Textbook of Gynecologic Robotic Surgery

Alaa El-Ghobashy
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I would like to thank my parents, wife (Abeer), and children (Maiar, Mirna, Amy) for their support and care throughout the journey of this textbook.

Alaa El-Ghobashy

I would like to thank my life partner, Andrea, for her unconditional support and for her acceptance of the time I dedicated to this project.

Javier Magrina

Preface

Surgical practice has undergone significant evolution over the past few decades from open access through to laparoscopy approach to most recently robotic techniques. Since the first description of robotic hysterectomy in 2005, the technique has gained popularity and its indications have broadened. Therefore, it was timely to offer a comprehensive review of the present status of robotic surgery in gynecology using the *Da Vinci* system.

This book is not only a compilation of the knowledge and experiences of the world renowned robotic surgeons, but it has also incorporated the recent advances and updates in gynecological surgery.

The textbook is aimed at practicing gynecologists, urogynecologists, and gynecological oncologists and is designed to provide a detailed guide to common robotic gynecologic procedures for the purpose of helping novice surgeons in their transition to robotic surgery and seasoned robotic surgeons to refine their surgical technique and expand their repertoire of robotic procedures.

The descriptive, step-by-step, text is complemented by figures, intraoperative photographs, and videos detailing the nuances of each procedure. Emphasis is placed on the operative setup, instrument and equipment needs, and surgical techniques for both the primary surgeon and the operative assistant.

This edition will provide unique insights into robotic gynecologic surgery and reduce the learning curve of accomplishing these increasingly popular procedures.

We would like to express our deepest thanks and gratitude to all the contributors, who so graciously have given their time and effort, and without whom this book would not have been born. There are many more people who have made this book possible specially Springer who supported this project since its inception. To all, thank you for the advice and help and for making this book a reality.

Alaa El-Ghobashy
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The Development of Robotic Surgery: Evolution or Revolution?

1

John H. Shepherd and Marielle Nobbenhuis

A Historical Perspective

The history of mechanical automatons can be traced back to the ancient world with the development of the earliest mechanical machinery. During the fourth century BC, the Greek mathematician Archytas designed a mechanical bird, 'the pigeon' driven by steam. In 320 BC Aristotle postulated that automatons would replace human slavery. He quoted Greek mythology in which Hephaestus, the Greek god of craftsmen, created three-legged tables that could action under their own power.

In the twelfth century Al-Jazari, a Muslim inventor designed automated machines that could play music and carry out simple duties. Villard de Honnecourt in the thirteenth century created similar machines. At the end of that century, Robert of Artouis designed and built a number of humanoid and animal robots displayed in his castle at Hesdin. It was some time later in 1495 that Leonardo da Vinci made several drawings of a mechanical knight in armour which was able to move its limbs and head (Fig. 1.1) [1].

This was based on his anatomical sketches and research described in the 'Vitruvian Man'. There is no record as to whether the robot was in fact built. The following century Johannes Müller designed and built an automated eagle made of iron that did fly. Descartes, in his 'Discourse on the Method', 1657, postulated that automatons could be made by man but did not predict that one day they would be able to respond to human instruction [2].

A flurry of developments occurred in the early 1700s with mechanical toys created that could play music, fly, draw and even move as puppets. The most imaginative of these was 'the Digesting Duck' of Jacques de Vaucanson which had wings that flapped as well as a 'digestive system' which could swallow grain and defecate from a hidden storage chamber. Later that century in Japan, Hisashige Tanaka developed a number of complex mechanical toys that were able to fire arrows from a bow, serve Japanese tea and paint.

During the late nineteenth century, remotely controlled machinery was developed, mainly for usage during wartime as radio-controlled torpedoes and rockets.

Deep-sea robots followed in time (Fig. 1.2) as did the first remote-controlled robot to land and move on the surface of the moon followed in 1970.

The word robot is attributed to Joseph Kapak, derived from the Czech word 'robota' meaning service, in his 1921 play, 'Universal Robots'. The film industry subsequently developed human machines as the forerunners of science fiction. A humanoid robot was exhibited in London at an exhibition of Model Engineers in 1928 designed by WH Richards with an aluminium body containing 11 electromagnets and a battery powered motor. This robot could move its hands and head by remote control. In 1939 Electro, a humanoid robot was exhibited at the world fair. The aluminium outer skin contained a motorised skeleton; it could respond to voice commands, smoke cigarettes, blow up balloons and move its head and arms.

The term robotics was coined by Asimov in his short story 'Runaround 1942' [3]. In this he described 'three rules of robotics' in which he postulated that (1) a robot should not injure a human being or through interaction allow one to come to harm; (2) a robot must obey all orders given to it from humans, except where such orders would contradict the previous Law; and (3) a robot must protect its own existence, except when to do so would contradict the previous two Laws. These rules remain a reasonable ethical framework upon which robot development may be applied to surgical care. Subsequently, in 1949 complex behavioural autonomous robots were created at the Burden Neurological Institute in Bristol by William Walter. He used analogue electronics to stimulate brain processes, whilst Alan Turing and John Von Neumann developed digital computation [4, 5]. Artificial intelligence was a short step away.

The first robotic arm was developed at the Rancho Los Amigos hospital in California and further modified at Stanford

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Fig. 1.1 Model of Leonardo da Vinci's mechanical knight with inner workings, as displayed in Berlin. Photo by Erik Möller

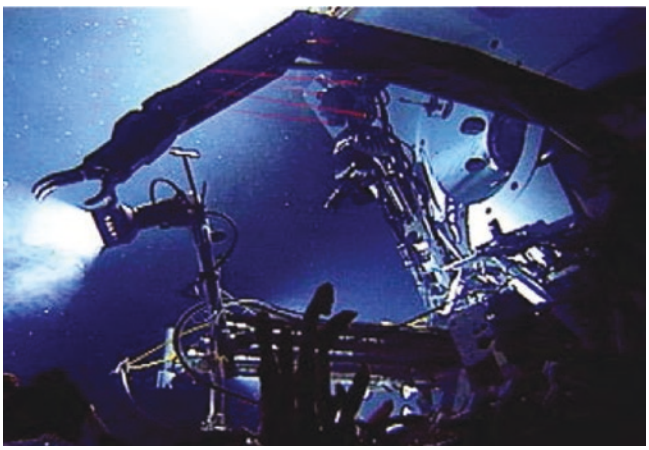

Fig. 1.2 Submersible, called 'Alvin', built for US Navy in 1964, operated by Woods Hale Oceanographic Institution

University in 1963. The following year the IBM system/360 was released and proved to be faster and more capable than previous machines. The Stanford Research Institute subsequently produced a mobile robot capable of reasoning with multiple sensory input in order to navigate. One of the first robotic applications came from the Stanford Artificial Intelligence Lab (SAIL) in 1969. They designed a robotic arm with six degrees of freedom all-electric mechanical manipulator exclusively for computer control. The Stanford Arm and SAIL helped to develop the knowledge base which has been applied in essentially all the industrial robots.

In the 1970s, the robots 'Freddy' and 'Freddy II' were built in the United Kingdom to assemble wooden blocks. The SCARA, Selective Compliance Assembly Robot Arm, created in 1978 was able to pick up parts and place them in various locations useful for assembly lines in factories. In 1986 Honda created a research programme capable of interacting successfully with humans.

It can be seen that with these exciting developments in technology, it was a short step to extending robotic usage into the operating theatre in order to aid and initiate already established laparoscopic and other instrumental techniques.

Surgical Developments

A major step forward in medicine was the invention by Dr. John Adler in 1994 of the CyberKnife, which was able to carry out stereotactic radiosurgery robotically for the treatment of the brain and subsequently other tumours [6]. With advances in microelectronics and computing robotic telecontrol technology with the use of robotic arms to assist in surgical procedures became a reality. Aesop (Computer Motion Inc., Goleta, California) utilised a voice-activated robotic arm. The same company developed Zeus, with remote control robotic arms. Intuitive Surgical Inc., Sunnyvale, California, produced the da Vinci robot controlled by a surgeon-operated console with foot and hand controls. Improvements in stereoscopic imaging gave a three-dimensional view far superior to previously available laparoscopic minimal access techniques although utilising similar optical equipment. Side carts with three and four robotic arms placed at the operating table side allowed further developments and an extension of numerous surgical techniques. In all surgical specialties, the use of fibre-optic technology has allowed diagnostic procedures to be extended to therapeutic and surgical procedures in a truly minimally invasive manner. Examples that can be given include: in urology, prostatectomy, cystectomy and nephrectomy; in colorectal surgery, anterior resection and hemicolectomy; in hepatobiliary and upper gastrointestinal surgery, liver resection, fundoplication and gastric banding, cholecystectomy, pancreatectomy and splenectomy; in cardiothoracic surgery, coronary artery bypass grafting and valve replacement; in otolaryngology, laryngectomy.

Whilst it may seem impractical and difficult to find a role for robotic assistance or minimal access surgery in the practice of obstetrics, in the field of gynaecology the possibilities are clearly endless. The pelvis lends itself anatomically to performing laparoscopy, and therefore robotic assistance will be applicable as has been shown with multiple procedures, when appropriate. The uterus is an obvious organ for such an approach when surgical intervention is necessary. Thus hysterectomy may be aided by robotic assistance and minimal access techniques. Similarly approaches to the pelvic sidewalls and retroperitoneum when dealing with endometriosis can be greatly facilitated with robotic assistance as may

sacrocolpopexy and myomectomy. Magnification gained by the optics at the console can be a great aid to the surgeon as can the obliteration of any tremor with delicate procedures.

Oncological Surgery

Similarly it has been shown that pelvic oncological procedures including pelvic node dissection and radical hysterectomy may be greatly facilitated by the use of robotic assistance. With more flexibility using rotating arms, newly developed robots are able to access the pelvis and then the mid and upper abdomen without the necessity to de-dock. Thus more extensive procedures including pelvic exenteration and reconstruction as well as on occasions ovarian cancer surgery may be performed. The indications for these procedures will depend upon the particular circumstances present will be discussed in other sections of this textbook.

Surgical Training

In the past surgical training has occurred in the operating theatre at the table side by observation, assisting and then carry out procedures under direct supervision (Figs. 1.3 and 1.4).

Whilst animal laboratories are not available in the United Kingdom, simulation of anatomical structures and pathology have now given way to computerised models in laboratories (Fig. 1.5).

Robotically assisted surgery may be ideally taught and learnt from such programmes and will have an increasing impact on the quality of training and therefore surgical practice. Just as airline pilots take refresher courses with tests in simulation chambers, so will the surgeons of the future be able to maintain their skills and test their ability. At the same

Fig. 1.3 St Bartholomews surgeons, London, in the 1900s. Archived photo from Medical Photography Department at St Bartholomews Hospital (from Professor John Shepherd's personal collection)

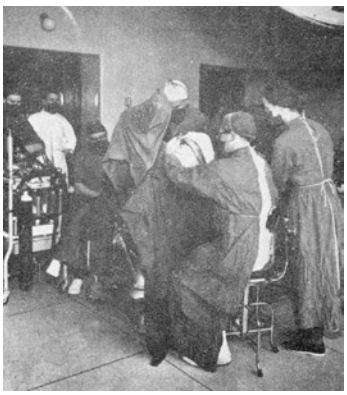

Fig. 1.4 St Bartholomews surgeons in the 1940s. Archived photo from Medical Photography Department at St Bartholomews Hospital (from Professor John Shepherd's personal collection)

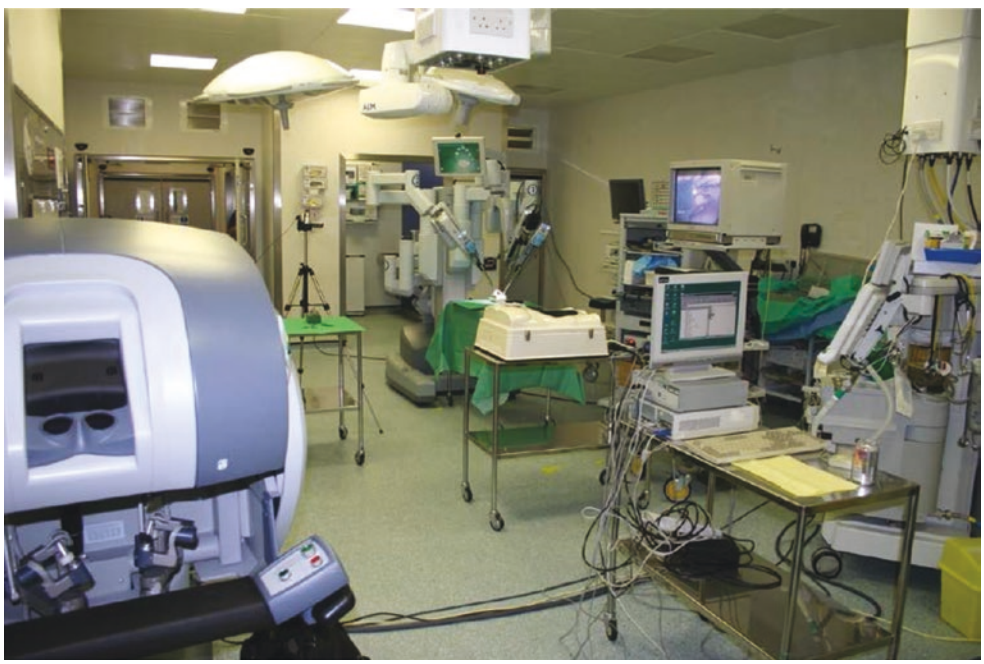

Fig. 1.5 Set-up of robotic 'lab' at the Royal Marsden Hospital at time of introduction of robotic gynaecological programme in 2007 (With permission from Thomas Ind)

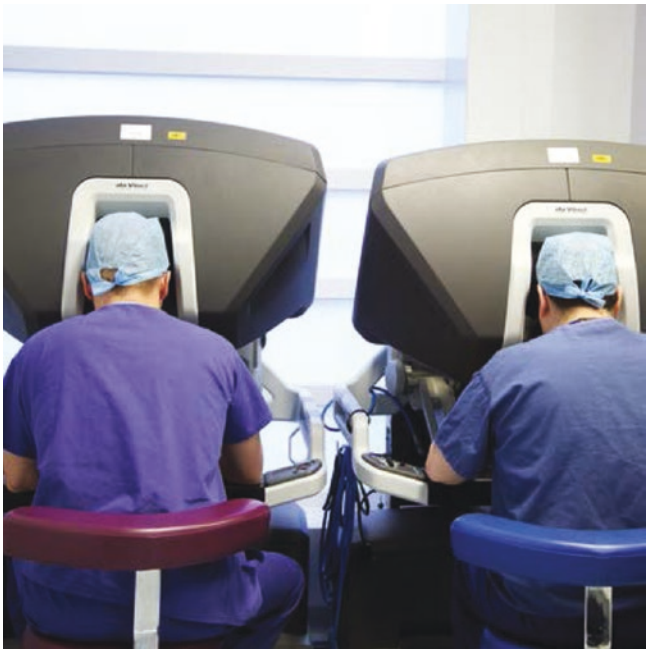

Fig. 1.6 Double console robotic surgery. The Royal Marsden Hospital (permission Press Office The Royal Marsden Hospital London)

time the surgeon's brain activity can be measured to assess fatigue and even stress levels. The impact on patient safety is quite clear. Newer models of robot equipment have dual controls which will allow tutoring and co-surgical techniques to be performed (Fig. 1.6).

Added Tools and Technology

With further developments in imaging especially using MRI, three-dimensional images may be superimposed into the optics at the console of the robot to enable tumours and other anatomical structures to be visualised prior to a surgical procedure being carried out. This will be especially useful in cancer surgery for identifying tumours as well as other anatomical features, such as with the development and incorporation of fluorescent imaging identifying sentinel lymph nodes (Fig. 1.7).

Similarly, with developments in immunocytochemistry and microscopy in histology, in vivo identification of pathology becomes a realistic possibility allowing intelligent knives to excise malignant tissue with greater dexterity than the surgeons' hand. With developments with haptic feedback, this will facilitate precision microsurgery. An alternative is the use of robotic endoscope holders providing an alternative to telesurgery systems by offering a third arm to the surgeon during an operation.

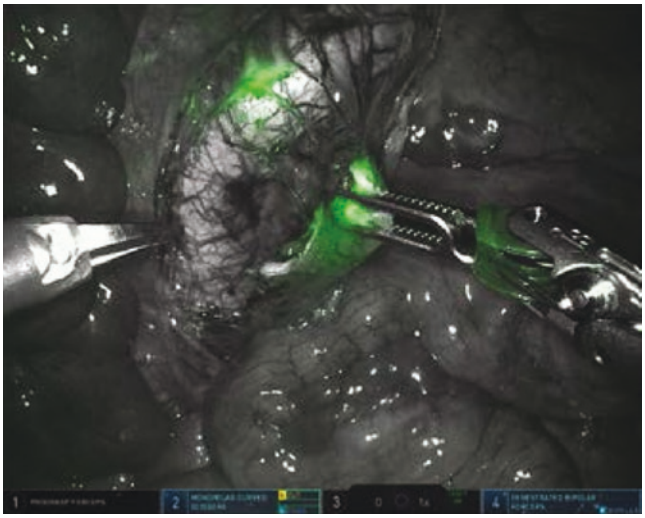

Fig. 1.7 Sentinel lymph node detection external iliac artery using indocyanine green and Firefly filter (archive MA Nobbenhuis)

The Future

The future is already here; we do not need to go back to it. Smaller robots with artificial intelligence are being developed with almost frightening possibilities for their use. Nanotechnology will supersede today's machinery. Research will continue at an accelerating pace, and the place of new techniques and technologies will need to be carefully evaluated in a critical way as they become available. This will be at an inevitable cost, but this must be offset by an improvement in efficiency and success of treatments available. A reduction of morbidity and inevitable sequelae of treatment must be shown to be achieved with a reduction in hospitalisation and time away from home and work. Advances in medical care need to be supported and encouraged but their correct place carefully assessed. To quote Martin Luther King "Nothing in all the world is more dangerous than sincere ignorance and conscientious stupidity". We just must accept anything is possible although not always practical.

References

1. Pasek A. Renaissance robotics: Leonardo da Vinci's lost knight and enlivened materiality. Grad J Vis Mater Cult. 2014;7:1–25.
2. Descartes R.. Discours de la Méthode. Leiden; 1637.
3. Asimov I. The complete robot. Garden City: Doubleday; 1982.
4. Turing A. Computing machinery and intelligence. Mind. 1950;LIX(236):433–60.
5. Von Neumann J. The general and logical theory of automata. In: Jefferies LA, editor. Cerebral mechanisms in behaviour—the Hixon symposium. New York: Wiley; 1951. p. 1–31.
6. Adler John R Jr, et al. The Cyberknife: a frameless robotic system for radiosurgery. Stereotact Funct Neurosurg. 1997;69:124–8.

Training and Proctoring in Robotic Gynaecological Surgery

2

René H.M. Verheijen

Introduction

Although laparoscopic surgery had been introduced in the late 1960s, it lasted until this century for regulatory authorities and professionals to realize that medical training following a master-apprentice principle is insufficient to provide safe and adequate mastering and monitoring of competence and proficiency [1]. As a consequence, also the introduction of robot-assisted surgery was viewed with scepticism and criticism on the way surgeons were trained [2]. This has rightfully led to a call for (a) more structured, (b) more validated and (c) more virtual training in specifically a field-like laparoscopic surgery where more and more technology is being introduced.

It has gradually been acknowledged that a long learning curve as well as the use of technical equipment put patients at risks during the apprenticeship. It was also recognized that these risks could easily be avoided by preparation through e-learning, followed by practicing first in dry and wet laboratory conditions, using virtual or physical models, and as a next step using animal or cadaver models to prepare for surgery in real patients.

Curricula have been developed that have been incorporated into specialist training for most of the surgical specialties. Also, some professional societies have set criteria within the specialty training programmes, which need to be met for a trainee to be allowed to start operating on a real patient as well as for established specialists continuing to do so.

Both the training methods as well as methods of assessment must be validated in order to objectively and accurately measure and monitor progress. E-learning modules have been developed to prepare for hands-on training. Virtual training modules have been developed for technical and procedural training. Box training for technical instruction as well as development of, e.g., eye-hand co-ordination has equally been validated. In this way trainees become well prepared for surgery on life or cadaver models, which are more suitable for procedural training. Finally, performance during real-life operations can now equally objectively be evaluated using validated assessment tools, such as objective structured assessment of technical skills (OSATS) [3].

Although curricula and criteria for training in conventional laparoscopic surgery have now been well established in many parts of Europe, this is as yet not the case in robot-assisted surgery. No accredited training programmes or fellowships exist that might be used to certify specialists to perform robot-assisted surgery. Nevertheless, already in 2007 the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) together with the Minimal Invasive Robotic Association (MIRA) drafted a position paper with formal guidelines for training and credentialing [4]. The European Board and College of Obstetricians and Gynaecologists (EBCOG) has also issued 'Robotic Surgery Standards' as part of their 'Gynaecology Standards' [5]. Although this latter document only describes training in broad terms, it does clearly define the learning curve of surgeons that should be 'specifically trained' for robot-assisted procedures, including sufficient systematic and validated system and procedural (didactic and skills) training, as well as proctor-assisted procedures.

Not surprisingly, urologists have been first to propose a curriculum for proper training. Although several groups (e.g. Florida Hospital Nicholson Center and Roswell Cancer Center) have developed surgical curricula, the curriculum developed by the EAU Robotic Urology Section (ERUS) is the only one that encompasses the whole learning path, from technical instruction to patient procedures [6].

From their experience gynaecologists could learn that modular training of procedures is more efficient than non-structured training [7]. This seems a quite obvious conclusion, but in practice structured training is badly implemented. The Society of European Robotic Gynaecological Surgery (SERGS) is developing guidelines and a gynaecological curriculum for safe introduction in robot-assisted gynaecological surgery.

