<br>Porpiglia et al. (2017) | 263<br>212 | TB diagnosed 44% more clinically significant cancer<br>MRI and TB diagnosed 25.8% more significant cancer than SB |
| BiopSee (Pi Medical/MedComs) | Biplanar probe on stepper | Stepper with build-in sensors | Rigid | TP | Radtke et al. (2015) | 294 | TB+SB detected similar clinically significant cancer compared with saturation biopsy |

[a]Until August 2017, *TR* transrectal, *TP* transperineal, *TB* targeted biopsy, *SB* systematic biopsy

### 39.3.1 Real-Time Needle Tracking

Real-time needle tracking is required in fusion biopsy to confirm biopsy positions. All available systems utilize one of the three major needle tracking mechanisms: Robotic arm with position encoders in joints, Electromagnetic tracking, and Image based software tracking (Fig. 39.1).

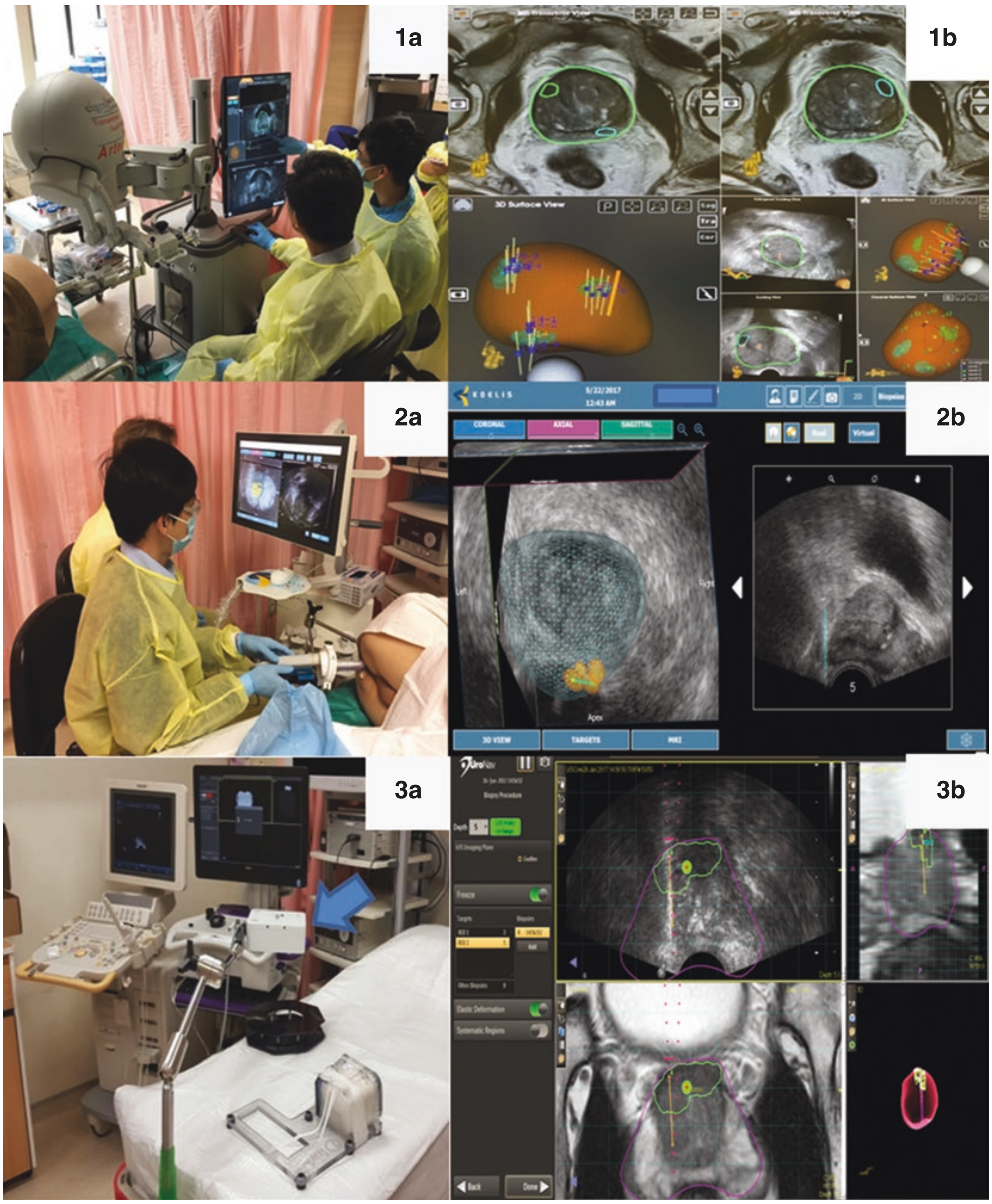


**Fig. 39.1** Fusion biopsy machines with different needle tracking mechanisms (**1a**, **2a**, **3a**, **4a**) and respective screen shots during fusion biopsy done under local anaesthesia (**1b**, **2b**, **3b**, **4b**). **1a**, Robotic arm with sensor encoded joints (Artemis, Eigen), require additional ultrasound machine; **1b**, Green line (prostate border on MRI) overlaps with real-time ultrasound using elastic fusion, and target lesion reached with rotation of robotic arm over a fixed axis; **2a**, Image based tracking (Trinity, Koelis) with intrinsically incorporated ultrasound, and option of mechanical probe holder (Steady Pro); **2b**, Elastic fusion, Needle path of a biopsy core targeting a very apical lesion; **3a**, Electromagnetic tracking (Uronav, Invivo/Philips) with magnetic field generator (blue arrow), require additional ultrasound machine; **3b**, MRI prostate border (purple) and Biopsy needle track going right through an anterior lesion (green); **4a**, Electromagnetic tracking (Virtual Navigator, Esaote) with intrinsically incorporated ultrasound, and magnetic field generator (blue arrow); **4b**, MRI image (yellow shadow) overlapping on a ultrasound image of slightly deformed prostate with transrectal probe in-situ. Anatomical landmarks (bladder neck, rectum, pubic bone, urethra) needed to facilitate manual rigid fusion

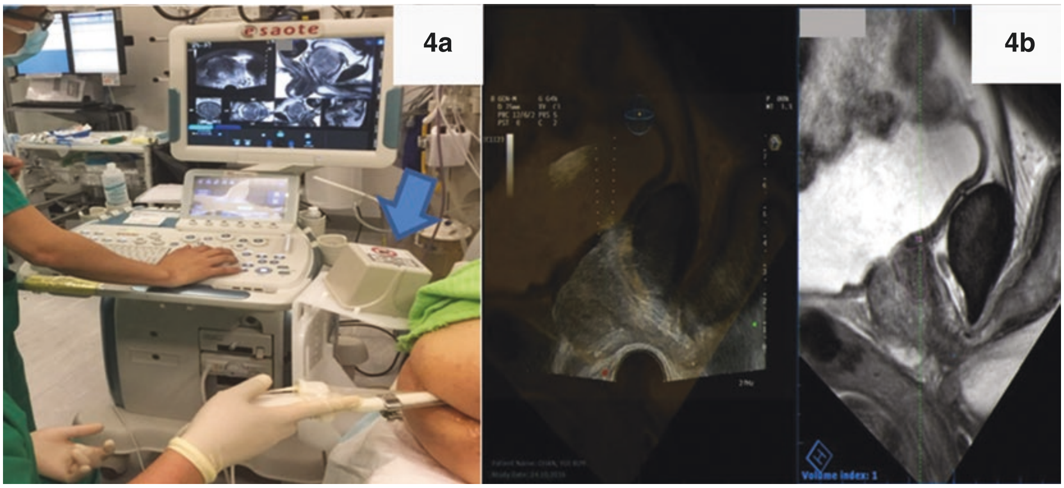