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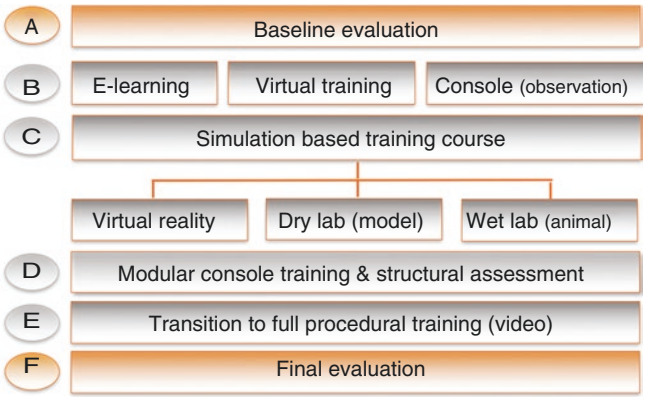

Fig. 2.1 Modular training programme as proposed by SERGS, based on a model developed by ERUS [8]

Modular Training

Specifically for training in complex procedures using sophisticated technology, the various aspects that are important to know and to master cannot be learned haphazardly. Modular training refers to both consecutive modules, each with an essential and defined part of the training, and to teaching the actual procedures in steps, rather than at once completely. This has been developed and validated by ERUS for the most common robot-assisted procedure, the radical prostatectomy [8].

Ideally, a *curriculum* is being built up from e-learning, through virtual and box training to artificial and animal model training (Fig. 2.1). Finally, full procedural training is done step-by-step. As each module contains essential information and teaches skills that are important for the next module, it is important that each module is followed and finished successfully, before embarking on the next module. Also each module is designed for specific types of information and/or skills.

Apart from other aspects, this modular training reflects also the three phases in which training of motoric skills is commonly divided, (a) a cognitive phase (knowledge), (b) an integrative or associative phase (skills) and (c) an autonomous phase (performance) (after Kopta [9]).

The e-learning module could, for example, contain basic information on technical features of the robot, clinical indications and regulatory issues. But in later stages of training and practice, e-learning also provides tools for permanent training by showing information provided by professionals themselves (e.g. WebSurg from IRCAD, websurg.com, and ESGO's eAcademy, eacademy.esgo.org). Most e-learning tools are designed to teach cognitive and/or psychomotor skills. But it is difficult to compare their effectiveness in teaching surgical competencies with other educational interventions and curricula. Given these restrictions e-learning seems to perform at least as good as other educational tools [10].

Table 2.1 Virtual training systems for robot-assisted surgery

Name	Manufacturer
dV-Trainer®	MIMIC Technologies
Da Vinci Skills Simulator®	Intuitive Surgery
ProMIS®	Haptica
SEP® robot simulator	SimSurgery
RoSS™ Trainer	Simulated Surgical Systems
VR simulator[a]	University of Nebraska

[a]Not commercially available

Virtual training may teach technical skills in a simulated and therefore safe environment, at the same time providing tools for objective assessment of progress. Virtual systems are commercially available and offer exercises for specific skills and practice on virtual procedures or parts of them [11, 12] (Table 2.1). The exercises need to be validated before they can be used as a serious preparation for real-life surgery. Construct validation (whether the exercise is indeed discriminatory, i.e. really measures the ability or quality tested for) and face validation (to which extent the exercise resembles the real-life situation) need to have been carried out and have actually widely been published [13].

Model training may teach technical skills in a more realistic environment, be it by the addition of haptic feedback and working in a physical environment like a box or by providing a near to real-life environment as in animal or cadaver models.

E-learning modules and learning programmes are being developed. Manufacturers in particular are keen to develop training programmes, including e-learning, for safe and cost-effective introduction of their equipment in the hospital. Although medical professionals and hospitals themselves are responsible for guidance and assessment, training programmes from within the profession are only slowly being developed and implemented and in all honesty lag behind or at best parallel manufacturers' initiatives.

An important and final part of the training is *procedural training*, first virtually and/or on a model and finally in the patient. Life patient procedures should be performed in the presence of and guided by an experienced tutor. In the experience of ERUS a modular sequential introduction to complex procedures is the safest and most effective way to learn complex surgery. Rather than starting a procedure and finishing the whole procedure, with or without interference by the tutor, modular training takes the trainee step-by-step, through very well defined and structured steps which are not performed all in one session. Training in a specific procedure starts with first steps, after which the tutor should take over, adding further steps at each next procedure that the trainee is offered to perform. This step-by-step approach has the advantage that the trainee will have maximum attention for the essential steps that are being taught, without losing attention and concentration like in a procedure requiring a longer span of attention. In this way each step is learned more effec-

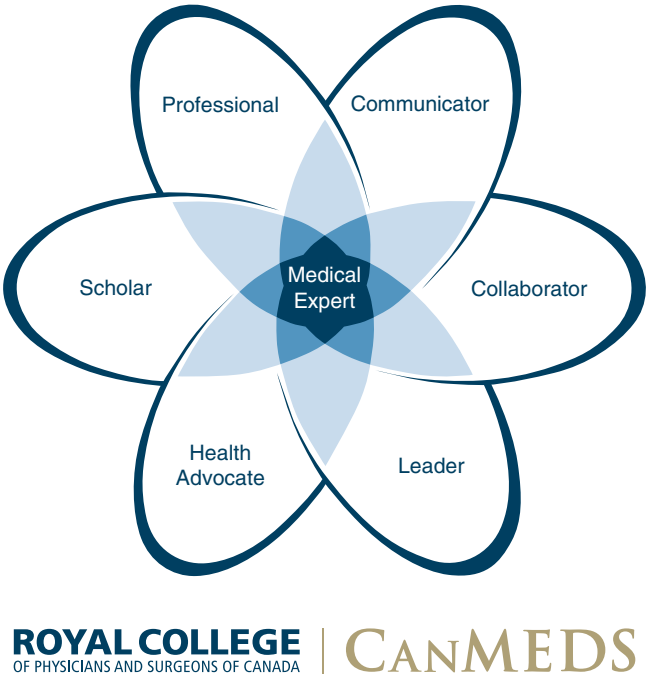

Fig. 2.2 CanMEDS roles describing a truly competent physician [15]

tively, and the procedure is done more safely than in a case where the whole procedure is performed at once.

Competency Based Assessment

After the successful introduction of competence-based training in general gynaecology and of structural assessment [14], these should also be the basis of advanced training in robot-assisted surgery. This provides a framework for trainees to assess regularly and systematically their progress. Thus necessary adjustments in the training and focus on specific needs can be made early on in the training.

The Royal College of Physicians and Surgeons of Canada were the first to recognize and use seven roles of a physician, each requiring specific competencies: professional, communicator, collaborator, leader, health advocate, scholar and medical expert as the central role [15] (Fig. 2.2). The performance in each of these roles determines the level of training in any field of medicine. Such evaluation of the various roles and the defined competencies is now an integrated part of assessment in general training in obstetrics and gynaecology, as reflected by compulsory national programmes such as in the United Kingdom and the Netherlands. It is important to realize that even in a technical field as robot-assisted surgery, these roles and competencies are essential for the future expert to develop and to assess. Robot-assisted surgery, e.g. requires good co-operation between the surgeon and the bedside team, including scrub nurses, surgical assistants and anaesthesiologists.

Table 2.2 Instruments for structured assessment in surgery

Name	Abbreviation
Global evaluative assessment of robotic skills[a]	GEARS
Objective structured assessment of technical skills	OSATS
Objective structured clinical examination	OSCE
Mini-clinical evaluation exercise	mini-CEX
Objective structured performance-related examination	OSPRE
Case-based discussion	CbD
Non-technical skills for surgeons portfolio	NOTSS

[a]Instrument specifically designed for robot-assisted surgery

Assessment of each of the subsequent phases of training should therefore also include evaluation of these competencies in the different roles of the physician, and this should be and actually is integrated into the assessments (see further in structured assessment).

Structured Assessment

If anything has changed in surgical training, it is surely the systematic and structured way learning goals are being defined and assessed. The ‘see one, do one, teach one’ principle has long since been abandoned and assessment of surgical performance is no longer a matter of a short observation by a single tutor resulting in a brief and undocumented verdict. A regular, non-judgemental and objective evaluation of progress is essential for effective learning. Also, or particularly, training in robot-assisted surgery is not a matter of trial and error.

Modular set-up of the curriculum allows safe introduction of new skills and at the same time guarantees adequate preparation for each next step in the training. This should be monitored by assessments after each of the modules or parts thereof. This may be built in an e-learning module, but should be undertaken by a tutor in other parts. Following a structured assessment avoids forgetting important issues to assess and also forces the tutor to systematically review the various skills and competencies that need to be evaluated. Numerical scoring as in Global Evaluative Assessment of Robotic Skills (GEARS) and OSATS facilitates a quick evaluation, which allows also quick reference to earlier performance to measure progress. Various instruments have been developed and validated (Table 2.2). Such brief and standardized assessment should be followed by the identification of specific positive elements (‘what went well’) and issues that might need some more attention (‘what can be improved’). In this way the trainee is stimulated to set new goals for the next phase of the training.

GEARS is the only instrument specifically designed and validated for robot-assisted surgery [16, 17]. In order to integrate also non-technical competencies, a brief instrument, Non-

Table 2.3 Non-technical skills for surgeons (NOTSS) taxonomy

Category	Elements
Situation awareness	– Gathering information – Understanding information – Projecting and anticipating future state
Decision making	– Considering options – Selecting and communicating options – Implementing and reviewing decisions
Communication and teamwork	– Exchanging information – Establishing a shared understanding – Coordinating team activities
Leadership	– Setting and maintaining standards – Supporting others – Coping with pressure

technical Skills for Surgeons (NOTSS), has been developed [18, 19] (Table 2.3). This provides a rating system that may be used within or in combination with instruments of objective assessment, such as GEARS and OSATS. The urologists have incorporated these instruments in their ERUS curriculum, and SERGS is developing this for the gynaecologists.

At the end of training assessment of a (full and unedited) video of a procedure performed by the trainee should be part of final evaluation. This also allows assessment by an independent assessor who will use tools like GEARS. Video assessment is now even offered commercially in order to monitor the performance of individual robotic surgeons [20].

Moments of structured assessment are not limited to the end of modules. In virtual training, every exercise will be individually and automatically scored, and exercises or (part of) procedures in models may each or at least regularly be followed by a brief assessment. In this way a portfolio is built up, which through the ratings of the subsequent exercises and procedures allows monitoring of progress of the trainee.

Conclusion

Training in robot-assisted surgery should be offered in a systematic and modular fashion with structured assessment. Tools are now available to objectively assess and monitor progress of trainees. These should be used, rather than the personal and unstructured opinion of tutors, in order for trainees to complete a portfolio that eventually may be used for certification. For urologists and gynaecologists, curricula have been developed which are basically divided into an introductory period of about 3 months of mainly e-learning and virtual learning and an intense 1 week course of simulation training in a dedicated training centre, followed by approximately 6 months procedural training (Fig. 2.2). This approach provides the professional community as well as patients a framework to safely develop and judge proficiency in robot-assisted surgery.

References

1. IGZ Netherlands. Risks of minimal invasive surgery underestimated (in Dutch). 2007. www.igz.nl.
2. IGZ Netherlands. Unsatisfactory diligence at the introduction of surgical robots (in Dutch). 2010. www.igz.nl.
3. Faulkner H, Regehr G, Martin J, Reznick R. Validation of an objective structured assessment of technical skill for surgical residents. Acad Med. 1996;71:1363–5.
4. Herron DM, Marohn M, SAGES-MIRA Robotic Surgery Consensus Group. A consensus document on robotic surgery. Surg Endosc. 2008;22:313–25.
5. EBCOG. Standards of care for women's health in Europe, Gynaecology Services, Standard 25. 2014. www.ebcog.eu.
6. 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.
7. Lovegrove C, Novarra G, Mottrie A, Guru KA, Brown M, Challacombe B, Popert R, Raza J, van der Poel H, Peabody J, Dasgupta P, Ahmed K. Structured and modular training pathways for robot-assisted radical prostatectomy (RARP): validation of the RARP assessment score and learning curve assessment. Eur Urol. 2016;69:626–35.
8. Volpe A, Ahmed K, Dasgupta P, Ficarra V, Novarra G, van der Poel H, Mottrie A. Pilot validation study of the European Association of Urology robotic training curriculum. Eur Urol. 2015;68:292–9.
9. Kopta JA. The development of motoric skills in orthopaedic education. Clin Orthop Relat Res. 1971;75:80–5.
10. Maertens H, Madani A, Landry T, Vermassen F, Van Herzeele I, Aggarwal R. Systematic review of e-learning for surgical training. BJS. 2016;103(11):1428–37. https://doi.org/10.1002/bjs.10236.
11. Abboudi H, Khan MS, Aboumarzouk O, Guru KA, Challacombe B, Dasgupta P, Ahmed K. Current status of validation for robotic surgery simulators—a systematic review. BJU Int. 2012;111:194–205.
12. Moglia A, Ferrari V, Morelli L, Ferrari M, Mosca F, Cuschieri A. A systematic review of virtual reality simulators for robot-assisted surgery. Eur Urol. 2016;69:1065–80.
13. Schreuder HW, Wolswijk R, Zweemer RP, Schijven MP, Verheijen RH. Training and learning robotic surgery, time for a more structured approach: a systematic review. BJOG. 2012;119:137–49.
14. Boerebach BCM, Arah OA, Heineman MJ, Lombarts KMJMH. Embracing the complexity of valid assessments of clinician's performance: a call for in-depth examination of methodological and statistical contexts that affect the measurement of change. Acad Med. 2016;91:215–20.
15. The Royal College of Physicians and Surgeons of Canada. CanMEDS interactive. 2015. http://canmeds.royalcollege.ca.
16. Goh A, Goldfarb DW, Sander JC, Miles BJ, Dunkin BJ. Global evaluative assessment of robotic skills: validation of a clinical assessment tool to measure robotic surgical skills. J Urol. 2012;1:247–52.
17. Sánchez R, Rodríguez O, Rosciano J, Vegas L, Bond V, Rojas A, Sanchez-Ismayel A. Robotic surgery training: construct validity of Global Evaluative Assessment of Robotic Skills (GEARS). J Robot Surg. 2016;10(3):227–31. https://doi.org/10.1007/s11701-016-0572-1.
18. Flin R, Yule S, Paterson-Brown S, Maran N, Rowley D, Youngson G. Experimental evaluation of a behavioural marker system for Surgeons' Non-Technical Skills (NOTSS). Proc Hum Factors Ergon Soc Annu Meet. 2006;50:969–72.
19. Yule S, Flin R, Maran N, Rowley D, Youngson G, Paterson-Brown S. Surgeons' non-technical skills in the operating room: reliability testing of the NOTSS behaviour rating system. World J Surg. 2008;32:548–56.
20. Lendvay TS, White L, Kowalewski T. Crowdsourcing to assess surgical skill. JAMA Surg. 2015;150:1086–7.

Anaesthesia for Robotic Gynaecological Surgery

3

Sorana White, Shashank Agarwal, and Athula Ratnayake

Introduction

The role of general anaesthesia is to produce a reversible and safe loss of consciousness, to maintain the patient's physiological parameters within a normal range while blunting the sympathetic response to noxious stimuli and to facilitate optimum surgical conditions for the operation.

Anaesthesia for classical laparoscopic gynaecological surgery has been well described in many textbooks, but robotic gynaecological surgery is a new and evolving field, bringing different challenges in anaesthetic management. Principally a much steeper Trendelenburg position is required in order to improve access to the pelvic structures, usually in the order of 30°–45°. This, together with the CO_2 pneumoperitoneum and increased length of surgery, has a marked effect on a patient's physiology that can pose a significant challenge for the anaesthetist. Also, another major consideration is having very limited access to the patient once surgery is underway.

The patient's journey starts with the initial diagnosis, counselling and consent followed by pre-assessment and optimisation for surgery. Once admitted to the hospital, the patient undergoes general anaesthesia and surgery followed by post-operative care. A sound understanding of the conduct of surgery and in particular the changes in physiology brought about by the steep Trendelenburg positioning and the CO_2 pneumoperitoneum are paramount for ensuring patient safety during this journey.

Anaesthetic Management

General principles of preoperative assessment are followed, with particular attention to coexisting comorbidities. Patients are often relatively young and commonly anxious. Sedative premedication may be required. Caution should be exercised particularly if they are obese, as ventilation may be especially difficult.

Perioperative Management

Before inducing general anaesthesia, appropriate monitoring should be attached. This includes pulse oximetry, capnography, ECG and blood pressure monitoring (invasive if indicated). Endotracheal intubation provides a means for adequate ventilation, in addition to protection from aspiration. It is important to have intravenous lines secured, as they are usually inaccessible during the surgery. Further monitoring is also advised, e.g. temperature and neuromuscular monitoring.

At our institution the patient is anaesthetised on the operating table. They are supine on a non-slip mattress (although this is not universal practice). They are then placed in the lithotomy position with the arms fixed by their side. The perineum is positioned so that it is in alignment with the break in the table. Once the lower half of the table is removed, the surgeon will have good access.

The endotracheal tube is firmly fixed in position (ensuring ties are not so tight as to occlude venous drainage from above the neck), eyes are padded and the head is secured. Padded shoulder braces are attached and positioned away from the shoulders in the supine position. This is to avoid brachial plexus injuries in steep Trendelenburg position. We apply a heated blanket above the chest, before transferring the patient into the operating room. Subsequently drapes are applied, and surgery begins to site the trocars. Once this has been satisfactorily achieved, pneumoperitoneum is initiated followed by Trendelenburg position of 30°–45°. Additional ports are inserted so that the robotic arms (up to four) can be attached. Once the robot is positioned over the patient and the robotic arms docked, access to the airway, to any lines or monitoring is virtually impossible. It is important to note that moving the patient or performing CPR would require the robot to first be detached.

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Physiological Changes Caused by Steep Trendelenburg

Airway

Increased intra-abdominal pressure secondary to CO_2 pneumoperitoneum and the gravitational effects of the intra-abdominal organs in Trendelenburg position result in a cephalad displacement of the diaphragm and consequently of mediastinal structures including the trachea. This can result in malpositioning of the endotracheal tube in the anaesthetised patient leading to endobronchial intubation [1].

Respiratory

Studies have shown that in procedures involving Trendelenburg position and pneumoperitoneum, lung compliance can be reduced by as much as 68% [2, 3].

The cephalad displacement of the diaphragm also results in collapse of the bases of the lungs (atelectasis) with reduced lung vital capacity and reduced functional residual capacity. Intra-abdominal pressures up to 15 mmHg are commonly used with the range being between 12 and 15 mmHg to allow enough operative space in the peritoneal cavity. When combined with Trendelenburg position, the European Association for Endoscopic Surgery recommends to avoid pressures higher than 12 mmHg because of decreased pulmonary compliance [10]. Following pneumoperitoneum, the increase in pulmonary blood volume further reduces lung compliance leading to higher airway peak and plateau pressures during mechanical ventilation and an increase in ventilation/perfusion mismatch. The need for higher airway ventilation pressures increases the risk of baro-/volutrauma to the lung. Higher intra-abdominal pneumoperitoneum pressures and pre-existing diaphragmatic defects have been associated with increased risk of post-operative pmeumothorax and pneumoperitoneum.

The amount of CO_2 absorption into the blood from the pneumoperitoneum increases with the length of the operation [4]. With pre-existing lung disease such as emphysema and chronic bronchitis, gas exchange is impaired so the extent of hypercarbia may be exaggerated. Ultimately this results in a combination of hypoxia and hypercarbia.

Cardiovascular

The Trendelenburg position increases the return of blood from the legs causing an increase in preload and cardiac output. There is an increase in the central venous pressure (CVP), mean pulmonary artery pressure (MPAP) and pulmonary capillary wedge pressure. The increase in CVP and MPAP has been shown to be up to threefold and twofold, respectively, in one study [5]. Mean arterial pressure increases to a greater extent than CVP, in part due to the increase in cardiac output and systemic vascular resistance during steep Trendelenburg and pneumoperitoneum. The main reason for this is compression of the intra-abdominal aorta resulting in an increase in the afterload as well as in humoral factors secondary to sympathetic stimulation [6].

Doppler studies have shown significant increases in stroke volume associated with this positioning with a compensatory decrease in heart rate and an increase in the time of isovolumetric relaxation of the heart [7].

These physiological principles are important as in patients with impaired left ventricular function the initial fluid redistribution (secondary to positioning) combined with increased afterload can precipitate heart failure. Furthermore, gas insufflation can result in traction on the peritoneum leading to vagal stimulation, causing bradycardia, and if severe it can lead to asystole. Finally, with increased duration of surgery, a combination of hypercarbia, acidosis and hypoxia can lead to arrhythmias and cardiovascular compromise [8].

Cerebrovascular

The steep Trendelenburg position and pneumoperitoneum are known to cause increased intracranial pressure (ICP). In patients with pre-existing raised ICP adopting this position can be catastrophic. Furthermore there can be a significant reduction in the cerebral tissue oxygen saturation in elderly patients.

Cerebral perfusion pressure (CPP) is calculated as the difference between the mean arterial pressure (MAP) and the highest of either intracranial pressure or CVP. As detailed above, MAP increases to a greater extent than CVP when a patient is positioned for robotically assisted surgery. Kalmar et al. showed using second-generation near-infrared spectrometry that the CPP and cerebral tissue oxygen saturation increased during surgery and were well above the level at which cerebral blood flow autoregulation would be affected or below which cerebral tissue hypoxia could occur.

The combination of altered respiratory physiology and CO_2 pneumoperitoneum results in an increase in arterial partial pressure of CO_2 which in turn leads not only to cerebral vasodilatation but also choroidal vasodilatation and an increase in intraocular pressure. Maintaining an acceptable end tidal CO_2 as a surrogate marker of arterial partial pressure of CO_2 and regularly monitoring the end tidal—arterial gradient is essential in minimising the risk of serious ocular consequences such as bilateral visual loss (Kalmar et al.).