**Fig. 39.1** (continued)

#### 39.3.1.1 Robotic Arm with Position Encoders in Joints

A robotic arm is directly attached to the fusion biopsy machine, and position of the probe and needle is detected by the sensors in the robotic arm joints. The 3-dimensional ultrasound image is acquired by probe rotation along a fixed axis. The movements of the probe are mainly by in-out or rotation. A robotic arm has the advantages of a steady probe position (which eliminates probe pressure variations throughout the procedure) and operator's comfort when the probe does not need to be held. However, the degree of freedom is less compared with systems with freehand probe, and the manipulation of robotic arm may increase the learning curve. Examples of fusion biopsy systems using robotic arm include Artemis (Eigen) (Mendhiratta et al. 2015; Meng et al. 2016; Sonn et al. 2013), Biojet (BK) (Borkowetz et al. 2015; Porpiglia et al. 2017), and BiopSee (Medcom) (Radtke et al. 2015).

#### 39.3.1.2 Electromagnetic Tracking

Electromagnetic field is generated by a magnetic field generator next to the patient and current is generated at the transrectal probe and relayed to the fusion machine to create a 3-dimensional ultrasound image. The use of a freehand probe provides a higher degree of freedom and ease of use. The disadvantages are potential difficulty in keeping a constant probe pressure at freehand, and reduced accuracy when the probe is located further away from the field generator (e.g. during patient movement). Examples of fusion biopsy system using electromagnetic tracking include Uronav (Invivo) (Siddiqui et al. 2015; Salami et al. 2015a, b), Virtual netvigator (Esoate) (Delongchamps et al. 2013), and Real time virtual sonography RVS (Hitachi) (Miyagawa et al. 2010; Zhang et al. 2015).

#### 39.3.1.3 Image Based Software Tracking

This type of needle tracking does not need any external magnetic field generator or robotic arm. Instead, the system relies on the real-time Ultrasound images alone to track probe and needle position with a freehand probe. Before every targeted biopsy core, an automatic 3D ultrasound scanning of the whole prostate will be performed (Virtual biopsy) to confirm the needle trajectory falls onto the target. If it is off target, adjustment of the probe position and repeated ultrasound scanning will be needed to confirm position. After firing of the biopsy needle, another 3D ultrasound scanning will be retrospectively performed to match the needle track on ultrasound to the reference prostate. Repeated 3D ultrasound scanning ensures accurate elastic fusion at every biopsy core, and eliminates the need of motion compensation when the patient moves. The disadvantage includes the lack of real-time lesion targeting, learning curve in this unique targeting mechanism and the need of a stable probe position (by the operator) during ultrasound scanning and biopsy. There is so far only one fusion machine using this sole mechanism of needle tracking: Urostation/Trinity (Koelis) (Baco et al. 2016; de Gorski et al. 2015; Portalez et al. 2012).

## 39.4 The Elements of a Successful MRI USG Fusion Biopsy Program

An MRI-Ultrasound fusion biopsy is a multi-disciplinary effort, and a successful MRI-Ultrasound fusion biopsy program involves:

1. A standardized multi-parametric MRI prostate scanning protocol

2. Accurate and standardized reporting of MRI prostate
3. Accurate MRI-Ultrasound fusion biopsy
4. Multidisciplinary meetings with radiologists, Urologists and pathologists for review of results and improvement of program

### 39.4.1 A Standardized Multi-parametric MRI Prostate Scanning Protocol

A standardized MRI prostate scanning protocol should only include the essential sequences for the radiologists to provide accurate reporting of suspicious lesions, including T1W, T2W, diffusion weighted imaging (DWI) with ADC mapping, and dynamic contrast enhanced (DCE) sequences. An average multi-parametric MRI scan should take around 30–45 min depending on machine and efficiency. The DCE sequence would provide an upgrade of PI-RADS scoring from 3 to 4 in peripheral zone with area of restricted diffusion. For some radiologists, a DCE sequence also gives extra reassurance in defining a suspicious lesion. In biopsy programs where all PI-RADS 3 or above lesions will be biopsied and in situations outside a research setting, a DCE sequence may be omitted to save MRI scanning time. In the setting of a screening MRI, only T2W and DWI may be needed to reduce scanning time to less than 15 min.

### 39.4.2 Accurate and Standardized Reporting of MRI Prostate

Accurate reporting of MRI prostate is one of the keys in any targeted biopsy program. Dedicated and trained radiologists and MRI prostate is essential to ensure the reporting is standardized (PI-RADS) and accurate. It is common for inexperienced radiologists to report lesions of low suspicion of cancer (PIRADS 2) as equivocal or suspicious (PI-RADS 3 or above). It is actually not uncommon for larger (>1.5 cm) BPH nodules in transitional zone to be labelled as PI-RADS 5 due to size criteria. This would result in a lot of unnecessary biopsies and low cancer detection rates for suspicious lesions (PI-RADS 3, 4 or 5), resulting in an unsuccessful biopsy program. Whether there is restricted diffusion depends a lot on ADC values. There is no definite ADC cutoff in defining restricted diffusion or not as it varies in different MRI machines and protocols. Radiologists need to be familiar with their own MRI machine and have an appropriate cutoff for their own setting. Continuous correlation of MRI suspicious lesions with pathology results is essential in improving accuracy of MRI reporting.

### 39.4.3 Accurate MRI-Ultrasound Fusion Biopsy

In most transrectal software assisted fusion biopsy program, the biopsy workflow includes:

1. Segmentation of prostate
2. Anaesthesia
3. Co-registration of Ultrasound and MRI data
4. Targeted biopsy

#### 39.4.3.1 Segmentation of Prostate in MRI Images

Segmentation is the process of delineating the prostate borders on MRI images in the fusion biopsy system. It can be done prior to the biopsy date to save time on biopsy day. Most systems use T2W images as most suspicious lesions are seen, but DWI images would be helpful in marking lesions with restricted diffusion in peripheral zone. Most software in fusion biopsy systems provide automated assistance in defining prostate borders, but manual fine adjustment of the borders is essential to achieve perfect segmentation. Segmentation is usually done in the axial plane, with further fine adjustments of extreme borders (base, apex, lateral) in the sagittal and coronal planes. The marking of suspicious lesions during segmentation is preferably done by a dedicated radiologist or Urologist with a lot of experience in reading MRI prostates, as accurate localization of index lesion in this step is very important.

#### 39.4.3.2 Anaesthesia

Effective anaethesia is essential in keeping the patient static during a fusion biopsy procedure. A patient moving due to pain during biopsy needle insertion would lead to inaccurate targeting. The type of anaesthesia depends on the route of biopsy. Most transperineal biopsies require general or spinal anaesthesia. Transrectal biopsies can usually be done under local anaesthesia only, but in the case of a very sensitive patient or if the local block is not effective, additional sedation might be required. If the patient moves after co-registration and targeting, the biopsies would very likely be inaccurate even when the biopsy path is directed towards the intended marked target. Some fusion machines have some degree of motion compensation to correct for a moved prostate in the axial plane, but multiple corrections would still increase the error, especially when the prostate movement is not solely in the axial plane. It is always the best scenario to have the patients' movements eliminated under general or spinal anaesthesia, but this is associated with higher cost, operative room time, and anaesthetic risk to the patients.