Another factor to consider is cerebral oedema, which can occur due to a raised CVP, hypercarbia and cerebral vasodilatation. In order to minimise this appropriate ventilator

strategies may be needed employed, such as the use of positive end expiratory pressure (PEEP). In addition intravenous fluid should be restricted, at least until the patient is levelled off near the end of surgery.

Ocular

Raised intraocular pressure and corneal abrasions are more likely, again due to patient position, and the potential reflux of gastric acid. Eyes should be taped shut and padded for extra precaution.

Haematological

Pelvic surgery is associated with deep venous thrombosis (DVT), and in lithotomy position this risk is even greater as the return of blood from the legs is impaired. Another complication of lithotomy position for a prolonged period is the potential for rhabdomyolysis [9].

Musculoskeletal

There is a risk of brachial plexus nerve injury with shoulder bolsters in place, but this needs to be balanced with the risk of patient sliding off the table in such a steep position. Normally shoulder bolsters are positioned 4–5 cm away from the patient's shoulders when supine—once Trendelenburg position is established the anaesthetist needs to check the bolsters are not exerting traction onto the shoulders.

Another site for nerve injury is the common peroneal nerve, that can easily been compromised by the leg supports used for lithotomy position.

Monitoring of neuromuscular function must be in place as any coughing during surgery could be catastrophic once the robot is engaged.

Post-operative Management

Patients should be recovered by appropriately trained staff in a suitable environment. Those deemed high risk owing to their comorbidities or a turbulent perioperative phase should be managed in a high dependency environment.

The prolonged steep Trendelenburg position can result in complications in the recovery period that must be anticipated. Laryngeal oedema resulting in stridor and airway obstruction can occur, necessitating re-intubation. Post-operative confusion and delirium had also been reported, presumably secondary to cerebral oedema and inadequate clearance of CO_2, but studies suggesting this link have been underpowered due to the small numbers involved.

Post-operative pain relief is usually achieved through a multimodal analgesia technique. Intravenous or oral opiates, paracetamol and non-steroidal anti-inflammatory drugs are commonly used at our institution. The use of transverses abdominis plane (TAP) bocks and wound infiltration with local anaesthesia has also been described. Neuraxial blockade is generally not required for the post-operative pain relief and thus is rarely used.

Nausea and vomiting may persist in the post-operative, principally due to ileus, and anti-emetic medication should be given.

The Future

Minimally invasive robotic surgery has a future potential in providing cancer treatment to people who are unable to withstand the stress of a major laparotomy. As with other laparoscopic techniques, those that undergo surgery have an improved functional outcome, reduced length of hospital stay and faster recovery.

Due to the extreme positions involved and the effect on a patient's physiology, innovative monitoring and safety devices will no doubt be developed to reduce risks of injury and aid anaesthetists in controlling physiological parameters. Also with the advent of remote site access (so that the operator might be in a different city), communication aids between team members will also be vital to the continued success of this type of surgery.

References

1. Chang CH, Lee HK, Nam SH. The displacement of the tracheal tube during robot-assisted radical prostatectomy. Eur J Anaesthesiol. 2010;27(5):478–80.
2. Danic MJ, Chow M, Gayload A, Bhandari A, Menon M, Brown M. Anesthesia consideration for robotic-assisted laparoscopic prostatectomy: a review of 1500 cases. J Robot Surg. 2007;1:119–23.
3. Suh MK, Seong KW, Jung SH, Kim SS. The effect of pneumoperitoneum and Trendelenburg position on respiratory mechanics during pelviscopic surgery. Korean J Anesthesiol. 2010;59(5):329–34. Epub 2010 Nov 25.
4. Murdock CM, Wolff AJ, Van Geem T. Risk factors for hypercarbia, subcutaneous emphysema, pneumothorax, and pneumomediastinum during laparoscopy. Obstet Gynecol. 2000;95(5):704–9.
5. Lestar M, Gunnarsson L, Lagerstrand L, Wiklund P, Odeberg-Wernerman S. Hemodynamic perturbations during robot-assisted laparoscopic radical prostatectomy in 45° Trendelenburg position. Anesth Analg. 2011;113(5):1069–75. DOI 10.1213/ANE.0b013e3182075d1f. Epub 2011 Jan 13.
6. Falabella A, Moore-Jeffries E, Sullivan MJ, Nelson R, Lew M. Cardiac function during steep Trendelenburg position and CO_2 pneumoperitoneum for robotic-assisted prostatectomy: a trans-oesophageal Doppler probe study. Int J Med Robot. 2007;3:312–5.

7. Meininger D, Westphal K, Bremerich DH, Runkel H, Probst M, Zwissler B, Byhahn C. Effects of posture and prolonged pneumoperitoneum on hemodynamic parameters during laparoscopy. World J Surg. 2008;32(7):1400–5. DOI 10.1007/s00268-007-9424-5.
8. Kikuno N, Urakami S, Shigeno K, Kishi H, Shiina H, Igawa M. Traumatic rhabdomyolysis resulting from continuous compression in the exaggerated lithotomy position for radical perineal prostatectomy. Int J Urol. 2002;9(9):521–4.
9. Biswas S, Gnanasekaran I, Ivatury RR, Simon R, Patel AN. Exaggerated lithotomy position-related rhabdomyolysis. Am Surg. 1997;63(4):361–4.
10. Neudecker J, Sauerland S, Neugebauer E, Bergamaschi R, Bonjer HJ, Cuschieri A, et al. The European Association for Endoscopic Surgery clinical practice guideline on pneumoperitoneum for laparoscopic surgery. Surg Endosc. 2002;16:1121–43.

Robotic Machine and Instruments

4

Alaa El-Ghobashy and Damian Murphy

Introduction

The *da Vinci* Robotic System, manufactured by Intuitive Surgical, USA, was approved by the Food and Drug Administration (FDA) in 2000. It gained popularity worldwide as it facilitates the minimal access completion of complex surgical procedures. There are five known models of the *da Vinci* system (Standard, S, Si, X and Xi).

Earlier systems had one camera and two instrument arms. A fourth arm was subsequently added to assist the surgeon in handling and retracting without the need for an assistant. Further development included the high-definition 3D vision, motorised and dual console facilities. The latest robotic version, the *da Vinci* Xi Model, came to the market in 2014. It offers upgraded and better movement of the mechanical arms with an overhead alignment.

In principle, the *da Vinci* surgical system consists of three main components: the surgeon's console, the patient's surgical cart and the vision cart. Moreover, there are other accessories that are used with the *da Vinci* robot, namely metal trocars and *EndoWrist* instruments. The system translates the operator's hand, wrist and finger movements into delicate real-time precise corresponding/matching movements of the surgical instruments. In this chapter, we will describe the widely available *da Vinci* Si model in details.

Surgeon Console

The console is the workstation where the surgeon can sit comfortably and control the *da Vinci* system away from the sterile surgical field. The part of the system features the following elements: stereoviewer, master controllers, footswitch panel, arm rest bar with left/right side pods and touchpad for preference/feature selections.

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The surgeon views a 3D, real-time and high resolution image of the surgical field that is approximately magnified ×10 through the stereoviewer (Fig. 4.1). The system status icons and messages can also be seen while the surgeon operates. This allows maximum control of the system and warns the surgeon of any faults without having to move the head away from the stereoviewer. There are two infrared sensors on both sides of the stereoviewer that deactivate the robotic arms when the surgeon's head is moved away. Images can be seen either in full screen mode or in TiloPro™ mode (3D image and up to two auxiliary images). There is also an adjustable two-way audio communication with microphones

Fig. 4.1 Surgeon console with stereoviewer

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and speakers to allow the surgeon to exchange information with the rest of the operating team [1].

The master controllers are manoeuvred by the surgeon after inserting two fingers (index and thumb) in an adjustable Velcro straps to control the movement of the *EndoWrist* instruments and the camera (Fig. 4.2). The movements are created by opening and closing the controllers and by bringing them towards or away from the surgeon. The movements are precise, dextrous, scaled (fine 3:1 or normal 2:1) and filtered by the computer to avoid the transmission of any tremors to the instruments. The controllers in the Si model contain grey buttons (finger clutches) which when pressed disengage the controllers from the robotic arms to allow repositioning of the masters to a comfortable location without any change of the instruments' sites. It is generally recommended to adjust the working space of the masters when the surgeon's arms start to lift off from the armrest bar. The controllers can also adjust the camera focus when pressed and rotated clockwise and anticlockwise.

Located on the floor beneath the console is the footswitch panel. It contains three pedals to the left side (camera control, main clutch and the control of arms swap). There are other pedals to the right side (coagulation and cutting diathermy pedals) which are connected at the back of the console through coloured cables to the electrosurgical generator (Fig. 4.3).

In the armrest bar, there are left side pods which allow the ergonomic adjustment according to the surgeon's seating preferences (Fig. 4.4a). This avoids strains and discomfort during lengthy operations. Emergency stop and power buttons are located to the right side (right pods, Fig. 4.4b). In the middle of the armrest, there is a touchpad (integrated control interface) that offers adjustment of the audio-video settings as well as system control. Surgeons can save their preferred console settings in the users' profile for automatic recall in future cases (Fig. 4.5).

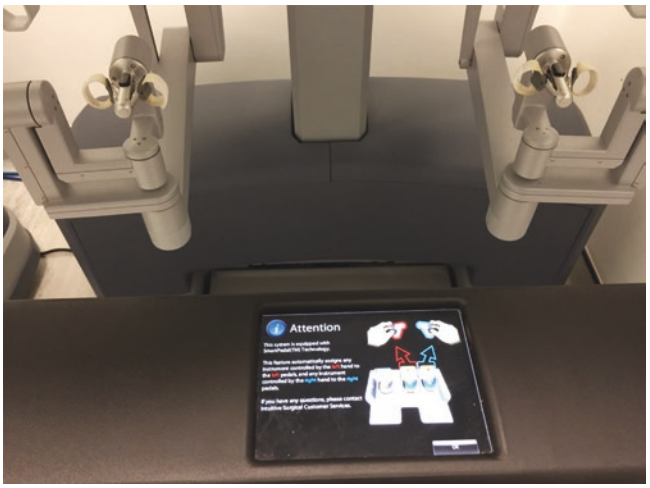

Fig. 4.2 The master controllers

Fig. 4.3 The footswitch panel

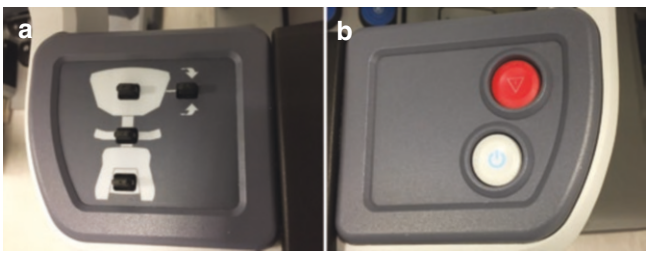

Fig. 4.4 (**a**) Left-sided pod. (**b**) Right-sided pod

Fig. 4.5 The armrest touchpad

Patient Cart

This is the surgical part of the system that is connected to the patient (Fig. 4.6). It is composed of motor-driven base with a main column attached to instruments and camera arms. The motor-driven patient cart facilitates the fast and controlled docking of the system to the patient. This part includes the steering

handles, throttles and their enabling switches and the shift switches [Neutral (N), Drive (D)]. There is a button in the centre of the steering handle to indicate power connection (Fig. 4.7). There are one endoscopic arm and three instrument arms (numbered 1, 2 and 3). The instruments and camera arms have two white clutch buttons (one is in the middle of the arm and the other one is closer to the port end) which assist with the gross movements of each arm for easy connection to the trocars. Each arm has an adjustable end to connect to the metal robotic and the endoscopic trocars. The robotic arms move around a fixed pivot points. There are specific instruments and camera clutch buttons located at the top to adjust the trajectory of each arm during docking and to allow the insertion and the withdrawal of the instruments. There are LED lights at the top of each arm to indicate its status and whether there are any faults in the arm or the attached instrument. The *da Vinci* surgical system's safety checks prevent independent movements of the instruments or robotic arms. Streamlined draping can be achieved with one piece of sterile draping that contains a built-in instrument adaptor. This facilitates efficient arms preparation [2].

Fig. 4.6 Patient's cart Si system before and after draping

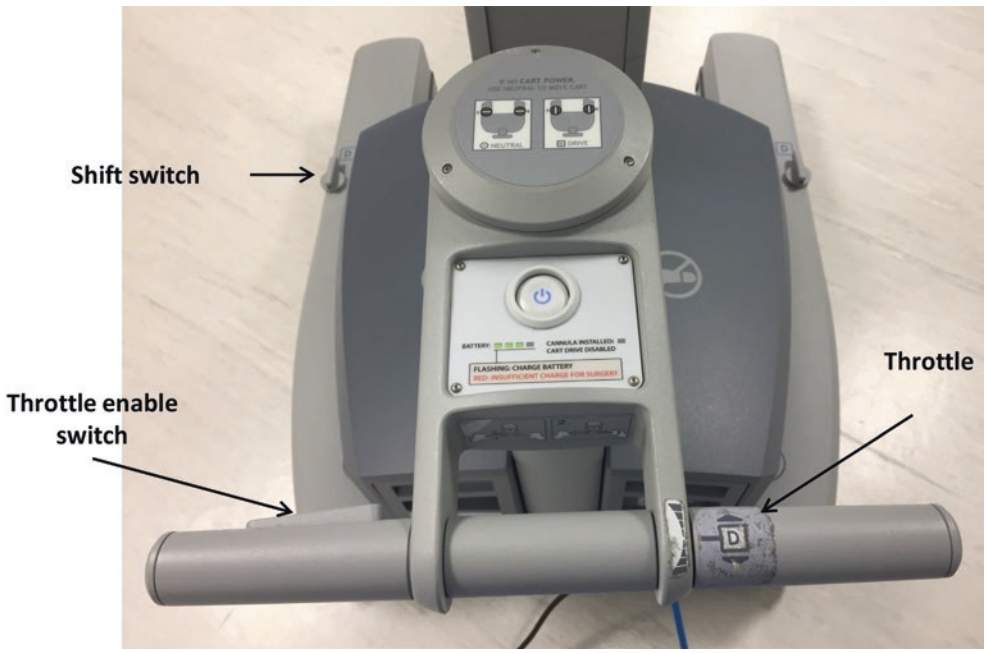

Fig. 4.7 Motor drive

Vision Cart

This is a standalone mobile tower that contains the following parts: the image processing equipment, the endoscope/camera head, the illuminator (light source and cables), touchscreen monitor and other empty shelves suitable for hosting the insufflation and the electrosurgical machines. The cart also has a tank holder site for the CO_2 cylinder required for the insufflation (Fig. 4.8).

The image processing equipment (camera control unit, CCU) controls centrally the acquisition and processing of the images from the camera to produce the three-dimensional view of up to ×10 magnification. It is connected to an HD stereo camera with integrated control for focus and illumination (Fig. 4.9). The Si model is equipped with a 12 mm endoscope with either a straight (0°) or angled (30°) tip for different indications in pelvic and upper abdominal surgeries (Fig. 4.10). Xenon light is provided by an illuminator which travels to the stereo endoscope via a fibre optic cable.

Fig. 4.8 The vision cart

Fig. 4.9 The HD stereo camera

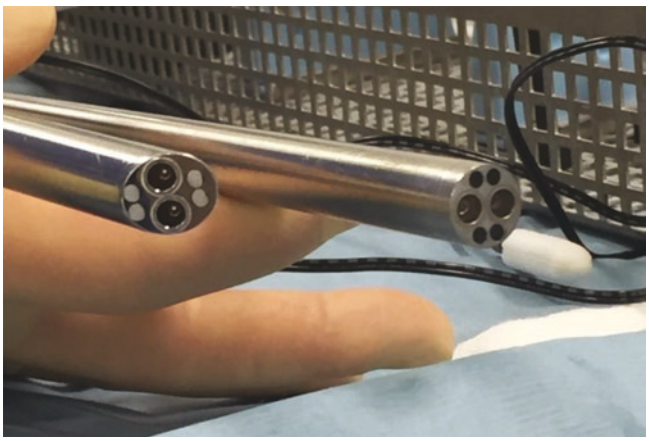

Fig. 4.10 Angled (30°) and straight (0°) endoscopes

The touchscreen monitor allows the bedside assistant to follow the surgical steps in a 3D HD view similar to that of the surgeon console. The system control settings can be adjusted through this screen. If needed, another screen can be connected to the vision cart to allow other theatre staff to monitor the operation.

The *da Vinci* audio system is designed to facilitate the communication between the operating surgeon and other theatre personnel (assistant, anaesthetist and nurses). Microphones and speakers are built in the surgeon console and the patient/vision carts [3].

EndoWrist Instruments

These instruments are designed to provide surgeons with natural dexterity (seven degree of motions) to provide a range of motion greater than the human wrist movements. Each instrument is designed to facilitate a broad range of procedures

(dissecting, clamping, coagulating, cutting and suturing tissues). The instruments are available in 8 mm diameters and are 57 cm in length (Fig. 4.11). Each instrument consists of movable tip, an articulating wrist, a long shaft and instrument housing end that fits into an adaptor of the sterile arm's cover. There are very fine internal cables that run along the shaft that are responsible for the fine movements of the instrument's tip. There is an interface between the instrument and the *da Vinci* system. Once mounted, the system recognises the type and the function of the instrument. This unique function detects the number of uses, any instrument's faults and when an instrument needs replacing [4].

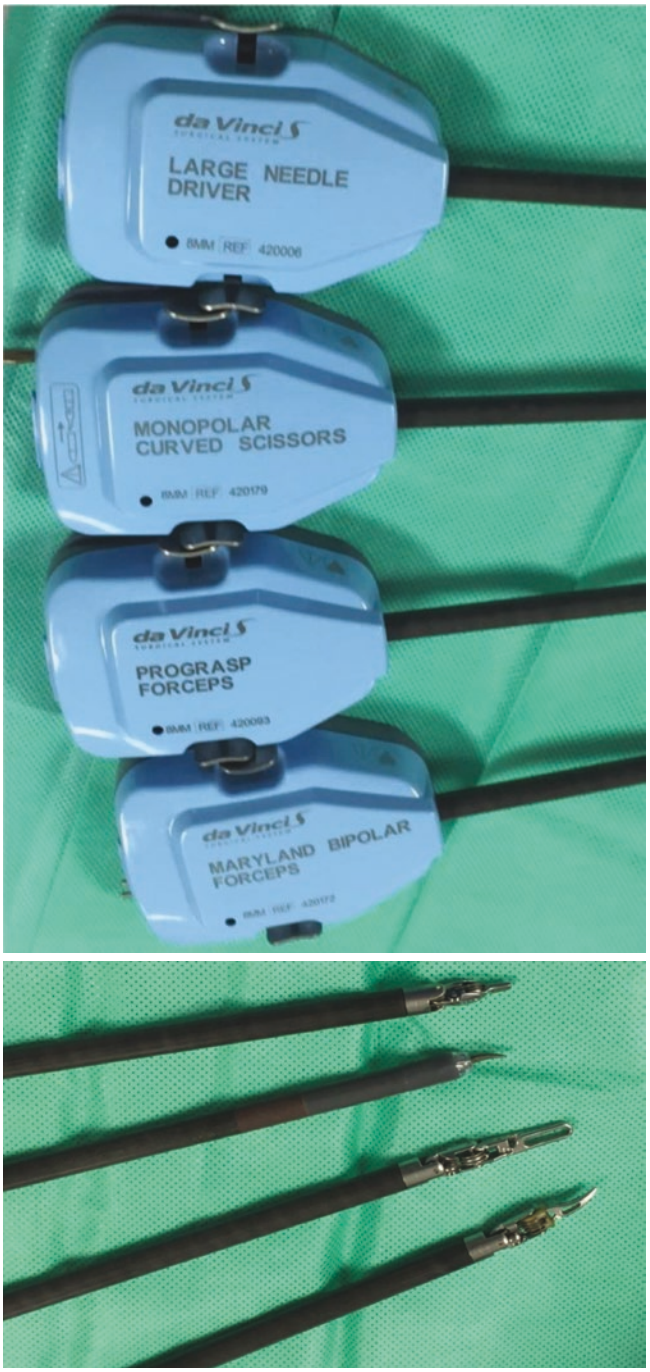

Fig. 4.11 Examples of some of EndoWrist instruments

Robotic Trocars and Other Instruments

The *da Vinci* robotic arms are compatible with metal trocars (8 mm) that can be inserted into the abdomen under direct vision using either blunt or sharp obturators. Each of these ports is topped with a green cap to allow the airtight insertion of the *EndoWrist* instruments. Another reducer cover is attached to the cap to allow the insertion of 5 mm instruments without gas leak. It is recommended that these trocars are inserted 8–10 cm apart from each other and from the camera trocar in order to allow an easy docking and to prevent intraoperative collision of instruments/arms (Fig. 4.12).

The stereo endoscope is inserted through a Visiport trocar (Ethicon Endo-Surgery) either at the umbilicus or few inches above depending on the uterine size. Another 10–12 mm Xcel port is used (assistant's port) to allow suction/irrigation, removal of specimen, retraction, needles insertion and removal (Fig. 4.12).