The peri-prostatic block with 1% lignocaine needs to target the triangular area (or Mount Everest) between the prostate and the seminal vesicles. An ultrasonic wheal should appear with separation of seminal vesicles and prostate from the rectal wall. (Soloway and Obek 2000; Nash et al. 1996) Further injection of local anaesthesia can be done at apex on either side to achieve better anaesthesia, with similar opening up of space between rectal wall and prostate after injection. Apex infiltration of local anaesthesia helps especially in the case for more apical or anterior lesions. Local anaesthesia should be done prior to co-registration of MRI and Ultrasound images.

#### 39.4.3.3 Co-registration of Ultrasound and MRI Data

After segmentation of the prostate in MRI images, the second part is to scan the prostate with ultrasound, acquiring three-dimensional ultrasound images. This is achieved either by semi-automatic or manual scanning of prostate. Manual scanning requires more experience as the speed and consistency of probe scanning relies on the operator. The prostate should lie within the scanning boundaries and the ultrasonic depth and focus should be adjusted to suit the size of the prostate. The ultrasound probe pressure onto the prostate is important as too much pressure on the prostate would lead to a deformed prostate, while too little pressure (or too far away) would lead to inferior ultrasound images. A deformed prostate would reduce the accuracy especially in machines with rigid fusion mechanism as it would be grossly different from that in MRI images. Even in machines with elastic fusion function, a grossly deformed prostate on ultrasound (compared with MRI) would also require a higher degree of software correction and possible lower accuracy. It is also important that the probe pressure during ultrasound image acquisition is similar to that during biopsy.

After the ultrasound images of the prostate are acquired, ultrasonic segmentation in all three planes (axial, sagittal, and coronal) is needed to define the prostate. Co-registration is then performed either automatically by the software, or manually by matching the key anatomical points like the prostatic apex, bladder neck, urethra, prostatic cysts, and pubic bone. The accuracy of co-registration is likely inferior in the case of manual co-registration especially in cases of irregularly-shaped prostates or when the anatomical landmarks are not easily identifiable.

The fusion of ultrasound and MRI images is either done under rigid or elastic fusion. Some machines utilize rigid fusion (e.g. Esaote Virtual Navigator, Hitachi Real-time Virtual Sonography), while others provide elastic fusion also (e.g. Eigen Artemis, Koelis Urostation/Trinity, Uronav Invivo). The prostate is invariably compressed by a certain degree after insertion of the transrectal ultrasound probe, and systems utilizing rigid fusion would require the operator to cognitively correct for the discrepancy between MRI and Ultrasound images. This problem is more prominent when the target lesion is in the peripheral zone, where the pre-marked MRI target may be situated outside the prostate (e.g. in the rectal wall) on real-time ultrasound screen. Although elastic fusion has the advantage of reducing the discrepancy between the shape of prostate on MRI and Ultrasound, the resulting anatomic distortion in order to match two datasets with discrepancies may carry inaccuracy unknown to the operator. Besides, elastic fusion is not a substitute for meticulous segmentation. Accurate elastic fusion would not occur if the prostate borders are not well defined in both MRI and ultrasound images. Although elastic fusion sounds more accurate than rigid fusion, a systematic review comparing 11 papers using elastic fusion and 10 papers using rigid fusion showed that the prostate cancer detection rate was actually similar (Venderink et al. 2018).

In using rigid fusion systems, experience in locating ultrasonic changes corresponding to the MRI lesions and cognitive correction of the image discrepancy could lead to good results. (Puech et al. 2013) Another study have also shown that MRI in-bore targeted biopsy showed no significant difference in cancer detection rate compared with cognitive targeted biopsy in small sized prostates (median 40 ml) with a median lesion size of 10–12 mm (Yaxley et al. 2017). However, it would definitely be a challenge for cognitive fusion or software-based rigid fusion systems in cases of larger prostates (>100 ml), smaller lesions (<5 mm), or lesions locating in extreme positions of prostate. It should be noted that for larger prostates (e.g. more than 150 ml), the accuracy of elastic fusion may decrease and some elastic fusion systems might not work properly.

#### 39.4.3.4 Targeted Biopsy

It is preferable to perform targeted biopsy before systematic biopsy, in order to reduce artefacts related to hemorrhage, pain, or patient's movements. In systems with the advantage of real-time motion compensation (e.g. Artemis, Uronav), any discrepancy in co-registration of MRI and ultrasound prostate borders need to be closely monitored and corrected. Although TRUS lesion is not commonly used for prostate cancer diagnosis due to limited specificity and sensitivity, it is not uncommon to see hypoechogenic areas at the site of MRI targeted lesion. If there is small discrepancy between the targeted area and ultrasonic lesion, it would be wise to add a core targeting the ultrasonic lesion.

Deflection of needle may occur in some prostates and it may deviate from the intended trajectory. This is more common in the case of more anterior lesions where the error related to deflection would be magnified. A stiffer biopsy needle or some degree of cognitive correction might be needed to direct the needle tip to the intended location. Prostate deformation may occur in some prostates during needle insertion for deeper lesions, and may lead to inaccurate recognition of the biopsy needle path by the system. It is advisable to insert the biopsy needle until it reaches the firing position, slightly pull back the biopsy needle tip to return the prostate to its original shape, and fire. At least two biopsy cores are recommended to be taken from each target to allow for error in the targeting process. (AUA and SAR 2016; Hong et al. 2015) Additional cores may be taken in larger lesions or when there is limited targeting accuracy. It cannot be over-emphasized that the probe pressure on the prostate should be kept similar to the time when co-registration was done to ensure accurate fusion. A robotic arm or probe holder may help to maintain a steady position but in the end it is the operator who controls it.

When systemic biopsy is omitted during a targeted biopsy, the chance of missing significant prostate cancers is in the range of 4–23%, depending on the number of prior negative systematic biopsies (Arsov et al. 2015; Abdi et al. 2015; Salami et al. 2015a, b; Sonn et al. 2014; Vourganti et al. 2012). It is recommended to do a concurrent systematic biopsy.

There is a certain learning curve in fusion prostate biopsy. A study demonstrated increasing detection of significant cancer in in later stages of a large cohort of >1500 fusion biopsies. (Calio et al. 2017) Another study demonstrated a significantly shorter biopsy time (25 vs 45 min) and higher target biopsy detection quotient after about 40 cases (Mager et al. 2017).

### 39.4.4 Multidisciplinary Meetings with Radiologists, Urologists and Pathologists for Review of Results and Improvement of Program

A successful fusion biopsy program relies on multi-disciplinary inputs, and regular audit meetings would enhance quality and provide feedback to Urologists, radiologists and pathologists (Tay et al. 2016; Vourganti et al. 2017). A comparison of positive biopsy rates for lesions with different PI-RADS score with that reported in the literature would be helpful. Pathology results including both biopsy results and corresponding whole mount radical prostatectomy specimen are also essential in improving skills of MRI reporting and targeted biopsy.

## 39.5 Current Status in Asia

Comparing with the Caucasian literature, Asian reports in image fusion prostate biopsy are sparse. Factors associated with the delayed development of fusion targeted prostate biopsy in Asia include overall lower prostate cancer incidences compared with the West, less profound use of PSA screening in Asian countries in the past, learning curve of uro-radiologists in reading mpMRI, and the more intense health economic demands in developing Asian countries. Cognitive fusion rather than MRI-US fusion technology is currently more widely adopted in Asia, attributed by the unavailability of image fusion device in most urology centers. Studies have shown comparable improvement in cancer detection rate using cognitive fusion for targeted prostate biopsy when compared with Western literature (Lee et al. 2016; Washino et al. 2017). The overall cancer detection rate by cognitive fusion was not increased compared with conventional TRUS biopsy, but there is significant improvement in detection of clinically significant caner (Lee et al. 2016). However, cognitive fusion biopsy technique relies on an experienced operator, thus suffering from operator handling error. This error is especially prominent when targeting smaller lesions on mpMRI. The negative predictive value of PI-RADS version 2 with cognitive fusion was relatively low (Washino et al. 2017). Another source of error in Asia mpMRI cognitive fusion studies was a lower inter-observer concordance on the PI-RADS v2 score when compared with Caucasian data (Zhao et al. 2016; Purysko et al. 2017). This may be due to differences in MRI machines, MRI protocols, variability in experiences of PI-RADS scoring, and differences in patient characteristics.

With the gradual improvement of radiological expertise in mpMRI of prostate and dedication in overcoming the limitations of cognitive fusion biopsy, image fusion devices were increasingly utilized in some Asian urology centers in recent years for targeted biopsy. Among different fusion devices, Hitachi RVS and Eigen Artemis were the two devices with more Asian studies published (Table 39.2). Most series have demonstrated substantial improvement in detecting clinically significant prostate cancer (Zhang et al. 2015; Bansal et al. 2017; Lian et al. 2017; Ma et al. 2017). While the Artemis system is currently available for transrectal approach only at the time of the studies, studies on the Hitachi RVS include both transrectal and transperineal approaches. The benefit of fusion targeted biopsy has been shown in a study including Chinese patients undergoing initial biopsy, demonstrating its potentially more promising benefit in reducing unnecessary biopsies in Asian countries (Ma et al. 2017), although more large scale studies are awaited. Apart from those devices approved by the US FDA, a robotic fusion device was designed and developed in Singapore with promising initial results, although larger series publication for this device is awaited. Even though effective, MRI/TRUS fusion biopsy is more expensive than cognitive fusion biopsy due to its requirement of a specific device and computer software. To date, there is no prospective trial in Asia directly comparing cognitive fusion and software image fusion technique in detecting clinically significant prostate cancer.