Other laparoscopic and open surgery instruments can also be utilised during robotic operations (Figs. 4.13)

New Developments

da Vinci Xi Model

In 2014, Intuitive Surgical introduced the recent generation of *da Vinci* machines, the Xi model (Fig. 4.14). The patient cart has a boom mounted overhead system to allow arms to rotate as a group around the surgical field. The arms are light in weight and can be positioned easily in comparison with

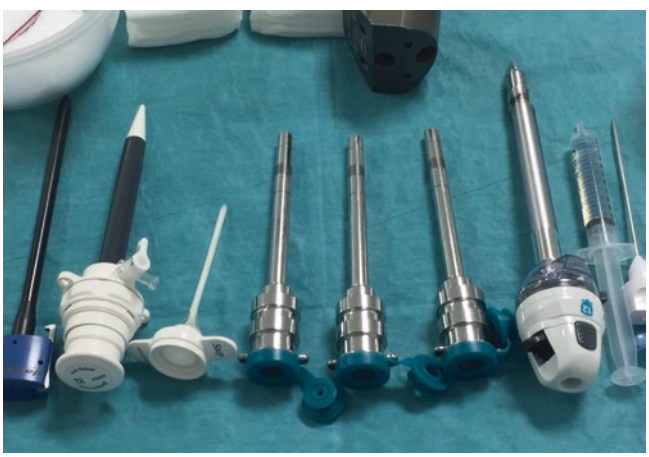

Fig. 4.12 Trocars essential for robotic surgery

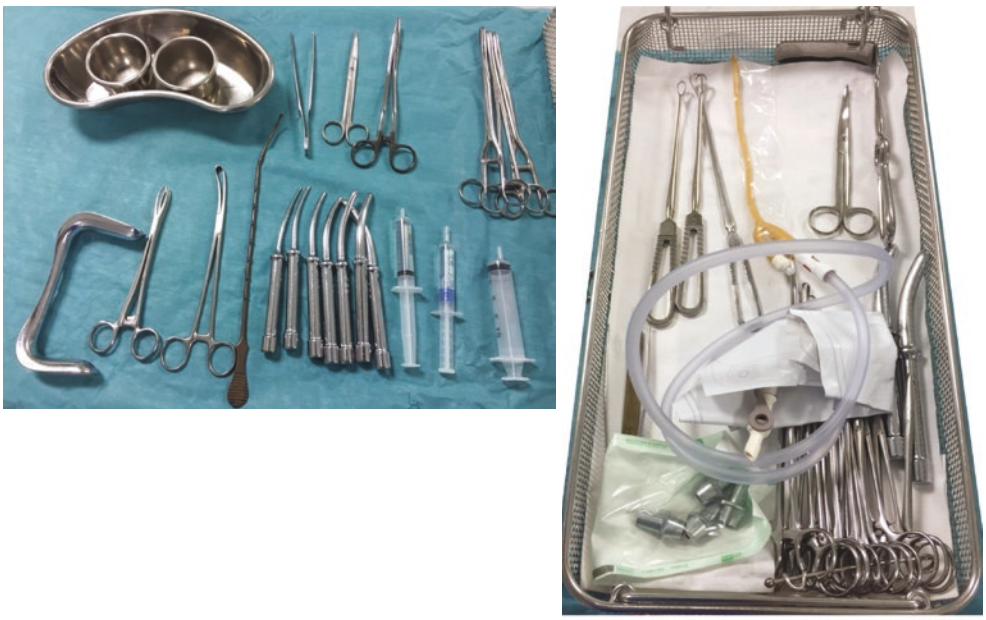

Fig. 4.13 Instruments essential for the vaginal surgery preparation of the patient

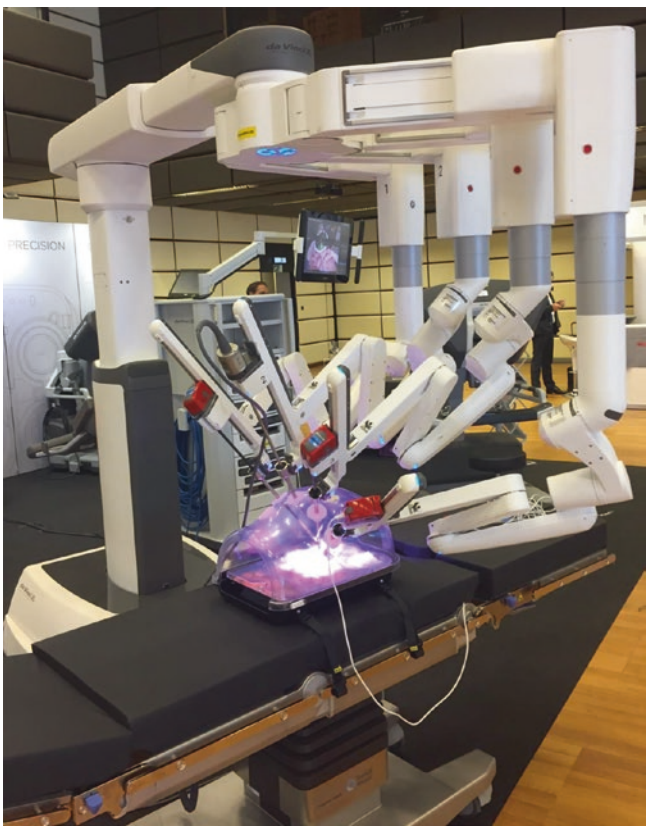

Fig. 4.14 The Xi da Vinci robot

the Si models. The endoscope is 8 mm in width. This allows fitting the endoscope in any robotic trocars for great accessibility and manoeuvrability. The camera and its attached endoscope are positioned towards the surgical site utilising a laser targeting system. Other robotic arms are then automatically calibrated, by pressing the targeting button, to provide maximum spatially adjusted positions. The robotic trocars are placed in a straight line position either at the level of umbilicus or slightly above it. This facilitates operating on both the lower pelvis and the upper abdomen without the need to move the patient's cart as in the Si models.

Fluorescence Imaging (Firefly)

Firefly Fluorescence system has been incorporated in the recent models of the *da Vinci* robots (Si and Xi versions). It enables the surgeon to precisely identify different anatomical structures (blood/lymphatic vessels and lymph nodes) using the near-infrared technology. The imaging equipment consists of fluorescence-enabled *da Vinci* hardware, illuminator LED with an infrared excitation laser, specific camera head and endoscope with updated coatings to pass the fluorescence signal.

The dye used is the fluorescent indocyanine green (ICG). It binds to the plasma protein in the blood and the lymphatic vessels and emits an infrared signal when excited by laser light. Several studies highlighted promising results regarding the sentinel lymph node detection in a minimally invasive manner for both endometrial and cervical cancers utilising the indocyanine green (ICG).

Single-Site Configuration

In this technique, a single port is inserted through a 2–3 cm umbilical incision. The port has five channels that provide

access for two curved cannulae, 5 mm and 10 mm straight cannulae and an insufflation adaptor. Semirigid instruments (5 mms) and an 8.5 mm high-definition three-dimensional endoscope are introduced through the cannulae. The *da Vinci* software automatically detects and re-associates the surgeon's hands with the tips of instruments to avoid cannula collisions, arm interferences and port-site movement (Fig. 4.15).

The single incision avoids injuries to inferior epigastric arteries due to insertion of lateral ports. It also decreases the number of incisions and improves cosmesis. There is an increased risk of incision-site hernia especially if the rectus sheath is not adequately closed.

Skills Simulator

Intuitive Surgical® developed and integrated this simulator with *da Vinci* Si and Xi models to enable surgeons and team members to comprehensively assess own skills and monitor the progress of their training (Fig. 4.16). System skills exercises and videos were developed for specific surgical procedures in each speciality. Each exercise covers one or more of the following categories: EndoWrist manipulation, camera and clutching, system settings, energy and dissection, needle control and driving.

Users can easily track their activities through the simulator curriculum tab. This method will also enable managers and educational supervisors to extract data for credentialing purposes.

Advanced Instrumentation

Recently, advanced instruments including *EndoWrist One* Vessel Sealer, suction/irrigation and *EndoWrist* Stapler (Stapler 45 System and Stapler 45 Reloads) have become available for use with the *da Vinci* robot. They require hardware upgrade to the *Si* Vision Cart in order to be compatible with the latest technology (Fig. 4.17).

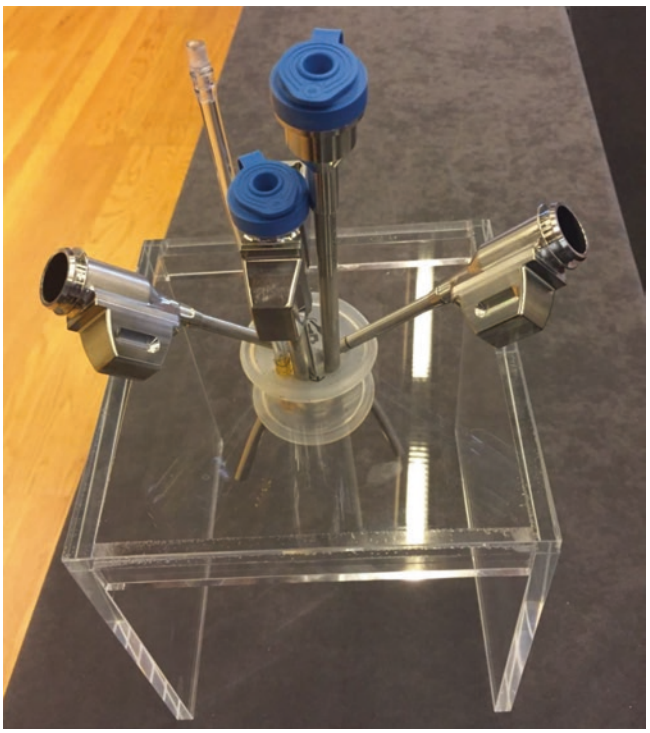

Fig. 4.15 The single-site port and cannulae

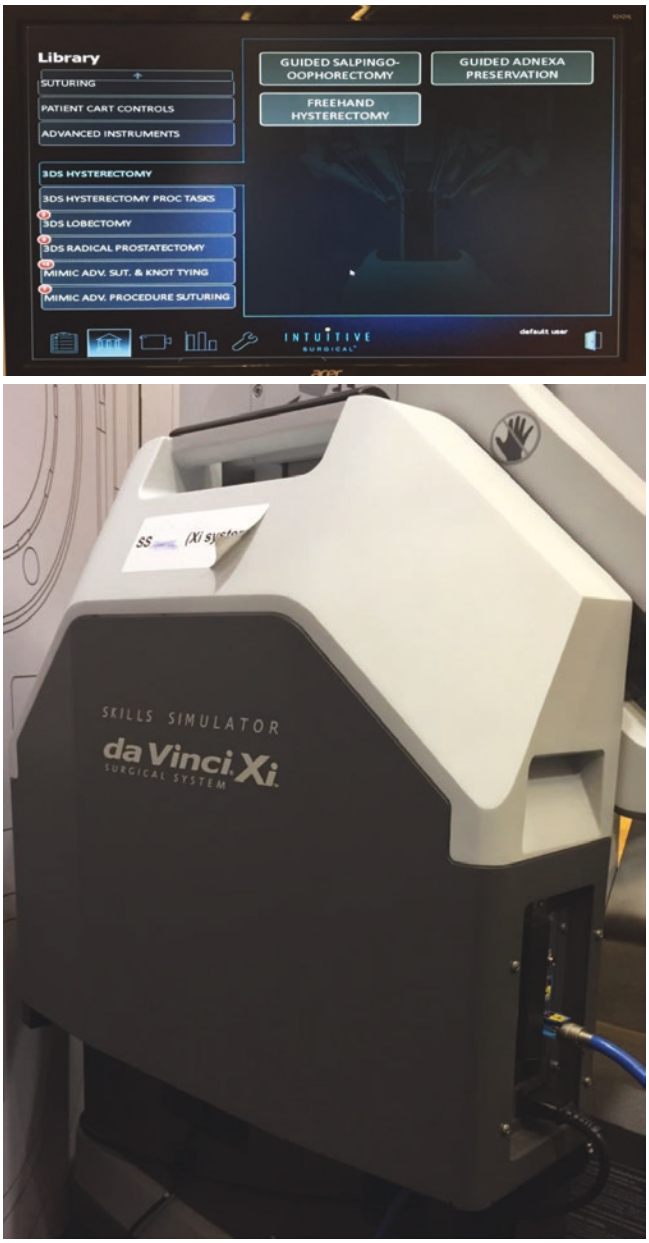

Fig. 4.16 The skill simulator

Fig. 4.17 EndoWrist suction/irrigation and vessel sealer

Dual Console

The innovation of the *da Vinci* dual console system in 2009 transformed surgical training and collaborations. Each surgeon sits at their individual console. They can see the same high-definition images and can operate in concert. The dual console also allows surgeons from different specialties to jointly work where indicated in complex procedures.

When the dual console is used during training, instruments can easily and quickly be swapped between a robotic trainer and a new trainee. This speeds up the learning curve and maintains safety and quality of the surgery.

Conclusions

Robotic technology enabled surgeons to perform the most complex gynaecological procedures through minimal access routes. The ergonomically designed *da Vinci* system (console, patient and vision carts) has become readily and accessible worldwide. Safe surgical outcomes depend on fundamental understanding of the system, training on simulators and wet labs, proctoring and teamworking.

References

1. Higuchi TT, Gettman MT. Robotic instrumentation, personnel and operating room setup. In: Su LM, editor. Atlas of robotic urologic surgery. Humana Press; 2011. p. 15–30.
2. Hagen ME, Stein H, Curet MJ. Introduction to the robotic system. In: Kim KC, editor. Robotics in general surgery. New York: Springer Science; 2014. p. 9–15.
3. Narula VK, Melvin SM. Robotic surgical systems. In: Patel VR, editor. Robotic urologic surgery. London: Springer; 2007. p. 5–14.
4. Bhandari A, Hemal A, Menon M. Instrumentation, sterilization, and preparation of robot. Indian J Urol. 2005;21(2):83–5.

Patient Positioning and Trocar Placement for Robotic Procedures

5

Megan Wasson

Introduction

Patient positioning and robotic port placement are essential to successfully performing a gynecologic robotic procedure. The goal when positioning the patient and selecting port placement is primarily to maintain the safety of the patient and avoid any injury or harm. Additional focus is to allow the robotic arms to maintain their maximum range of motion. Correct patient positioning and setup of the robotic system allows for an efficient and elegant surgical procedure.

Background

Robotic surgical procedures focused on pelvic anatomy require Trendelenburg and dorsal lithotomy positioning. Alternatively, for procedures addressing pathology in the upper abdomen, reverse Trendelenburg positioning with or without dorsal lithotomy is necessary. If performed incorrectly, patient positioning can result in compression or stretch injuries involving the neurologic system with increased operating times being directly related to risk of injury [1, 2]. Robotic procedures requiring Trendelenburg positioning and lasting greater than 3 h have also been associated with increased risk of corneal abrasion, laryngeal edema, cerebral edema, and posterior ischemic optic neuropathy [3].

Following advanced laparoscopic procedures, the rate of brachial plexus nerve injuries has been reported to be as high as 0.16% [4]. This is the most commonly reported peripheral nerve injury directly related to positioning during surgery [4]. Patients can present with sensory deficits along the arm, forearm, and hand. Motor deficits can result in Erb's palsy or Klumpke's paralysis [5].

Robotic surgery poses unique risks to the patient. The robotic arms do not sense when they are in contact with other structures, including patient legs. Care must be taken to avoid any direct pressure between the robotic arms and the patient throughout the surgical procedure to decrease the risk of injury. Additionally, extreme Trendelenburg and reverse Trendelenburg positioning is associated with a potential risk of patient shift cephalad or caudad on the operating table, respectively. The rigid and stable characteristics of the robotic arms do not allow them to accommodate this shift. This can result in an excessive amount of strain on the abdominal wall and potential trauma to surrounding organs.

Dorsal lithotomy positioning is commonly utilized during gynecologic robotic procedures. Lithotomy positioning can cause injury to nerves throughout the lower extremities with resulting motor deficits in 0.03% and sensory deficits in 1.5% [1, 2]. Nerves that are vulnerable to injury include the femoral, obturator, sciatic, lateral femoral cutaneous, and common peroneal nerves. Femoral nerve injuries can result in difficulty with knee extension or thigh abduction. This results in difficulty with ambulation [5].

To complete robotic surgical procedures, the abdomen must be accessed and accessory trocars placed. The location, number, and size of the trocars are dependent on the planned surgical procedure and the anticipated pathology that will be encountered. Conventionally, the first robotic trocar is the optical trocar. Two or three additional trocars are then placed. The fourth robotic arm is used when the surgeon requires additional assistance for dissection, retraction, or manipulation. For completion of a simple robotic gynecologic procedure, such as a hysterectomy for a normal-sized uterus, four robotic trocars are typically not required. An additional trocar port can be placed to allow for a bedside assistant.

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Surgical Technique

Patient Positioning

Standardized methods of preparing the operating table for the patient using antiskid material have been shown to result in minimal patient shift [6, 7]. The described technique does not require the use of shoulder braces or wrist straps [6]. A drawsheet is first placed horizontally across the operating table. This will be used to secure the patient's arms at her side and reduce the risk of brachial plexus injury. A 2 × 3-foot section of antiskid material, such as egg crate foam or a gel pad, is then placed above the drawsheet. The antiskid material is secured to the operating table at the superior and inferior aspects using broad tape. When positioned on the operating table, the patient should lie directly on the pink foam with no intervening materials to provide maximum friction (Figs. 5.1 and 5.2).

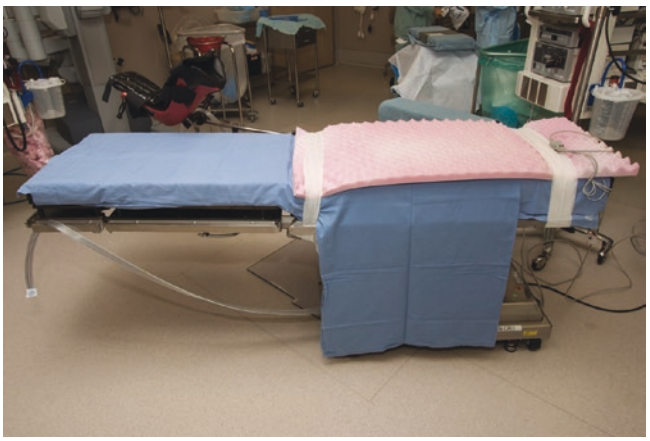

Fig. 5.1 Operating table preparation for robotic surgical procedure using antiskid material

Fig. 5.2 Antiskid material is secured to operating table with underlying drawsheet in preparation for robotic surgical procedure

Correct dorsal lithotomy positioning includes minimal external hip rotation, hip flexion between 60° and 170°, hip abduction less than 90°, and knee flexion between 90° and 120°. The thighs should remain at or above the plane of the table [5]. The buttocks are positioned at the edge of the table with support and padding of the sacrum. Padded stirrups are recommended that allow for full support of the ankle and foot with minimal pressure on the fibular head (Fig. 5.3).

After positioning of the patient's torso and legs, attention can be turned to the upper extremities. To reduce risk of brachial plexus injury, it is recommended that the arms be tucked at the side of the patient and shoulder blocks and/or wrist straps be avoided. If arm abduction is required, the arms should not be extended beyond 90°. If shoulder blocks are used, placement should occur directly over the acromioclavicular joint.

A soft foam cradle can be placed from the axilla to the forearm to decrease pressure on the radial and ulnar nerves. To maintain anatomic position and decrease risk of nerve injury, the arm is rested along the side of the body. The hand is positioned with the palm facing the thigh and the fingers are unclenched. All ports along the intravenous tubing are wrapped with gauze to decrease pressure on the patient's skin (Fig. 5.4).

The arm is secured by wrapping the drawsheet over the arm and tucking it under the lateral aspect of the patient's back. If the arms or torso of the patient is not supported by the operating table, bed extenders or arm boards should be placed alongside the operating table (Fig. 5.5).

After positioning is completed, the patient should be inspected to ensure that anatomic positioning has been maintained for the upper extremities. Dorsal lithotomy position is confirmed to adhere to the guidelines for safe positioning in respect to the hips, knees, and ankles (Fig. 5.6). When proper positioning is confirmed, the patient can be prepped and draped for the robotic surgical procedure.

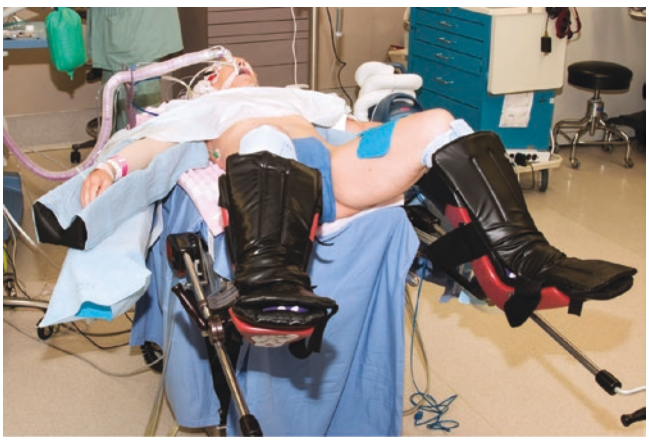

Fig. 5.3 Correct dorsal lithotomy position is completed prior to positioning of the patient's arms

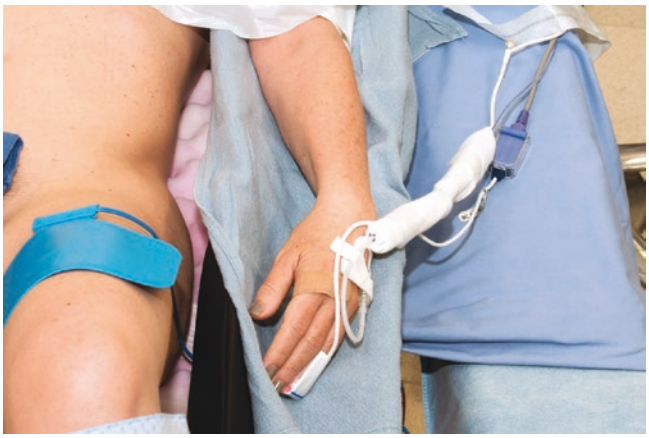

Fig. 5.4 Anatomic positioning of the arm is maintained with avoidance of excessive pressure on the tissue

Fig. 5.5 The arm is secured at the patient's side using the drawsheet. Anatomic positioning is maintained

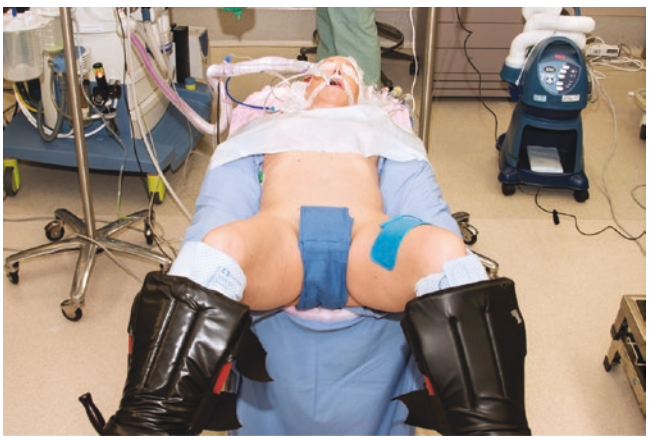

Fig. 5.6 Correct positioning for robotic surgical procedure. Patient is in dorsal lithotomy position with arms tucks securely at her sides

Trocar Placement

The most common robotic procedures performed by gynecologists are focused in the pelvis. Correct placement of the robotic trocars allows for avoidance of robotic arm collision during the surgical procedure. To gain access to the abdomen, the first trocar is conventionally placed through the base of the umbilicus (Fig. 5.7, blue). This is an 8.5 or 12 mm trocar and will serve as the optical trocar [8, 9]. To decrease the risk of injuries related to abdominal entry, including vascular injuries, a transumbilical open technique is used in all of our patients [10]. In a series of 10,840 procedures using an open entry technique, no major vascular injuries occurred [11].