**Table 39.2** Software fusion prostate biopsy studies in Asia published in English language

| Year | Author | n | Route of biopsy | Fusion platform | Age | PSA (ng/ml) | Prostate volume (ml) | Overall CDR[a] | | Clinically significant cancer CDR[a] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Random biopsy | Targeted biopsy | Random biopsy | Targeted biopsy |
| 2010 | Miyagawa T | 85 | Transrectal | Hitachi RVS | 69 | 9.9 | 37.2 | 40.0% | 52.9% | NR[b] | NR |
| 2015 | Zhang Q | 62 | Transperineal | Hitachi RVS | 68.38 | 10.21 | 34.05 | 33.9% | 43.5% | 23.8% | 51.9% |
| 2017 | Bansal S | 96 | Transrectal | Eigen Artemis | 64.4 | 8.6 | 41.0 | 53.1% | 51.0% | 66.7% | 73.7% |
| 2017 | Lian H | 101 | Transperineal | Hitachi RVS | 68.9 | 10.8 | 42.1 | 26.7% | 30.7% | 48.1% | 71.0% |
| 2017 | Ma WK | 57 | Transrectal | Eigen Artemis | 66.2 | 8.5 | 40.2 | 17.6% | 19.3% | 59.1% | 87.5% |

[a]CDR: cancer detection rate
[b]NR: not reported

## 39.6 Conclusion

For both initial and repeated biopsies of prostate, the addition of MRI and targeted biopsy to routine systematic biopsy has been shown to increase detection of clinically significant prostate cancer across all available studies. MRI-Ultrasound fusion biopsy is the most commonly reported method of targeted prostate biopsy in the literature. A standardized MRI scanning protocol and PI-RADS reporting system is important, but accurate reporting from experienced MRI radiologists is equally important. Similarly good results have been reported from fusion biopsy machines with different needle tracking strategies, and none of them have been shown to be superior to another. The option of elastic fusion reduces the need of manual and cognitive adjustments during biopsy as in the case of rigid fusion, but cancer detection rates are similar in both methods. Continuous auditing of biopsy results and multi-disciplinary meetings are essential for all parties (Urologist, Radiologist, and Pathologist) to learn and improve in order to achieve the best results. Fusion prostate biopsy in Asia started later than the West, but more and more Asian Urology centres have started a Fusion biopsy program in recent years and exponential growth is expected in the near future.

## References

Abdi H, Zargar H, Goldenberg SL, et al. Multiparametric magnetic resonance imaging-targeted biopsy for the detection of prostate cancer in patients with prior negative biopsy results. Urol Oncol. 2015;33(4):165.e1–7.

Ahmed HU, El-Shater Bosaily A, Brown LC, et al. Diagnostic accuracy of multi-parametric MRI and TRUS biopsy in prostate cancer (PROMIS): a paired validating confirmatory study. Lancet. 2017;389(10071):815–22.

American Urological Association (AUA) and Society of Abdominal Radiology (SAR) Joint Consensus Statement. Prostate MRI and MRI-targeted biopsy in patients with prior negative biopsy. Collaborative initiative of the American Urological Association and the Society of Abdominal Radiology's Prostate Cancer Disease-Focused Panel. 2016. https://c.ymcdn.com/sites/abdominalradiology.site-ym.com/resource/resmgr/Edu_DFPprostate/AUA-SAR.pdf.

Arsov C, Rabenalt R, Blondin D, et al. Prospective randomized trial comparing magnetic resonance imaging (MRI)guided in-bore biopsy to MRI-ultrasound fusion and transrectal ultrasound-guided prostate biopsy in patients with prior negative biopsies. Eur Urol. 2015;68(4):713–20.

Baco E, Rud E, Eri LM, et al. A randomized controlled trial to assess and compare the outcomes of two-core prostate biopsy guided by fused magnetic resonance and transrectal ultrasound images and traditional 12-core systematic biopsy. Eur Urol. 2016;69:149–56.

Bansal S, Gupta NP, Yadav R, et al. Multiparametric magnetic resonance imaging-transrectal ultrasound fusion prostate biopsy: a prospective, single centre study. Indian J Urol. 2017;33(2):134–9.

Barentsz JO, Richenberg J, Clements R, et al. ESUR prostate MR guidelines 2012. Eur Radiol. 2012;22(4):746–57.

Bjurlin MA, Meng X, Le Nobin J, et al. Optimization of prostate biopsy: the role of magnetic resonance imaging targeted biopsy in detection, localization and risk assessment. J Urol. 2014;192(3):648–58.

Borkowetz A, Platzek I, Toma M, et al. Comparison of systematic transrectal biopsy to transperineal magnetic resonance imaging/ultrasound-fusion biopsy for the diagnosis of prostate cancer. BJU Int. 2015;116:873–9.

Calio B, Sidana A, Sugano D, et al. Changes in prostate cancer detection rate of MRI-TRUS fusion vs systematic biopsy over time: evidence of a learning curve. Prostate Cancer Prostatic Dis. 2017;20(4):436–41.