Following full survey of the abdomen and pelvis, accessory trocars are placed. All accessory trocars are placed under direct visualization to decrease risk of intestinal or vascular injuries [10]. Current platforms available include the da Vinci Si, da Vinci Xi, and single-site da Vinci surgical systems.

When using the da Vinci Si, two 8-mm robotic trocars are placed 10-cm lateral to the midline at or slightly below the level of the umbilicus (Fig. 5.7, yellow and red). The lateral ports should be maintained a minimum of 3-cm away from the anterior superior iliac spine to reduce risk of collision and patient injury. A 5- or 10-mm assistant trocar is then placed 3-cm cranial and halfway between the umbilical and left lateral robotic trocars (Fig. 5.7, green). If a fourth robotic arm is desired, an additional 8-mm robotic trocar is placed on the patient's right side mirroring the assistant trocar (Fig. 5.7, white) [8, 9]. This creates a conventional "M" configuration.

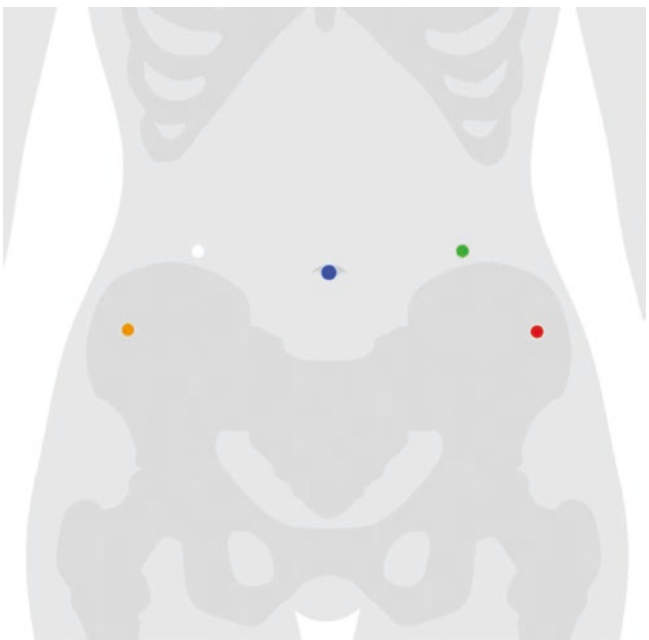

Fig. 5.7 Conventional robotic trocar configuration for pelvic surgery; image reproduced with permission from Intuitive Surgical

The da Vinci Xi allows the use of the 8 mm optical trocar. Accessory trocars are placed horizontally, parallel to the level of the umbilicus. Robotic trocars are placed 8 cm apart. If a fourth robotic arm is desired, two robotic trocars are placed on the patient's right and one robotic trocar is placed on the patient's left. The left lateral trocar is placed approximately 16-cm lateral to the umbilicus. The assistant trocar is placed 3-cm cranial and halfway between the umbilical and left lateral robotic trocars.

The single-site da Vinci surgical system allows for placement of all trocars through the umbilicus, including the assistant port. A 2.5-cm vertical skin incision is made at the umbilicus and the single-site port is placed. An 8 mm camera cannula is placed and the camera arm is docked (Fig. 5.8, blue). The cannulas for the second and third robotic arms are then placed and docked (Fig. 5.8, green and yellow). A 5-mm assistant port is placed through the single-site apparatus (Fig. 5.8, gray).

Robotic trocars should be advanced until the thick black band of the cannula is visualized at the level of the peritoneum (Fig. 5.9). This is the remote center of the cannula. Correct positioning decreases tissue trauma from the robotic arms.

Robotic procedures in gynecology can focus in the upper abdomen. These procedures include excision of diaphragmatic endometriosis and ovarian cancer metastases to the diaphragm. To access the upper abdomen, the optical trocar is then placed through the umbilicus. When using the da Vinci Si, the "M" configuration is then inverted and directed toward the upper abdomen. Two robotic trocars are placed 10-cm lateral to the midline at the level of the umbilicus. A 5- or 10-mm assistant trocar is then placed 3-cm caudal and halfway between the umbilical and left lateral robotic trocars. If a fourth robotic arm is desired, it is placed on the patient's right side mirroring the assistant trocar. When using the da Vinci Xi, the trocars should be placed parallel to the target anatomy.

Once the robotic ports have been placed, patient positioning is reinspected. It should be ensured that the table is in maximum Trendelenburg or reverse Trendelenburg and the table is fully lowered. The robotic arms are positioned as high as possible to decrease risk of collision with the patient. The robotic column is brought to the operating table for docking (attachment of the robotic arms to the robotic ports). The robot is then side-docked over the patient's hip or shoulder (Figs. 5.10 and 5.11). This is the preferred approach. Alternatively, the robot can be positioned centrally; however,

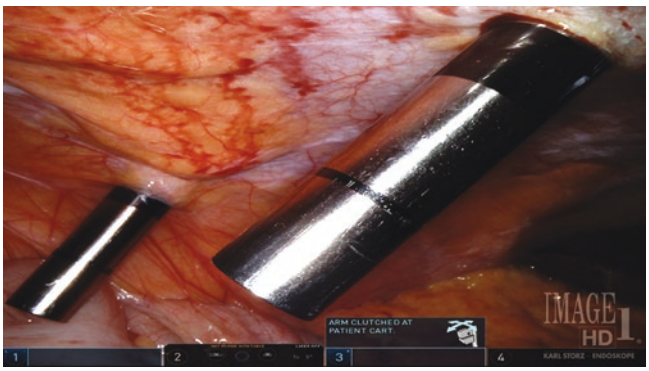

Fig. 5.9 Correct trocar placement with respect to peritoneum to decrease torque on the abdominal wall

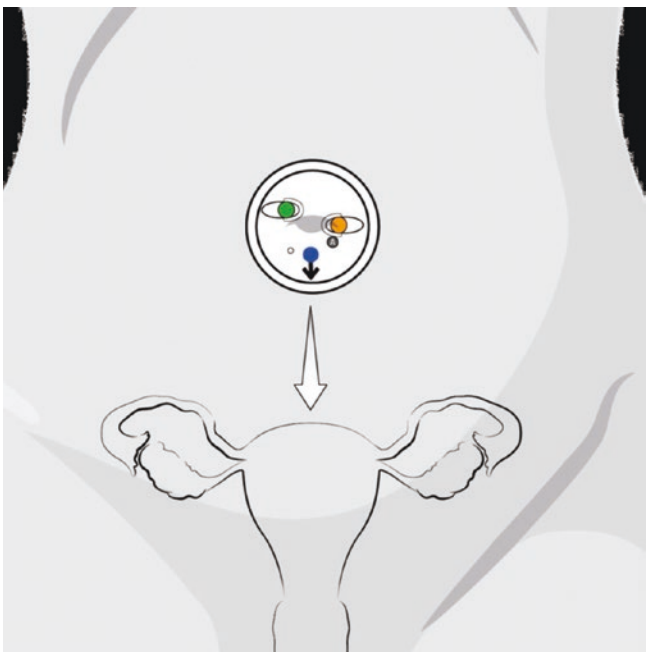

Fig. 5.8 Conventional single-site robotic trocar configuration for pelvic surgery; image reproduced with permission from Intuitive Surgical

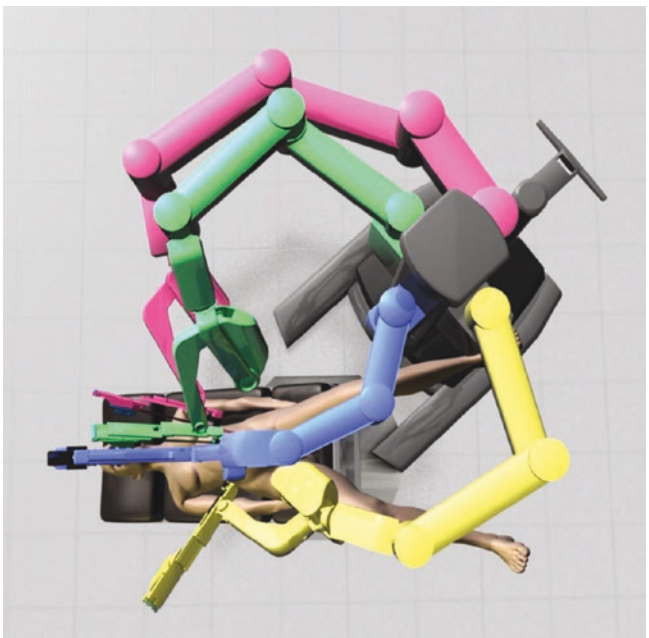

Fig. 5.10 Side-docked 4-arm robotic system for pelvic surgery; image reproduced with permission from Intuitive Surgical

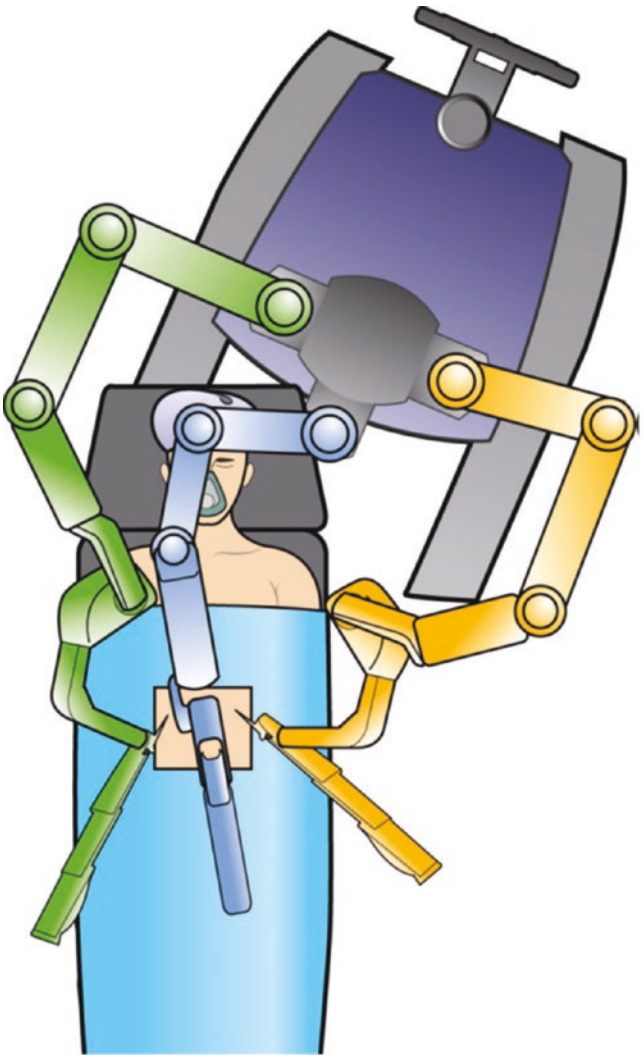

Fig. 5.11 Side-docked 4-arm robotic system for upper abdominal surgery; image reproduced with permission from Intuitive Surgical

midline placement is not recommended as this impedes access to the vagina or head (Figs. 5.12 and 5.13). This results in decreased ease of uterine manipulation and decreased accessibility for anesthesia administration. After the robotic arms are attached to the trocars, the joints of the robotic arms should be adjusted to maximize spacing between the various arms.

Conclusion/Personal Review

Sound knowledge and application of correct patient positioning and port placement for gynecologic robotic procedures allow surgeries to be completed efficiently and safely. Most commonly, gynecologic procedures require Trendelenburg and dorsal lithotomy positioning. Incorrect placement of patients into this position can result in serious effects, including nerve injuries. It is essential to ensure that anatomic positioning is maintained and that excessive pressure is avoided.

Fig. 5.12 Centrally docked 4-arm robotic system for pelvic surgery; image reproduced with permission from Intuitive Surgical

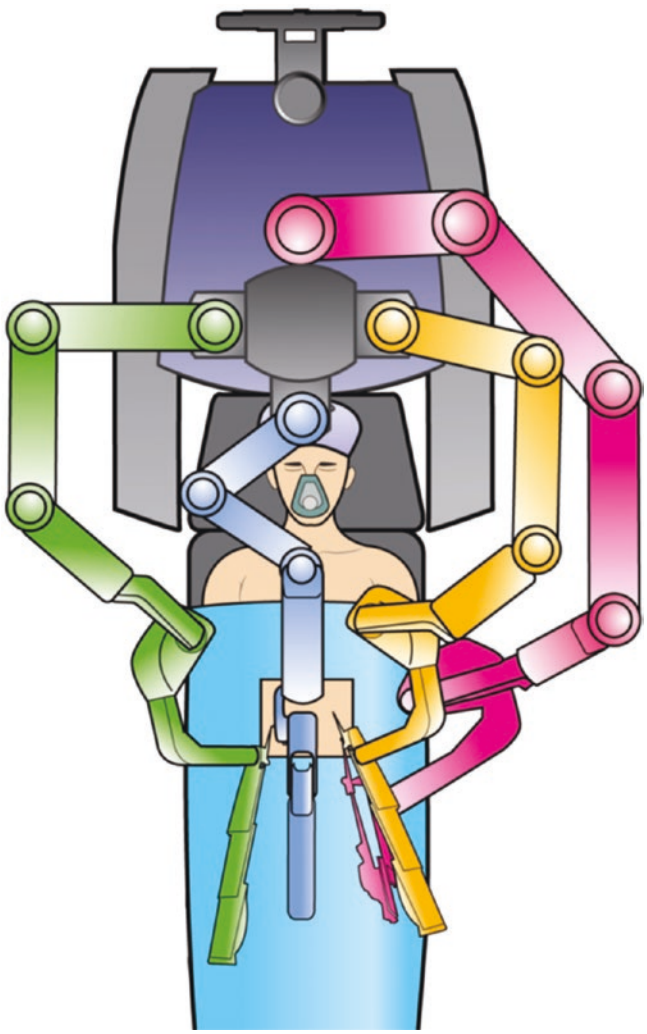

Fig. 5.13 Centrally docked 4-arm robotic system for upper abdominal surgery; image reproduced with permission from Intuitive Surgical

When selecting port placement, revert to the conventional "M" configuration and direct the "M" at your target anatomy and pathology. This will allow the intended pathology to be easily accessed and addressed.

Understanding of patient positioning and port placement is key to allowing a robotic procedure to be completed efficiently. This will decrease the level of frustration that can occur and resulting increase in surgical procedure time for novice and expert robotic surgeons alike.

References

1. Warner MA, Martin JT, Schroeder DR, Offord KP, Chute CG. Lower-extremity motor neuropathy associated with surgery performed on patients in a lithotomy position. Anesthesiology. 1994;81(1):6–12.
2. Warner MA, Warner DO, Harper CM, Schroeder DR, Maxson PM. Lower extremity neuropathies associated with lithotomy positions. Anesthesiology. 2000;93(4):938–42.
3. Gainsburg DM. Anesthetic concerns for robotic-assisted laparoscopic radical prostatectomy. Minerva Anestesiol. 2012;78(5):596–604.
4. Romanowski L, Reich H, McGlynn F, Adelson MD, Taylor PJ. Brachial plexus neuropathies after advanced laparoscopic surgery. Fertil Steril. 1993;60(4):729–32.
5. Barnett JC, Hurd WW, Rogers RM Jr, Williams NL, Shapiro SA. Laparoscopic positioning and nerve injuries. J. Minim. Invasive Gynecol. 2007;14(5):664–72. Quiz 73.
6. Klauschie J, Wechter ME, Jacob K, Zanagnolo V, Montero R, Magrina J, et al. Use of anti-skid material and patient-positioning to prevent patient shifting during robotic-assisted gynecologic procedures. J Minim Invasive Gynecol. 2010;17(4):504–7.
7. Wechter ME, Kho RM, Chen AH, Magrina JF, Pettit PD. Preventing slide in Trendelenburg position: randomized trial comparing foam and gel pads. J Robot Surg. 2013;7(3):267–71.
8. Kho RM, Hilger WS, Hentz JG, Magtibay PM, Magrina JF. Robotic hysterectomy: technique and initial outcomes. Am J Obstet Gynecol. 2007;197(1):113.e1–4.
9. Magrina JF, Kho R, Magtibay PM. Robotic radical hysterectomy: technical aspects. Gynecol Oncol. 2009;113(1):28–31.
10. Magrina JF. Complications of laparoscopic surgery. Clin Obstet Gynecol. 2002;45(2):469–80.
11. Penfield AJ. How to prevent complications of open laparoscopy. J Reprod Med. 1985;30(9):660–3.

Single-Port Robotic Practice

6

Mete Gungor, M. Murat Naki, Ozguc Takmaz, and M. Faruk Kose

Abbreviations

FDA	Food and Drug Administration
LESS	Laparoendoscopic single-site surgery
R-LESS	Robotic laparoendoscopic single-site surgery
SILS	Single incision laparoscopic surgery
SPA	Single-port access

Introduction

In the past 20 years, surgical techniques have moved toward a less invasive approach from open to single-incision minimally invasive surgery. Innovations in minimally invasive surgical technology, such as multichannel ports, articulating instruments, and flexible high-definition endoscopes, have allowed laparoendoscopic surgeons to perform increasingly complex surgeries through smaller incisions.

The LESS is introduced as an alternative to conventional multiport laparoscopy. LESS surgery, otherwise known as SPA surgery or SILS, which allows several ports to be introduced into the abdomen via one central incision is a recent technical advancement in MIS, developed as a less invasive alternative to conventional laparoscopy [1]. LESS is comparable with traditional laparoscopy in terms of efficacy and safety for treatment of gynecological conditions, and its feasibility and safety has been shown in multiple studies in literature. It is thought that single-port surgery has the advantages of minimal scarring and improved cosmesis, minimal pain, low blood loss, low analgesic consumption, quicker recovery, and high patient satisfaction compared with conventional laparoscopy [2–4]. This might be explained by the fact that each port added raises the probability of organ injury and hemorrhage [4].

But there are several difficulties to perform LESS, such as poor exposition, loss of triangulation, lack of space on patient's exterior because of crowded instruments, and "sword fighting" among instruments. In multiport laparoscopic surgery (MLS), the placement of the ports allows for triangulation to the target anatomy, fewer instrument collisions, wide angles of retraction, and better surgeon ergonomic comfort, all of which improve the surgical procedure and its safety. In current SILS, many of these advantages are lost. Instruments enter the abdomen parallel through the umbilicus, resulting in the loss of the triangulation of the target anatomy. In addition, the parallel approach and the resulting lack of space between instruments impair visualization and cause greater collisions between instruments and/or the camera. This may also compromise the ability to retract the target anatomy, resulting in suboptimal tissue exposure. The other disadvantages of SILS are surgeon fatigue and discomfort secondary to unusual body positioning dictated by instrumentation.

To minimize these issues, various surgical device manufacturers have developed articulating instruments and flexible endoscopic cameras. These instruments are complex to use, have a learning curve associated with their use, need for significant laparoscopic skills, and do not offset all of the ergonomic issues. Therefore, developing a better surgical instrument for single-port surgery is essential.

In order to overcome the disadvantages of the LESS technique, some surgeons combined it with robotic surgery which led to a new kind of surgery named R-LESS. R-LESS surgery is the new MIS technique [5–9]. Researchers used a combination of commercially available single-incision laparoscopy equipment and augmented it with robotic technology.

Robot-assisted laparoscopic surgery which has been demonstrated to provide benefits very similar to those of

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traditional laparoscopic surgery has also additional advantages in some aspects. Robotic surgery has greatly improved surgeon dexterity, surgical precision, visualization, ergonomics, and technical limitations of laparoscopic surgery (instrument crowding and loss of depth of perception with current two-dimensional flexible optics) and may shorten the minimally invasive learning curve for surgeons compared with traditional laparoscopy. However, robotic surgery has substantially increased the number and size of ports required.

Intuitive Surgical developed a novel set of single-site instruments and accessories. The accessories include a multichannel access port (Fig. 6.1) with room for four cannulas and an insufflation valve. Two curved cannulas are for robotically controlled instruments. The other two cannulas are straight; one is 8.5 mm and accommodates the high-definition and three-dimensional (3D) endoscope, and the other is a 5 mm bedside assistant surgeon port.

The da Vinci® (Intuitive Surgical Inc., Sunnyvale, CA, USA) single-site instruments are similar to those of the existing da Vinci Si EndoWrist except that the entire length of the instruments is semirigid, allowing them to be inserted through the curved cannulas and triangulation of the anatomy. These instruments do not have the wrist at the tip of the instrument, in contrast to standard robotic instrumentation. The instruments currently available for this platform include needle drivers, Cadiere grasper, Maryland dissector, hook with cautery, curved shears, clip applier, and suction irrigation device.

Same-sided hand-eye control of the instruments is maintained through assignment of software of the SI system that enables the surgeon's right hand to control the screen right instrument even though the instrument is in the left robotic arm, and reciprocally the left hand controls the screen left instrument even though the instrument is in the right robotic arms. This coordination of screen images with the operating hand removes many of the current issues of single-port articulated instrumentation. Other benefits of the da Vinci surgical system for single-port surgery include 3D visualization, motion scaling, and tremor filtration.