Chen R, Ren S, Chinese Prostate Cancer Consortium, et al. Prostate cancer in Asia: a collaborative report. Asian J Urol. 2014;1(1):15–29.

Delongchamps NB, Peyromaure M, Schull A, et al. Prebiopsy magnetic resonance imaging and prostate cancer detection: comparison of random and targeted biopsies. J Urol. 2013;189:493–9.

Dickinson L, Ahmed HU, Allen C, et al. Magnetic resonance imaging for the detection, localisation, and characterisation of prostate cancer: recommendations from a European consensus meeting. Eur Urol. 2011;59(4):477–94.

Futterer JJ, Briganti A, De Visschere P, et al. Can clinically significant prostate cancer be detected with multiparametric magnetic resonance imaging? A systematic review of the literature. Eur Urol. 2015;68:1045–53.

de Gorski A, Roupret M, Peyronnet B, et al. Accuracy of magnetic resonance imaging/ultrasound fusion targeted biopsies to diagnose clinical significant prostate cancer in enlarged compared to smaller prostates. J Urol. 2015;194:669–73.

Halpern JA, Shoag JE, Artis AS, et al. National trends in prostate biopsy and radical prostatectomy volumes following the US Preventive Services Task Force guidelines against prostate-specific antigen screening. JAMA Surg. 2017;152(2):192–8.

Hoeks CM, Schouten MG, Bomers JG, et al. Three-Tesla magnetic resonance-guided prostate biopsy in men with increased prostate-specific antigen and repeated, negative, random, systematic, transrectal ultrasound biopsies: detection of clinically significant prostate cancers. Eur Urol. 2012;62(5):902–9.

Hong CW, Rais-Bahrami S, Walton-Diaz A, et al. Comparison of magnetic resonance imaging and ultrasound (MRI-US) fusion guided prostate biopsies obtained from axial and sagittal approaches. BJU Int. 2015;115(5):772–9.

Ikonen S, Kivisaari L, Vehmas T, et al. Optimal timing of post-biopsy MR imaging of the prostate. Acta Radiol. 2001;42(1):70–3.

Katahira K, Takahara T, Kwee TC, et al. Ultra-high-b-value diffusion-weighted MR imaging for the detection of prostate cancer: evaluation in 201 cases with histopathological correlation. Eur Radiol. 2011;21(1):188–96.

Kongnyuy M, George AK, Rastinehad AR, et al. Magnetic resonance imaging-ultrasound fusion-guided prostate biopsy: review of technology, techniques, and outcomes. Curr Urol Rep. 2016;17(4):32.

Lee DH, Nam JK, Park SW, et al. Visually estimated MRI targeted prostate biopsy could improve the detection of significant prostate cancer in patients with a PSA level <10 ng/mL. Yonsei Med J. 2016;57(3):565–71.

Lian H, Zhuang J, Wang W, et al. Assessment of free-hand transperineal targeted prostate biopsy using multiparametric magnetic resonance imaging-transrectal ultrasound fusion in Chinese men with prior negative biopsy and elevated prostate-specific antigen. BMC Urol. 2017;17(1):52.

Ma WK, Ho BS, Lai AS, et al. Multiparametric magnetic resonance imaging/transrectal ultrasound fusion prostate biopsy with semi-robotic navigation in the Chinese population: initial results. Asian J Androl. 2017;20(1):93–4. https://doi.org/10.4103/1008-682X.196855.

Mager R, Brandt MP, Borgmann H, et al. From novice to expert: analyzing the learning curve for MRI-transrectal ultrasonography