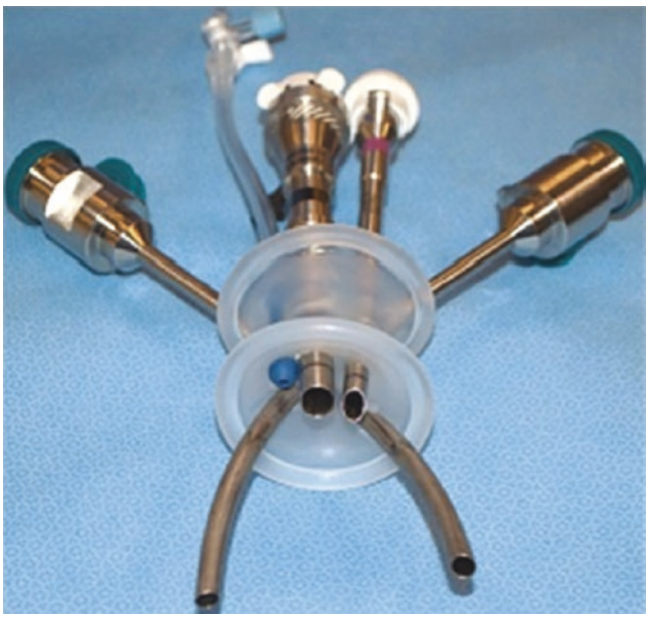

Fig. 6.1 Two curved cannulas, assistant's 5 mm cannula, and camera arm

Despite these advantages, the current version of the set still has limitations. First, the instruments are not wristed. Manual suturing and other advanced manipulations are thus more difficult to perform when compared with the wristed robotic instruments. Second, the da Vinci single-site instrumentation has a very limited range of motion within the surgical field. Larger moves require coordinated rearrangement of all instruments and the camera. Finally, operative field setting is strongly determined by cannulas position and length. Once cannulas are assembled, it is not possible to work at significantly different depths without changing their size [10]. The da Vinci system, already having quite widespread use in urology and general surgery and also has expanded its use in gynecology. Haber et al. reported their initial experience in the laboratory, which was followed shortly after by Escobar et al., who used the *da Vinci robot* to carry out the first cadaveric hysterectomy [10, 11].

FDA approval for R-LESS hysterectomy and adnexal surgery was granted in 2013, and preliminary case reports for gynecological procedures suggest favorable surgical outcomes and furthermore, with regard to gynecological oncology procedures [5, 12].

Surgical Technique

Patients undergo induction of general anesthesia, placement of a urinary catheter, and administration of preincision antibiotics. A single 2.0–2.5 cm trans-umbilical incision is made through the midpoint of the umbilicus. The fascia is entered sharply and the incision is extended and stretched with retractors to 3 cm. An open-laparoscopy technique (Hasson) is thus used to create an incision that allowed insertion of a single-port robotic trocar system (Intuitive Surgical) (Fig. 6.2a, b).

The abdominal cavity is insufflated directly through the port system with CO_2 to an intra-abdominal pressure of 15 mmHg. Diagnostic laparoscopy is performed before robotic docking. Then the surgical table is tilted to a 30° Trendelenburg position to displace the abdominal viscera cranially the operative robot then is brought between the patients' legs. The robotic camera used for all procedures is an 8.5 mm high-definition camera. The 8.5 mm camera trocar and camera is placed first through the access port, and the camera arm is docked. After, the 5 × 250 mm^2

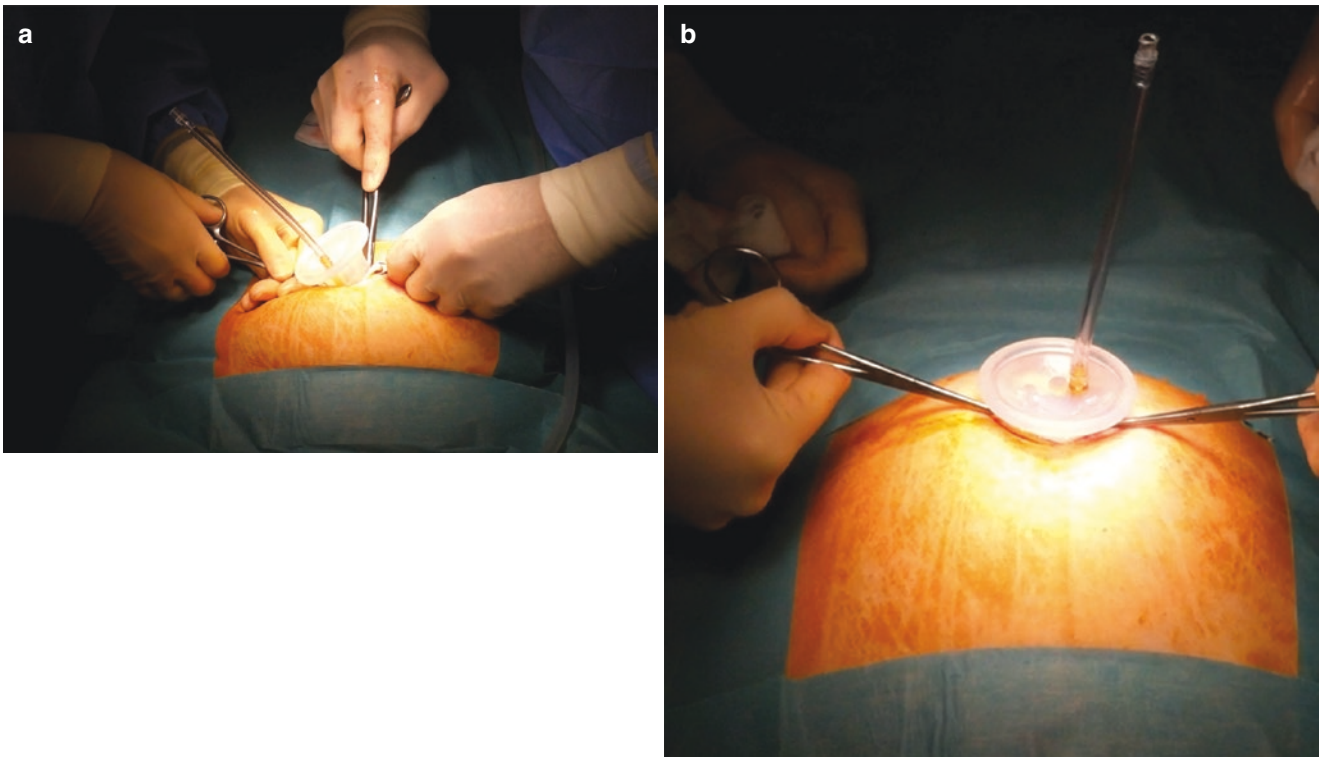

Fig. 6.2 (**a** and **b**) Insertion of robotic single-port platform

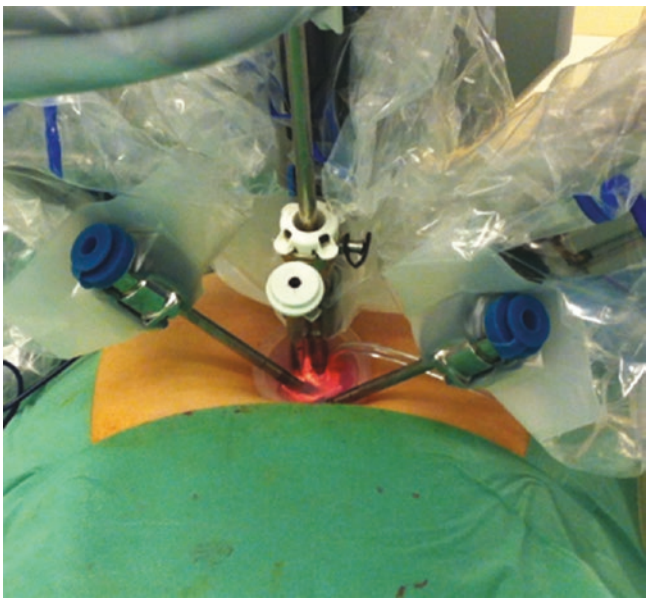

Fig. 6.3 Single-port robotic system

curved cannulas are lubricated and inserted through the designated lumen under direct vision so that the remote centers are located in the middle of the access port, and then the two robotic arms are docked (Fig. 6.3). Finally, the instruments were introduced: a monopolar cautery on the left cannulas for the right side and a bipolar grasper on

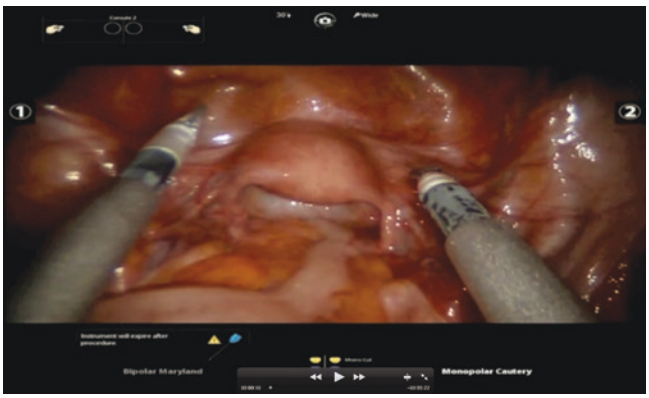

Fig. 6.4 Two instruments in the curved cannulas seen in situ

right cannulas for the left side (Fig. 6.4). The assistant's 5 mm accessory cannula, with which the assistant holds and moves either a suction/irrigator or a multifunctional versatile laparoscopic device, that grasps, coagulates, and transects simultaneously was inserted, lastly (Fig. 6.5a, b).

The operating surgeon then moves to the console. At the console the surgeon confirms that the robotic arms are swapped such that the screen right instrument is being controlled by the right master and vice versa. The use of a 30° robotic camera is rotated to look upward allows additional space for robotic arms to move more freely. No accessory trocar that is not part of the single-site device is inserted.

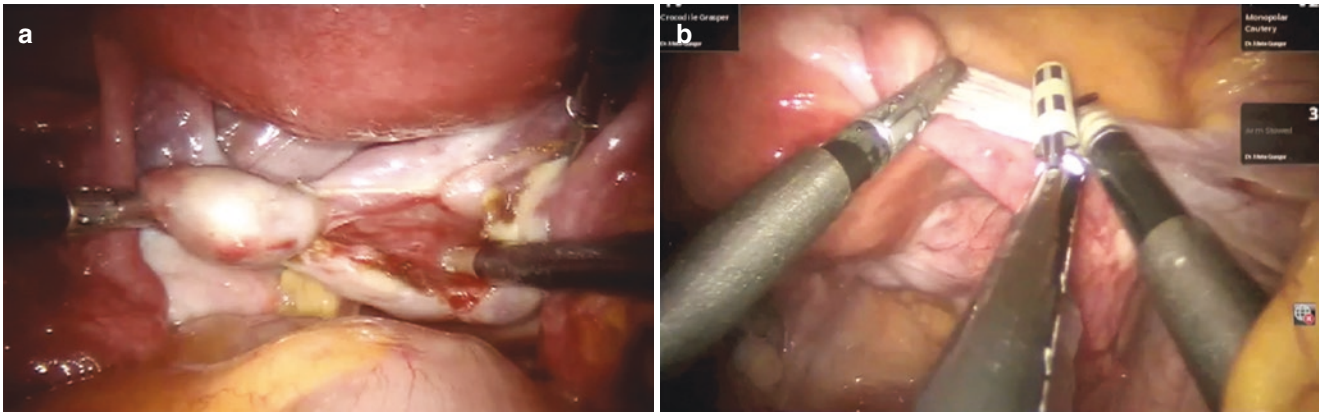

Fig. 6.5 (**a** and **b**) The assistant helps the surgeon by using grasper and vessel-sealing device

Discussion

Single-incision or single-port surgeries have recently become the preferred surgical methods, involving less blood loss, shorter hospital stays, improving the cosmetic benefits, and improved recovery time. It is suggested by multiple disciplines that the outcomes of LESS is feasible and safe in comparison with conventional laparoscopic and robotic techniques. Multiport operative complications related to trocar insertion, such as epigastric vessel injury, operative wound infection, and hematoma formation might be avoided by reducing the number of ancillary ports penetrating the abdominal wall. In addition to these, umbilical incision is larger in LESS which may make it easier to extract the mass out. On the other hand, there may be a risk of incisional hernia because of larger incision. But with proper techniques such as quick fascia closure and use of delayed absorbable or permanent suture the risk of hernia is similar to traditional laparoscopic and robotic surgery [13]. Although, it is supported by the studies that LESS leads to less postoperative pain and better cosmetic results and similar the risk of postoperative hernia, the power of the prospective studies are not enough to have definitive conclusion. However, there are limitations to these techniques, such as inferior ergonomics including significant collisions between instruments, a limited degree of movement, loss of triangulation, and a longer learning curve and operative time [13–15]. Single-site robotic surgery has the same advantages as LESS, and in addition to that robotic systems can overcome technical difficulties of LESS [9, 16]. Single-site robotic-assisted surgery offers many advantages such as three-dimensional visualization, a stable camera platform, tremor control, scaling of movement, and range of motion superior to that with conventional laparoscopy and greater maneuverability ergonomics compared with other single-site methods.

Escobar et al. reported the first experience with robotic-assisted single-port gynecologic surgery utilizing the da Vinci S platform. They performed hysterectomy with bilateral salpingo-oophorectomy and reported that single-port robotic surgery using the novel single-site platform is feasible and safe for a variety of gynecologic procedures [6].

Nam et al. report a single-institution retrospective series of seven women with benign and malignant gynecologic disease who underwent robotic single-port trans-umbilical total hysterectomy using a homemade surgical glove port system. They reported that robotic single-port trans-umbilical total hysterectomy is technically feasible in selected patients with gynecological disease and offers some potential advantages over the standard robotic or laparoscopy. Compared with LESS surgery, robotic single-site technique offers a major range of motion and improved instrument and camera stability, with augmented surgical ergonomics [9].

Cela et al. reported clinical experience of R-LESS with the da Vinci Si single-port dedicated device; a group of 12 patients with benign or malignant gynecological disease underwent R-LESS. They were collected to evaluate the surgical feasibility and the possible influence of the body mass index (BMI) and the uterine weight on operative times. The results of that study confirmed the feasibility and safety of R-LESS hysterectomy in woman and suggested that an initial learning curve of six cases was necessary [17].

After the approval of FDA for the use of single-port gynecologic surgery including benign and malignant condition, the number of institutions using single-port robotic surgery has been increased.

Scheib and Fader performed robotic single-site surgery on 40 patients with benign and malignant gynecologic conditions. Procedures were successfully performed robotic single-site surgery in majority of cases; two cases required one additional port and there was one conversion to traditional multiport robotic surgery. There was only one major postoperative complication and no postoperative hernias diagnosed [13]. Tateo et al. presented a case report of robotic single-site pelvic lymphadenectomy in well-differentiated adenocarcinoma of the endometrium. They managed successfully total hysterectomy, bilateral adnexectomy, and pel-

vic lymphadenectomy with no intraoperative or postoperative complications [18].

Ha-Na Yoo et al. reported a study among six patients with early stage endometrial, ovarian and cervical cancer; no major bleeding occurs in any patients. In four patients, pelvic lymphadenectomy is successfully performed. Only downside of the operations were para-aortic lymphadenectomy rarely performed because of proximity between operative field and umbilicus and difficulty in placing SS-dV platform on the umbilicus in an obese patient [19]. Recent advances in the single-site robotic platform have made the performance of R-LESS radical hysterectomy with sentinel lymph node mapping and complete lymphadenectomy. Ideal candidates for this procedure are patients with small tumors (less than 2 cm), small uteri (less than 10 cm), and previous complicated surgery [20, 21]. Gungor M. et al. removed bulky pelvic lymph nodes successfully before chemoradiation in an advanced stage of cervical cancer [22].

In a large study by Bogliolo et al., 45 patients with benign and malignant gynecologic conditions were reported. They found no significant difference between the single-site and multiport approach in console time, surgical complication rate, conversion rate, and postoperative pain. The docking time was lower, and the estimated blood loss and length of hospitalization were lower in the R-LESS group. The cost analysis showed R-LESS is favorable. In only two cases did a major early postoperative complication occur, hemoperitoneum and vaginal cuff hematoma [23].

Corrado et al. compared surgical outcomes and cost of R-LESS versus robotic multiport hysterectomy in early stage endometrial cancer. They found that operative time was similar, blood loss was lower and hospital stay was shorter in R-LESS than multiport technique. No intraoperative complications occurred in both groups. Overall cost was higher in multiport technique than in R-LESS [24].

Even if single-site procedures are not approved by the FDA for lymphadenectomy, as seen above, robotic single-site surgery pelvic lymphadenectomy is easily done without any complication in early stage endometrial and cervical cancer (Fig. 6.6).

As far as we know, only few studies are done in behalf of robotic-assisted single-port myomectomy. Lewis E et al. recently reported four cases of R-LESS myomectomy. Advantages of R-LESS are that wristed needle drivers greatly increase the ease of suturing compared to laparoscopy and the usage of CO_2 laser which is less likely to result in delayed thermal damage compared with electrosurgery that accompanies the goal of promotion of myometrial healing and minimizes adhesion formation [25]. Regarding the larger umbilical incision mandates by this technique, may be an advantage considering avoiding additional incisions for tissue extraction and avoiding the risk of seeding occult malignancies.

There are several factors and limitations for using the da Vinci platform for single-port surgery. The lack of haptic feedback and the need for a well-trained surgical assistant

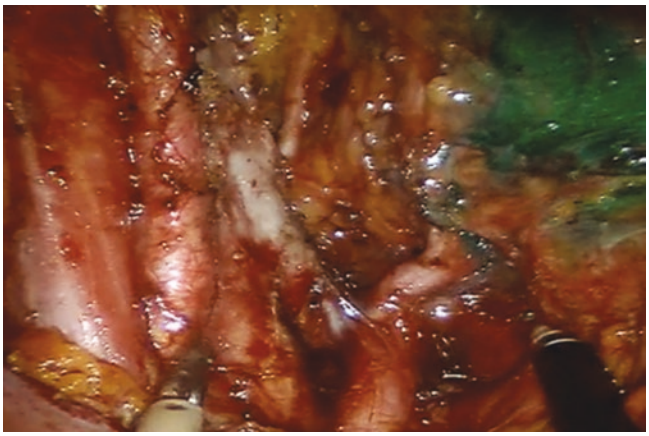

Fig. 6.6 Left pelvic lymphadenectomy

are the limitations of robotic surgery. Also, hardware (robotic trocars, cannulas, instrumentation, optics) and software were not designed for single-incision surgery and repertoire of non-articulating instruments and electrosurgical options compared with conventional multiport robotic surgery are limited. But recently, single-site robotic bipolar forceps has been tested and placed on the market, and it has gained popularity among surgeons. The width of the jaw of the bipolar cautery is too narrow to put effort in the desiccation of the utero-ovarian ligament or infundibulopelvic ligament. Therefore, sometimes one of the advanced bipolar devices performs desiccation of the large vessels instead of the Maryland bipolar of the R-LESS. The more surgical instruments specific to single-port robot are needed for using this technique for wide and common indications. The shaft of the R-LESS system has long curved cannulas to compensate the weak strength of curved semirigid instruments. Also, inverting controls of the robotic systems (right to left and vice versa) may allow the surgeon to operate without crossing the hands at the console; however, the robotic arms are crossed internally. This internal crossing and long cannulas presents a limitation of movement during pelvic surgery especially when working laterally or with large uteri [11].

There is a question of which is the best method for the vaginal vault closure such as transvaginal or intracorporeal robotic suturing. It has been known that multiport robotic surgery has advantages such as wristed instruments, 3D vision to laparoscopic vaginal vault suturing. Suturing of the vaginal cuff is considered to be one of the most technically difficult and time-consuming procedural steps in robotic-assisted single-incision hysterectomy because of non-articulating instruments. Currently, newly developed articulating instruments such as the single-site wristed needle driver are now approved for robotic-assisted single-access surgery. And yet due to the semirigidity of robotic instruments, vaginal cuff suturing with full strength still may not be provided sufficiently. Thus, a barbed suture with straightened needle can play a pivotal role with articulating instru-

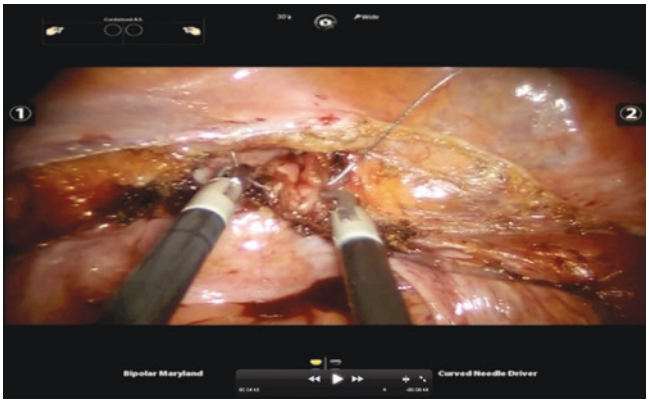

Fig. 6.7 Vaginal cuff closure with single-port robotic system

ments. The use of barbed sutures makes robotic single-site hysterectomy much easier, resulting in shorter operation time and less operative difficulty. This technique offers secure, fast, and effective incision closure [26] (Fig. 6.7).

Conclusion

The numerous benefits of MIS are better cosmetic results, reduced operative morbidity, reduced postoperative pain, and shorter length of hospital stay. Over the last decades, laparoscopic technologies have evolved remarkably, and robotic surgery using the da Vinci system has been introduced. But the current studies are not enough to define which of these techniques; LESS, R-LESS, and conventional robotic and laparoscopic system are superior to the others. New studies are needed to better define the ideal gynecological procedures to perform using robotic single-site surgery and to assess the benefits and costs of single-port robotic surgery compared with multiport robotic and conventional laparoscopic approaches. But further technological improvements, increased number of surgeries with robots, and with experienced surgeons, R-LESS seems to be promising for the future. However, the economic feasibility of robotic surgery still remains as another obstacle to be solved, and it is expected that the issue of high cost will be resolved.

References

1. Fader AN, Escobar PF. Laparoendoscopic single-site surgery (LESS) in gynecologic oncology: technique and initial report. Gynecol Oncol. 2009;114(2):157–61.
2. Bucher P, Pugin F, Buchs NC, Ostermann S. Randomized clinical trial of laparoendoscopic single-site versus conventional laparoscopic cholecystectomy. Br J Surg. 2011;98:1695–702.
3. Kim T-J, Lee Y-Y, Cha HH, et al. Single port access laparoscopic assisted vaginal hysterectomy versus conventional laparoscopic assisted vaginal hysterectomy: a comparison of perioperative outcomes. Surg Endosc. 2010;24(9):2248–52.
4. Tsimoyiannis EC, Tsimogiannis KE, Pappas-Gogos G, et al. Different pain scores in single transumbilical incision laparoscopic cholecystectomy versus classic laparoscopic cholecystectomy: a randomized controlled trial. Surg Endosc. 2010;24(8):1842–8.
5. Balaphas A, Hagen ME, Buchs NC, Pugin F, Volonté F, Inan I, et al. Robotic laparoendoscopy single site surgery: a transdisciplinary review. Int J Med Robot Comput Assist Surg. 2013;9:1–11.
6. Escobar PF, Fader AN, Paraiso MF, Kaouk JH, Falcone T. Robotic-assisted laparoendoscopic single-site surgery in gynecology: initial report and technique. J Minim Invasive Gynecol. 2009;16:589–91.
7. Kaouk JH, Goel RK, Haber GP, Crouzet S, Stein RJ. Robotic single-port transumbilical surgery in humans: initial report. BJU Int. 2009;103:366–9.
8. Stein RJ, White WM, Goel RK, Irwin BH, Haber GP, Kaouk JH. Robotic laparoendoscopic single-site surgery using GelPort as the access platform. Eur Urol. 2010;57:132–6.
9. Nam EJ, Kim SW, Lee M, et al. Robotic single-port transumbilical total hysterectomy: a pilot study. J Gynecol Oncol. 2011;22(2):120–6.
10. Haber G-P, White MA, Autorino R, et al. Novel robotic da Vinci instruments for laparoendoscopic single-site surgery. Urology. 2010;76(6):1279–82.
11. Escobar PF, Knight J, Rao S, Weinberg L. da Vinci® single-site platform: anthropometrical, docking and suturing considerations for hysterectomy in the cadaver model. Int J Med Robot. 2012;8(2):191–5.
12. Autorino R, Kaouk HJ, Stolzenburg JU, Gill IS, Mottrie A, Tewari A, et al. Current status and future directions of robotic single-site surgery: a systematic review. Eur Urol. 2013;63:266–80.
13. Scheib SA, Fader A. Gynecologic robotic laparoendoscopic single-site surgery: prospective analysis of feasibility, safety and technique. Am J Obstet Gynecol. 2015;212:179.e1–8.
14. Fanfani F, Rossitto C, Gagliardi ML, et al. Total laparoendoscopic single site surgery (LESS) hysterectomy in low risk early endometrial cancer: a pilot study. Surg Endosc. 2012;26:41–6.
15. Jung YW, Kim YT, Lee DW, Hwang YI, Nam EJ, Kim JH, et al. The feasibility of scarless single-port transumbilical total laparoscopic hysterectomy: initial clinical experience. Surg Endosc. 2010;24:1686–92.
16. 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;49:897–900.
17. Cela V, Freschi L, Simi G, Ruggiero M, Tana R, Pluchino N. Robotic single-site hysterectomy: feasibility, learning curve and surgical outcome. Surg Endosc. 2013;27:2638–43.
18. Tateo S, Nozza A, Del Pezzo C, Mereu L. Robotic single-site pelvic lymphadenectomy. Gynecol Oncol. 2014;134(3):631.
19. Yoo HN, Kim TJ, Lee YY, Choi CH, Lee JW, Bae DS, Kim BG. Single-site robotic surgery in gynecologic cancer: a pilot study. J Gynecol Oncol. 2015;26(1):62–7.
20. Tergas AI, Fader AN. Laparoendoscopic single-port surgery(LESS) radical hysterectomy for the treatment of early stage cervical cancer. Gynecol Oncol. 2013;129(1):241–3.
21. Boruta DM, Fagotti A, Bradford LS, Escobar PF, Scambia G, Kushnir CI, et al. Laparoendoscopic single-site radical hysterectomy with pelvic lymphadenectomy: initial multi-institutional experience for treatment of invasive cervical cancer. J Minim Invasive Gynecol. 2014;21(3):394–8.
22. Gungor M, Takmaz O, Afsar S, Ozbasli E, Gundogan S. Single-port robotic pelvic bulky lymph node resection: a case report. J. Minim. Invasive Gynecol. 2016;23(7):1030–1.
23. Bogliolo S, Mereu L, Cassani C, Gardella B, Zanellini F, Dominoni M, Babilonti L, Delpezzo C, Tateo S, Spinillo A. Robotic single-

site hysterectomy: two institutions' preliminary experience. Int J Med Robot. 2015;11(2):159–65.
24. Corrado G, Cutillo G, Mancini E, Baiocco E, Patrizi L, Saltari M, et al. Robotic single site versus robotic multiport hysterectomy in early endometrial cancer: a case control study. J Gynecol Oncol. 2016;27(4):e39.
25. Lewis EI, Srouji SS, Gargiulo AR. Robotic single-site myomectomy: initial report and technique. Fertil. Steril. 2015;103(5):1370–7.
26. Shin SJ, Chung H, Kwon SH, Cha SD, Cho CH. New suturing technique for robotic-assisted vaginal cuff closure during single-site hysterectomy. J Robot Surg. 2017;11(2):139–43.

Robotic Simple Hysterectomy

7

M.A.E. Nobbenhuis

Background

Hysterectomy is one of the most common operations in gynaecology. The advantages of minimally invasive over open hysterectomy have been demonstrated in several studies. A Cochrane review in 2009 and update in 2015 revealed significant improved peri- and postoperative outcomes in laparoscopic hysterectomy compared to open. Benefits include a shorter duration of hospital admission, faster recovery and return to normal daily activities, lower intraoperative blood loss, and reduced postoperative pain [1]. Conventional laparoscopy has seen limited application in many complex pelvic procedures due to the pelvis's restricted space and complex anatomy. The introduction of robotic-assisted minimally invasive surgery has overcome many of these limitations by providing superior dexterity, intuitive movement, 3-D vision, improved ergonomics, autonomy of camera control and a shorter learning curve. Compared to conventional laparoscopic surgery, robotic movements are filtered for tremor allowing for precise operating. The camera is fixed and in control by the surgeon providing a stable view. Another advantage of robotic surgery is the fact that the movement of the instruments are in the same direction as the movements of the surgeon hands, in comparison to laparoscopic surgery where the hand and instruments movements are counterintuitive. The availability of a dual console enables collaboration and facilitates teaching. This surpasses the disadvantages of the current robotic-assisted surgery including lack of haptic feedback and position of the surgeon away from the patient [2].

During the last 10 years, robotic laparoscopic-assisted surgery has substantially increased, initially with urological procedures before expanding to benign and oncological gynaecology and other specialities. The first robot-assisted hysterectomy was published in 2001 [3]. The first case series of robotic hysterectomies for various benign reasons was published by Diaz-Arrastia et al. [4]. This was followed by several publications describing small series of robot-assisted hysterectomies. In 2005, the US Food and Drug Administration formally approved the use of the Da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) for gynaecological procedures. At the time of approval, fewer intraoperative and major adverse events, a faster learning curve, and a lower conversion rate to open procedures was identified [5]. Since then, the number of minimally invasive gynaecologic procedures has increased dramatically, with the number of robotically laparoscopic-assisted hysterectomies surpassing the number of hysterectomies performed with conventional laparoscopy. Since 2010, 30.5% of benign hysterectomies were performed laparoscopically compared with only 14% in 2005 [6, 7]. The increase has been even steeper for robotic-assisted hysterectomy, with 0.5% of all hysterectomies performed robotically in 2007 compared with 9.5% in 2010 [7].

Despite this rapid increase, data on outcomes and costs are limited. Two RCTs compared robot-assisted and laparoscopic hysterectomy [8, 9]. In these two trials, a total of 148 patients were included. Operative times were significantly longer for robot-assisted hysterectomy (29 min and 77 min mean difference, respectively). However, no differences in blood loss, length of stay, type or number of complications, postoperative pain levels, analgesic use or recovery time were found. Patzkowsky et al. included 545 patients undergoing robotic or conventional laparoscopic hysterectomy for benign disease. In this retrospective study, the robotic group consisted of more complex cases with a larger uterine weight, extensive adhesions, previous history of laparotomy and higher prevalence of severe endometriosis. Despite this greater complexity, the perioperative outcomes in both groups were equivalent. Patzkowsky et al. [10] concluded that the introduction of robotic hysterectomy resulted in a decrease in the number of abdominal hysterectomy [11]. Lonnersford et al. described the effects of implementing a robotic surgical programme and concluded that after 1000 robotic surgeries, there was a sig-

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nificant increase in the number of patients undergoing minimally invasive surgery (26% in 2005 versus 81% in 2011) with a low rate of conversion rate (3.7%) [12].

A large cohort study analyzed 264,758 women who underwent hysterectomy for benign gynaecological disease at 441 hospitals in the United States from 2007 to 2010 [13]. A significantly shorter length of stay was seen in the robotic group with a lower transfusion rate; however, total costs in the robotic hysterectomy group were on average $2189 more. The same was concluded by Rosero et al. who, using the Nationwide Inpatient Sample data, identified 804,551 hysterectomies for benign conditions in 2009 and 2010. They found a significant increase in robotic hysterectomies from 9.5 to 13.6% ($p = 0.002$), with same overall complication rates but a higher cost of on average $2489 for patients undergoing robotic hysterectomy [14]. Other studies however show lower hospital costs after introduction of a robotic programme [15, 16].

In conclusion, studies show that robot-assisted gynaecologic surgery can be performed safely in centres with experienced surgeons and that this minimally invasive approach could be considered for procedures that might otherwise require laparotomy.

Procedure

Patient Selection

Almost all patients are eligible for robotic hysterectomy; there are no specific age, weight or body mass index (BMI) limits, unless co-morbidities result in patient being unfit for a surgical approach. Patients with large uteri can still benefit from a robotic hysterectomy; retrieval of the uterus through a mini-laparotomy should not affect the overall morbidity [17]. In morbidly obese patients, conventional laparoscopic hysterectomy has its limitations because of suboptimal vision, long operation duration and reduced operating freedom for the surgeon. Lavazza et al. performed a systematic review evaluating robotic hysterectomy in 2769 obese and morbidly obese patients. They concluded that robotic hysterectomy resulted in a lower conversion rate and potential better outcome than open or laparascopic techniques [18]. Robotic surgery is an ideal approach in (morbidly) obese patients without a significant increase in surgical outcome [19, 20].

Patient Positioning

Correct positioning of the patient, port insertion and docking are essential for a safe and successful robotic procedure [2].

Preoperatively there is no need for a full bowel preparation. Some surgeons prefer to give a laxative on the day of surgery to empty the rectosigmoid for better visualization. The patient should be in lithotomy position with the buttock just of the table. Legs should be placed in cushioned stirrups and knees flexed less than 60° to avoid nerve damage, and pressure points should be padded appropriately. During the surgery the patient will be in steep Trendelenburg, and appropriate measures should be taken to avoid slipping from the table. These can include shoulder braces, chest straps, foam mattress or a combination of those. Normally the arms are padded and tucked in on the side of the patient. The face should be protected to avoid contact with the robotic arms. An examination under anaesthesia is performed to assess the size and position of the uterus, and a uterine manipulator can be inserted. The patient should have an indwelling catheter.

Port Insertion and Docking

Port placement depends on the number of robotic arms used; this can be either three or four, one of which is the camera port (see Fig. 7.1). An assistant port will be added, normally in a subcostal position. Pneumoperitoneum needs to be secured in the usual manner. This can be performed either by a Veress needle technique or alternatively an open technique using a Hasson trocar with the patient in neutral position. A pneumoperitoneum of minimal 15 mmHg is necessary to safely position the robotic ports; this can be adjusted during the procedure. The camera port should be positioned 8–10 cm cephalic from the level of uterine fundus; this could be above the umbilicus in women with a large uterus or obese women. Measurements need to be taken after achieving pneumoperitoneum. After introducing the camera, the abdomen and pelvis should be inspected to look for safe entry, adhesions and surgical feasibility. The instrument ports must be inserted under vision. The patient should be positioned in maximum Trendelenburg to allow the bowels to migrate into the abdomen for optimal visualization. The remaining instrument ports are placed at least 8 cm apart (can be less when using the DaVinci Xi). Depending on the type of robot, the ports should be placed either in a straight line or lateral and cephalic from the camera port (see Fig. 7.1).

Docking of the robot can be done either ‘straight docked’ with the robotic platform between the legs or ‘side-docked’ under an angle of 45°. The main advantage of ‘side-docking’ is improved vaginal access.

Operating Technique-Stepwise

1. Inspection of the pelvis. Identification of the ureters.
2. The uterus is elevated from the pelvis. Incising the posterior broad ligament and creation of peritoneal window to isolate the infundibulopelvic ligament. Identification of the ureter. If the ovaries are to be removed, the infundibulopelvic ligament is cauterized with bipolar device and cut with monopolar scissors.

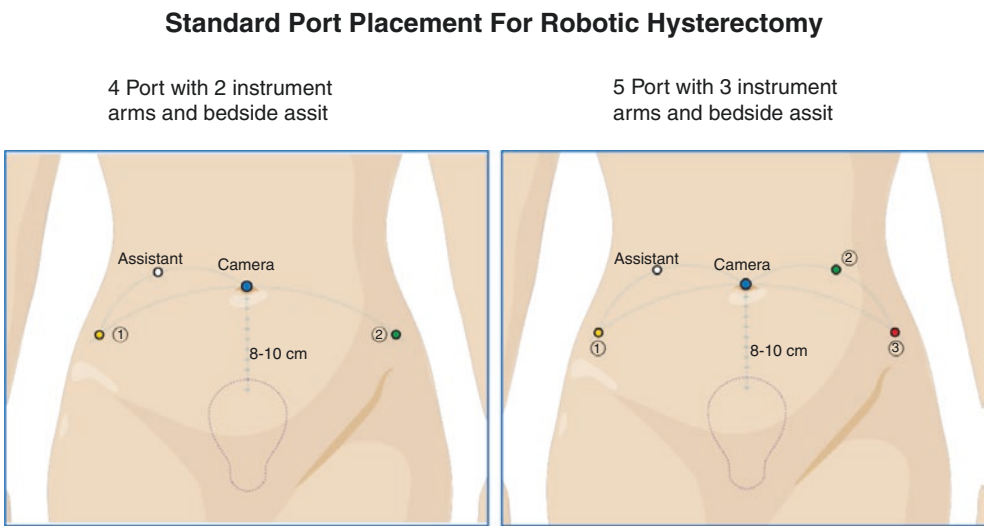

Fig. 7.1 Port placement for robotic hysterectomy using three or four arms (Courtesy Intuitive Surgical)

3. The posterior broad ligament leaf is incised, and the round ligament cauterized and divided.
4. The anterior broad leaf ligament is incised towards the bladder and the vesicouterine fold is developed. The fourth arm can be used to give counter traction.
5. Identification and skeletonizing of the uterine artery and vein.
6. The medial flap of the posterior peritoneum is incised to the level of the uterosacral ligament, allowing the ureter to drop to the pelvic floor.
7. Cauterizing and dividing of the uterine artery and vein.
8. The same will be performed on the contralateral side.
9. Further development of the vesicouterine fold. The uterine manipulator is pushed cephalic to elevate the cervix away from the bladder.
10. Colpotomy with monopolar scissors.
11. Removal specimen.
12. Closure vaginal vault. If repaired, irrigation to check for adequate haemostasis.
13. Remove instruments and dedocking of the robot.
14. Removal of all ports under vision. The sites of the trocars are repaired as per surgeon's preference.

Postoperative

Postoperatively the patient can start a normal diet. The Foley catheter will be removed early next morning. Discharge aim is the following day; however, there are centres with experience in discharge the same day. If this is the case, patients should be stable at least 4–6 h postoperatively. In order to avoid vaginal cuff evisceration, we recommend to refrain from vaginal intercourse for 6–8 weeks.

Surgical Outcome

Although some retrospective studies showed a significant increase in operating time, a recent paper by Mäenpää et al. [21] showed a significant shorter operating time for robotic-assisted hysterectomy versus traditional laparoscopic approach with no difference in outcome. Similar results were found when restricting analysis to hysterectomy for benign indications (odds ratio = 0.48; 95% CI = −16.72 to 17.69) [22]. Payne et al. [5] could demonstrate a reduction in the operating time in the robotic group comparing the last 25 cases with the first 25 procedures and Martinez-Maestre et al. attribute the significantly reduced surgical time to the easiness of surgery overall, and specifically during more complex steps such as the suture of colpotomy.

Conversion rate to laparotomy is lower in the robotic group in comparison to a laparoscopic approach (1.7% versus 6.2%; $p = 0.007$) [10]. In a case-control study by Jones et al., risk factors related to conversion are non-white ethnicity, bowel injury and increased body mass index [23]. When assessing surgeon-specific factors, increased case volume was associated with reduction in conversion [24]. A total of 5% conversion was found in their study, with complexity of surgery, ventilation complications and adhesive disease being responsible for more than half of the procedure conversions.

Perioperative Outcome

Patzkowsky et al. [10] found significant higher urinary tract infection and urinary retention in the robotic-assisted group. The authors postulated that more aggressive bladder dissection performed with robotic assistance may be associated with an increased risk of urinary retention [25].

The overall incidence of vaginal cuff dehiscence after any hysterectomy is 0.14–4.1%. Concern has arisen that vaginal cuff dehiscence may be more likely with minimally invasive hysterectomy due to electrocautery of the vaginal cuff, different suturing techniques are used, and a more magnified visualization of the surgical field could lead inadvertently to smaller areas of tissue being sutured. Specific surgical techniques that have been suggested to decrease the risk of cuff dehiscence after TLH or robotic hysterectomy include (1) the use of monopolar current on cutting mode (a continuous, low-voltage current that leads to less thermal spread compared with coagulation mode) to incise the cuff, (2) the achievement of cuff haemostasis with sutures rather than electrocoagulation, (3) the use of a two-layer cuff closure with polydioxanone suture that ensures adequate tissue edges when the vaginal cuff is sutured closed, and (4) bidirectional barbed suture for cuff closure [26]. Less blood loss and decrease in length of stay are more seen more often in robotic hysterectomy [10]. Injury and readmission are equal in both groups. Sarlos et al. found a significant higher postoperative quality on life index in robotic patients compared to laparoscopic [9].

Learning Curve

Several papers have discussed assessment of the learning curve in robotic procedures. The number of procedures a robotic surgeon needs to perform in order to be competent varies between 28 and 50 [27, 28]. Sandadi et al. prospectively analysed the operative times in a large single centre in more than 1000 robotic hysterectomies over a 5-year period, including the learning curve for fellows. A retrospective review from a single surgeon performing 100 robotic hysterectomies found that improvement in surgical times and complications peaked after 20 cases. A further small decrease in operating time was noted after each subsequent additional 20 cases [29]. All concluded that training of the surgical team is essential, and a minimum number of surgical cases should be performed before a surgeon is able to be proficient [2]. Furthermore, a consistent caseload should be maintained.

Conclusion

Robotic laparoscopic hysterectomy is considered to be a safe alternative procedure to the traditional laparoscopic approach. Challenges that arose in the earlier adoption stage of robotic surgery such as costs and operative times are becoming more optimized with greater experience, implementation of robotics in high-volume centres and with improved training of surgeons and robotic teams [30]. The importance of training of a robotic surgical team has been recognized, and learning programmes are set up around the world with the aim to introduce a safe robotic programme. Part of this should be an ongoing audit of performed cases to be able to assess outcomes and adverse events. Emphasis should be on the development of registry of robotic-assisted gynaecologic procedures via national societies.