fusion-guided transrectal prostate biopsy. Int Urol Nephrol. 2017;49(9):1537–44.
Mendhiratta N, Rosenkrantz AB, Meng X, et al. MRI-ultrasound fusion-targeted prostate biopsy in a consecutive cohort of men with no previous biopsy: reduction of over-detection through improved risk stratification. J Urol. 2015;194:1601–6.
Meng X, Rosenkrantz AB, Mendhiratta N, et al. Relationship between prebiopsy multiparametric magnetic resonance imaging (MRI), biopsy indication, and MRI-ultrasound fusion-targeted prostate biopsy outcomes. Eur Urol. 2016;69:512–7.
Miyagawa T, Ishikawa S, Kimura T, et al. Real-time Virtual Sonography for navigation during targeted prostate biopsy using magnetic resonance imaging data. Int J Urol. 2010;17(10):855–60.
Moore CM, Robertson NL, Arsanious N, et al. Image-guided prostate biopsy using magnetic resonance imaging-derived targets: a systematic review. Eur Urol. 2013;63(1):125–40.
Nash PA, Bruce JE, Indudhara R, et al. Transrectal ultrasound guided prostatic nerve blockade eases systematic needle biopsy of the prostate. J Urol. 1996;155(2):607–9.
Porpiglia F, Manfredi M, Mele F, et al. Diagnostic pathway with multiparametric magnetic resonance imaging versus standard pathway: results from a randomized prospective study in biopsy-naïve patients with suspected prostate cancer. Eur Urol. 2017;72(2):282–8.
Portalez D, Mozer P, Cornud F, et al. Validation of the European Society of Urogenital Radiology scoring system for prostate cancer diagnosis on multiparametric magnetic resonance imaging in a cohort of repeat biopsy patients. Eur Urol. 2012;62:986–96.
Puech P, Rouvière O, Renard-Penna R, et al. Prostate cancer diagnosis: multiparametric MR-targeted biopsy with cognitive and transrectal US-MR fusion guidance versus systematic biopsy—prospective multicenter study. Radiology. 2013;268:461–9.
Purysko AS, Bittencourt LK, Bullen JA, et al. Accuracy and interobserver agreement for prostate imaging reporting and data system, version 2, for the characterization of lesions identified on multiparametric MRI of the prostate. Am J Roentgenol. 2017;209(2):339–49.
Radtke JP, Kuru TH, Boxler S, et al. Comparative analysis of transperineal template saturation prostate biopsy versus magnetic resonance imaging targeted biopsy with magnetic resonance imaging-ultrasound fusion guidance. J Urol. 2015;193:87–94.
Salami SS, Ben-Levi E, Yaskiv O, et al. In patients with a previous negative prostate biopsy and a suspicious lesion on magnetic resonance imaging, is a 12-core biopsy still necessary in addition to a targeted biopsy? BJU Int. 2015a;115:562–70.
Salami SS, Ben-Levi E, Yaskiv O, et al. In patients with a previous negative prostate biopsy and a suspicious lesion on magnetic resonance imaging, is a 12-core biopsy still necessary in addition to a targeted biopsy? BJU Int. 2015b;115(4):56270.
Siddiqui MM, Rais-Bahrami S, Turkbey B, et al. Comparison of MR/ultrasound fusion-guided biopsy with ultrasound-guided biopsy for the diagnosis of prostate cancer. JAMA. 2015;313:390–7.
Soloway MS, Obek C. Periprostatic local anesthesia before ultrasound guided prostate biopsy. J Urol. 2000;163(1):172–3.
Sonn GA, Chang E, Natarajan S, et al. Value of targeted prostate biopsy using magnetic resonance-ultrasound fusion in men with prior negative biopsy and elevated prostate-specific antigen. Eur Urol. 2014;65(4):809–15.
Sonn GA, Natarajan S, Margolis DJ, et al. Targeted biopsy in the detection of prostate cancer using an office based magnetic resonance ultrasound fusion device. J Urol. 2013;189:86–91.
Tay KJ, Gupta RT, Rastinehad AR, et al. Navigating MRI-TRUS fusion biopsy: optimizing the process and avoiding technical pitfalls. Expert Rev Anticancer Ther. 2016;16(3):303–11.
Venderink W, de Rooij M, Sedelaar JPM, et al. Elastic versus rigid image registration in magnetic resonance imaging-transrectal ultrasound fusion prostate biopsy: a systematic review and meta-analysis. Eur Urol Focus. 2018;4(2):219–27.
Vourganti S, Rastinehad A, Yerram NK, et al. Multiparametric magnetic resonance imaging and ultrasound fusion biopsy detect prostate cancer in patients with prior negative transrectal ultrasound biopsies. J Urol. 2012;188(6):2152–7.
Vourganti S, Starkweather N, Wojtowycz A. MR/US fusion technology: what makes it tick? Curr Urol Rep. 2017;18(3):20.
Washino S, Okochi T, Saito K, et al. Combination of prostate imaging reporting and data system (PI-RADS) score and prostate-specific antigen (PSA) density predicts biopsy outcome in prostate biopsy naïve patients. BJU Int. 2017;119(2):225–33.
Weinreb JC, Barentsz JO, Choyke PL, et al. PI-RADS prostate imaging—reporting and data system: 2015, Version 2. Eur Urol. 2016;69(1):16–40.
Welch HG, Fisher ES, Gottlieb DJ, et al. Detection of prostate cancer via biopsy in the Medicare-SEER population during the PSA era. J Natl Cancer Inst. 2007;99(18):1395–400.
Yaxley AJ, Yaxley JW, Thangasamy I, et al. Comparison between target MRI in-gantry and cognitive target transperineal or transrectal guided prostate biopsies for PIRADS 3-5 MRI lesions. BJU Int. 2017;120(Suppl 3):43–50.
Zhang Q, Wang W, Yang R, et al. Free-hand transperineal targeted prostate biopsy with real-time fusion imaging of multiparametric magnetic resonance imaging and transrectal ultrasound: single-center experience in China. Int Urol Nephrol. 2015;47(5):727–33.
Zhao C, Gao G, Fang D, et al. The efficiency of multiparametric magnetic resonance imaging (mpMRI) using PI-RADS Version 2 in the diagnosis of clinically significant prostate cancer. Clin Imaging. 2016;40:885–8.