References

1. Aarts JWM, Nieboer TE, Johnson N, Tavender E, Garry R, Mol BWJ, Kluivers KB. Surgical approach to hysterectomy for benign gynaecological disease. Cochrane Database Syst Rev. 2015;8:CD003677.
2. Schreuder H, Verheijen R. Robotic surgery. BJOG. 2009;116:198–213.
3. Cadiere GB, Himpens J, Germay O, Izizaw R, Degueldre M, Vandromme J, Capelluto E, Bruyns J. Feasibility of robotic laparoscopic surgery: 146 cases. World J Surg. 2001;25:1467–77.
4. Diaz-Arrastia C, Jurnalov C, Gomez G, Townsend C Jr. Laparoscopic hysterectomy using a computer-enhanced surgical robot. Surg Endosc. 2002;16:1271–3.
5. Payne TN, Dauterive FR. A comparison of total laparoscopic hysterectomy to robotically assisted hysterectomy; surgical outcomes in a community practice. J Minim Invasive Gynecol. 2008;15:286–91.
6. Jacoby VL, Autry A, Jacobson G, Domush R, Nakagawa S, Jacoby A. Nationwide use of laparoscopic hysterectomy compared with abdominal and vaginal approaches. Obstet Gynecol. 2009;114:1041–8.
7. Wright JD, Anath CV, Lewin SN, Burke WM, Lu YS, Neugut AI, Herzog TJ, Hershman DL. Robotically assisted vs laparoscopic hysterectomy among women with benign gynecologic disease. JAMA. 2013;309:689–98.
8. Paraiso MF, Jelovsek JE, Frick A, Chen CC, Barber MD. Laparoscopic compared with robotic sacrocolpopexy for vaginal prolapse: a randomized controlled trial. Obstet Gynecol. 2011;118:1005–13.
9. Sarlos D, Kots L, Stevanovic N, von Felten S, Schar G. Robotic compared with conventional laparoscopic hysterectomy: a randomized controlled trial. Obstet Gynecol. 2012;120:604–11.
10. Patzkowsky KE, As-Sanie S, Smorgick N, Song AH, Advincula AP. Perioperative outcomes of robotic versus laparoscopic hysterectomy for benign disease. JSLS. 2013;17:100–6.
11. Smorgick N, Patzkowsky KE, Hoffman MR, Advincula AP, Song AH, As-Sanie S. The increasing use of robot-assisted approach for hysterectomy results in decreasing rates of abdominal hysterectomy and traditional laparoscopic hysterectomy. Arch Gynecol Obstet. 2014;289:101–5.
12. Lonnersford C, Persson J. Implementation and applications of robotic surgery within gynecologic oncology and gynecology; analysis of the first thousand cases. Ceska Gynekol. 2013;78:12–9.
13. Wright JD, Herzog TJ, Tsui J, Ananth CV, Lewin SN, Lu YS, et al. Nationwide trends in the performance of inpatient hysterectomy in the United States. Obstet Gynecol. 2013;122:233–41.
14. Rosero EB, Kimberly AK, Girish PJ, Giesecke M, Schaffer JI. Comparison of robotic and laparoscopic hysterectomy for benign gynecologic disease. Obstet Gynecol. 2013;122:778–86.
15. Ind TE, Marshall C, Hacking M, Harris M, Bishop L, Barton D, Bridges JE, Shepherd JH, Nobbenhuis M. Introducing robotic surgery into an endometrial cancer service—a prospective evaluation of clinical and economic outcomes in a UK institution. Int J Med Robot. 2016;12:137–44.
16. Lau S, Vaknin Z, Ramana-Kumar AV, Halliday D, Franco EL, Gotlieb WH. Outcomes and cost comparisons after introducing a robotics program for endometrial cancer surgery. Obstet Gynecol. 2012;119:717–24.

17. Hanna RK, Bogess JF. Applications of surgical robotics in gynecologic surgery. In: Rosen J, Hannaford B, Satava RM, editors. Surgical robotics. Systems applications and visions. New York: Springer; 2011. p. 761–91. DOI 10.1007/978-1-4419-1126-1.
18. Lavazzo C, Gkegkes ID. Robotic assisted hysterectomy in obese patients: a systematic review. Arch Gynecol Obstet. 2016;293:1169–83.
19. Eddib A, Danakas A, Hughes S, Erk M, Michalik C, Narayanan M, Krovi V, Singhal P. Influence of morbid obesity on surgical outcomes in robotic-assisted gynecologic surgery. J Gynecol Surg. 2014;30:81–6.
20. Nawfal AK, Orady M, Eisenstein D, Wegienka G. Effect of body mass index on robotic-assisted total laparoscopic hysterectomy. J Minim Invasive Gynecol. 2011;18:328–32.
21. Mäenpää MM, Nieminen K, Tomas EI, Laurila M, Luukkaala TH, Mäenpää JU. Robotic-assisted versus traditional laparoscopic surgery for endometrial cancer; a randomized controlled study. Am J Obstet Gynecol. 2016;215:588.e1–7.
22. Martinez-Maestre MA, Gambadouro P, Gonzalez-Cejodo C, Torrejon R. Total laparoscopic hysterectomy with or without robotic assistance: a prospective controlled study. Surg Innov. 2014;21:251–5.
23. Jones N, Fleming ND, Nick AM, Munsell MF, Rallapalli V, Westin SN, et al. Conversion from robotic surgery to laparotomy; a case-control study evaluating risk factors for conversion. Gynecol Oncol. 2014;134:238–42.
24. Unger CA, Lachiewicz MP, Ridgeway B. Risk factors for robotic gynaecologic procedures requiring conversion to surgical procedures. Int J Gynecol Oncol. 2016;135:299–303.
25. Smorgick N, DeLancey J, Patzkowsky K, Advincula A, Song A, As-Sanie S. Risk factors for postoperative urinary retention after laparoscopic and robotic hysterectomy for benign indications. Obstet Gynecol. 2012;120:581–6.
26. Cronin B, Sung VW, Matteson KA. Vaginal cuff dehiscence; risk factors and management. Am J Obstet Gynecol. 2012;206:284–8.
27. Sandadi S, Gadzinski JA, Lee S, Chi DS, Sonoda Y, Jewell EL, et al. Fellowship learning curve associated with completing a robotic assisted total laparoscopic hysterectomy. Gynecol Oncol. 2014;132:102–6.
28. Yim GW, Kim SW, Nam EJ, Kim S, Kim YT. Learning curve analysis of robot-assisted radical hysterectomy, adnexectomy and lymphadenectomy in endometrial cancer. J Minim Invasive Gynecol. 2013;24:303–12.
29. Bell MC, Torgerson J, Seshadri-Kreaden U, Suttle AW, Hunt S. Comparison of outcomes and cost for endometrial staging via traditional laparotomy, standard laparoscopy and robotic techniques. Gynecol Oncol. 2008;111:407–11.
30. Truong M, Kim JH, Scheib S, Patzkowsky K. Advantages of robotics in benign gynecologic surgery. Curr Opin Obstet Gynaecol. 2016;28:304–10.

8 Robotic-Assisted Video Laparoscopic Management of Genital and Extragenital Endometriosis

Camran Nezhat, Becca Falik, and Anjie Li

Introduction/Background

The use of robotic technology in medicine was developed following the realization that imaging could be used to plan surgery to a level of precision that could not be matched by human hands [1]. In 1989, a possible robotic approach to transurethral prostatectomy was published and was carried out as proof of concept in 1991 using the six-axis "Puma" robot [2, 3]. Development of a device to make telepresence surgery a reality began in the early 1990s when a team from medical technology laboratory (MTL) began to explore the concept of remote surgery as a way of addressing the challenges of increased access to laparoscopic surgical technology. The team consisted of a diverse group of engineers and scientists, including Phil Green, Ajit Shah, Joel Jensen, John Hill, Peter Schattner, and Yonael Gorfu. Together, the team had expertise in mechanical engineering, electrical engineering, bioengineering imaging, software, and clinical medicine [4].

This team approached Dr. Camran Nezhat for his clinical expertise, who invited them to witness firsthand how complicated procedures are performed laparoscopically in the operating room at Stanford University Medical Center. They soon realized a core benefit of the robotic platform could be to enable less-experienced surgeons to complete laparoscopic procedures with the same facility as a senior surgeon such as Dr. Nezhat. Dr. Nezhat served as a core advisor for the team and was critical in the development of a clinically relevant surgical robotic platform [4].

The most widespread commercially available robotic platform currently used by gynecologic surgeons is the da Vinci (Intuitive Surgical Inc.). The primary benefits offered by the da Vinci platform include increasing dexterity and precision of movement, restoring the ergonomics of surgery, improving visualization, and reducing tremor [4]. Limitations include no haptic force feedback while operating at the console; thus the surgeon must rely on visual cues while operating. In addition, the complexity of the robotic setup requires potential additional operating time and necessitates a team of operating room staff specifically trained and familiar with the device. The cost of purchasing a robotic platform, with the initial purchase price, ongoing maintenance costs, and individual tools designed for finite use, may also be prohibitive in certain clinical settings [5].

Robotic-assisted video laparoscopic surgery has enabled more surgeons to perform delicate video laparoscopic surgeries, including surgery for endometriosis. Endometriosis affects approximately 10% of all reproductive-aged women and approximately 35–50% of women with pelvic pain and infertility [6]. It involves the presence of endometrial glands and stroma outside the endometrial canal of the uterus. Extragenital endometriosis is a surgical challenge for many gynecologists, with bowel endometriosis accounting for 80% of extragenital lesions [7, 8]. Deep infiltrative endometriosis can also be encountered along the urinary tract, causing bladder symptoms, or, if invading the ureter, can lead to hydronephrosis [9]. Video laparoscopic surgery with the use of the robotic platform may aid in the surgical management of these pathologies.

Diagnosis and Patient Selection/Preparation: Endometriosis

Endometriosis should be suspected in women who report dysmenorrhea, deep dyspareunia, severe chronic pain, infertility, and/or dyschezia. A bimanual and rectal exam is opti-

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mally performed at the time of menstruation when lesions may be most active. Findings may include a palpable nodule or a thickened area along the uterosacral ligaments, uterus, vagina, or rectovaginal septum. In cases of severe disease, a speculum exam may reveal lesions as well [10]. General principles to medical treatment for endometriosis include the emphasis on long-term hormonal suppression and patient compliance [11]. Low-dose progestins or combined oral contraceptives are both generally well tolerated and have been suggested as first-line treatment due to reported efficacy and cost. Exposure to Depo-Lupron can be considered as well.

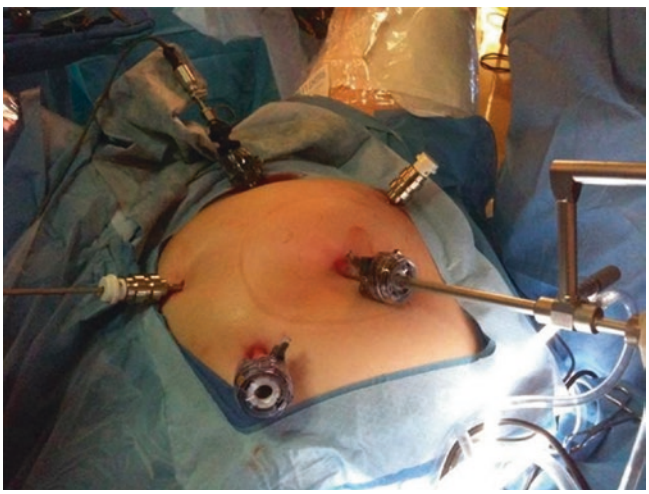

Photo 8.1 (Example of robotic trocar setup)—this can be redrawn by an artist if desired

Surgical management is recommended in patients who have failed medical management or for patients who have a medical contraindication to hormonal therapy. Video-assisted operative laparoscopy was first introduced by Nezhat in the early 1980s, which has allowed for complex surgical procedures to be performed in a minimally invasive fashion [12, 13]. Video laparoscopic treatment of endometriosis has been shown to be safe and effective with improvement of symptoms in >80% of patients, even in cases of stage IV endometriosis [14–20]. Video laparoscopic in general has been shown to be as safe as open surgery [21], with fewer resulting intraoperative and postoperative complications [22]. If the use of the robotic platform is planned, trocars should be placed ideally 10 cm apart to allow for proper triangulation and robotic setup (Photo 8.1), with care taken to avoid the inferior epigastric vessels (Photo 8.2). The most popular staging criteria is the revised American Fertility Society classification of endometriosis [23]; however, this system is dated, and clinicians have found it challenging to reproduce [24]. In our practice, we make a distinction between genital and extragenital endometriosis and describe the disease as mild, moderate, or severe with mild lesions limited to superficial disease, severe disease as more than 5 mm deep and moderate disease anything in between. Genital endometriosis describes lesions on the uterus, cervix, or adnexa. Lesions on any other location are categorized as extragenital.

Benefits of video laparoscopy include increased magnification and excellent video resolution allowing for improved visualization of pelvic and abdominal anatomy. This makes

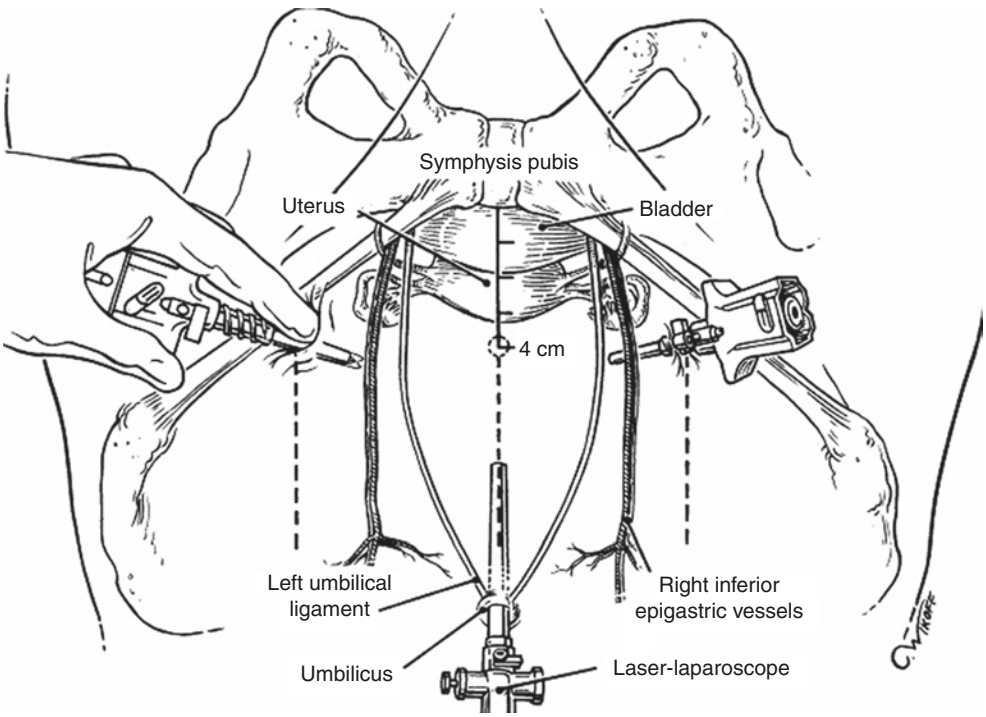

Photo 8.2 Course of inferior epigastrics

video laparoscopy with or without the robotic platform an ideal approach for thorough identification and treatment of endometriotic lesions and especially extragenital lesions on the bowel, genitourinary system, posterior cul-de-sac, and upper abdomen. The restored ergonomics of surgery offered by the robotic platform is particularly useful in the obese patient population. In addition, the three-dimensional visualization provided by robotic-assisted approach allows for improved diagnosis of subtle endometriotic lesions and facilitates dissection of delicate structures, potentially reducing risk of nerve damage and facilitates laparoscopic suturing [4, 22, 34].

Bowel Endometriosis: Patient Selection

Suspicion of bowel endometriosis starts with clinical history and physical exam, with some women reporting catamenial diarrhea or bloody stools, constipation, diarrhea, and radiation of pain to the perineum [25, 26]. Severe endometriosis on the low rectum can often be palpable on rectovaginal exam. Lesions often feel firm and can extend laterally to the pelvic sidewall. Correct and precise management of these lesions is critical as disruption of the surrounding vascular and nervous plexus may result in long-term bowel dysfunction [20].

To date, there is no established optimal hormonal regimen to treat deep infiltrative endometriosis of the bowel. Surgery is considered the cornerstone for the management of clinically symptomatic patients whose work-up is consistent with endometriosis of the bowel. In addition to physical exam, various imaging modalities may aid in the localization of bowel disease. Imaging modalities include transvaginal ultrasound (TVUS), rectal endoscopic sonography (RES), magnetic resonance imaging (MRI), and barium enema [27, 28]. It is recommended that these cases be multidisciplinary, with the involvement of colorectal surgeons familiar with bowel endometriosis [29, 30].

Prophylactic broad-spectrum antibiotics can be given 30–60 min prior to the procedure as surgical resection and bowel excision are considered clean-contaminated procedures. Oral mechanical bowel preparations have been shown to potentially increase the risk of spilling bowel contents due to the large volume of liquid stool that results [31]. As such, bowel preparation preoperatively is not routinely performed. Generally, a clear liquid diet 24 h prior to surgery is recommended, and patients are asked to perform up to three enemas on the night prior to surgery to allow for better visualization of the posterior cul-de-sac and mobilization of the bowel. Proctoscopy with an air leak test should be performed at the end of the procedure to ensure bowel integrity [32].

Bladder Endometriosis: Patient Selection

Urinary tract endometriosis is a rare presentation of extragenital endometriosis, estimated to exist in 1–3% of women with proven endometriosis [33]. Bladder endometriosis can mimic cystitis in presentation; however, ureteral endometriosis can often be initially asymptomatic and result in silent loss of a kidney should the disease be allowed to progress without treatment [34, 35]. On bimanual exam, deeply infiltrating nodules of the posterior cul-de-sac extending laterally should prompt concern for potential ureteral involvement.

Ureteral endometriosis can present as intrinsic or extrinsic disease, with a reported incidence ratio of 1:4 [36, 37]. To aid in mapping of disease, multiple imaging modalities have been used including CT, MRI, 3D ultrasound, and intravenous pyelogram [38–40]. Medical management alone is not recommended in the setting of obstruction and hydronephrosis given the potential risk of renal compromise [41]. When extensive disease is expected, the recommendation exists for a multidisciplinary approach to include urology, gynecology, and colorectal surgery as needed for optimal outcomes [36, 40]. Video laparoscopy with or without robot assistance is the recommended approach for optimal short- and long-term patient outcomes [34, 42, 43]. The referral to a surgical team with the proper technical skill and access to the proper instrumentation is of utmost importance [22, 34, 42].

Operative Technique

Endometriosis can present in various forms, including but not limited to peritoneal implants, endometriomas, and deep infiltrative extragenital lesions. Increased awareness of its various presentations can lead to an almost twofold increase in diagnosis of endometriosis at the time of video laparoscopy [44]. When possible, the diagnosis and operative treatment of endometriosis may be performed in one procedure. Complete removal of endometriotic implants can be difficult given the variability in appearance. The three-dimensional visualization offered by the robotic platform enables improved identification of subtle lesions [4, 22, 34, 45].

The surgeon should take advantage of the magnification offered by the robotic camera to assess the extent of disease in the abdomen and identify abnormalities or distortions of surrounding organs. Prior to docking the robot, the upper abdomen should be evaluated in a systematic fashion, including a thorough evaluation of the abdominal wall, liver, and diaphragm. After the robot has been docked in the typical fashion, the uterus, ovaries, ovarian fossa, boundaries of the bladder, ureters, colon, rectum, paracolic and pelvic gutters, uterosacral ligaments, and major blood vessels should be thoroughly investigated. It is estimated that 15% of patients with

endometriosis have appendicial involvement; therefore, identification and survey of the appendix are recommended [46].

With blunt forceps or a blunt probe such as the monopolar hook, identified endometriotic lesions should be probed to gauge size, depth, and proximity to normal structures. An implant can act as an "iceberg" lesion, where the superficial presenting disease is a reflection of several centimeters of retroperitonealized pathology [47]. The operative procedure begins by the restoration of abdominopelvic anatomy. This includes lysis of adhesions between the bowel and pelvic organs to expose the pelvis adequately. Approach to lysis of bowel adhesions varies depending on the density, vascularity, and location of the adhesion. Filmy adhesions may be stretched without shearing of the bowel itself. The use of CO_2 laser, plasma jet [48], harmonic scalpel, scissors, or electrosurgery at the point of attachment to surrounding structures is also reasonable. Dense adhesions may require the use of a cutting instrument such as scissors or CO_2 laser which offers precise and controlled penetration of dissected tissue. Hydro-dissection can be used liberally to identify and develop the correct dissection plane and also provides a buffer between diseased tissue and underlying structures to aid in subsequent excision [49]. The ovaries should be dissected from their pathologist adhesions to the pelvic sidewall or posterior cul-de-sac, and tubes should be freed from adhesions with subsequent chromopertubation performed. Endometrial implants and endometriomas can then be resected or thoroughly vaporized [49].

The principle behind surgical treatment is for the destruction of endometriotic implants in the most effective but least traumatic manner. Various modalities can be used as outlined above. Hydro-dissection followed by CO_2 laser or plasma jet excision [48] is a commonly used technique in our practice [18]. The CO_2 laser, which is available on the robotic platform, does not penetrate water; thus, hydro-dissection essentially creates a safety margin that allows surgeons to work in delicate areas without harming nearby major anatomic and vascular structures. Sharp dissection using robotic scissors and electrocautery using the monopolar hook are also reasonable approaches for excision as well. Often, following hydro-dissection, subtle lesions can be magnified, and previously invisible disease becomes apparent. Retroperitoneal disease can be grasped using forceps, pulled medially, and removed with a combination of blunt and sharp dissections [49].

Minimizing trauma to surrounding tissue is a paramount principle during the surgical treatment of endometriosis. On one hand, gentle dissection may hypothetically minimize postoperative scar formation. More importantly, minimizing unintended trauma to surrounding structures should align with the patient's overarching treatment goals. For example, treatment of endometriosis on the fallopian tubes of a nulliparous woman desiring future pregnancy should be tailored to minimizing tubal damage. Along the same lines, if the ovary is highly diseased, it is important to balance thorough treatment with preservation of ovarian tissue as to limit compromising future fertility [49].

Bowel Endometriosis: Operative Technique

Bowel endometriosis tends to be associated with fibrosis and sclerosis in the bowel wall, which may not respond to hormonal treatment alone. In the hands of experienced surgeons, surgery is associated with low morbidity and mortality and is the recommended approach [50]. A multidisciplinary care team, with the involvement of colorectal surgeons familiar with bowel endometriosis, is optimal [29, 30]. Several surgical techniques are available, including shaving of endometriotic lesions, disc excision, and segmental bowel resection with or without robotic assistance [16, 29, 49, 51]. Choice of technique varies depending on location of the endometriotic implant and depth of bowel lumen involvement [14, 30, 51, 52].

Bowel Endometriosis: Operative Technique—Shave Excision

Shave excision has been described since the 1980s as a conservative technique for treatment of extensive rectovaginal endometriosis and to restore the posterior cul-de-sac [13, 17, 18]. Its purpose is to remove or ablate all superficial endometriotic lesions on the bowel while leaving the bowel mucosa intact and preserving bowel integrity [17]. Cul-de-sac restoration is delicate work and should not be attempted by a gynecologist unfamiliar with bowel or urinary tract surgery.

Once the robotic platform has been docked, an assistant can stand at the perineum and, using a uterine manipulator, holds the uterus on tension to aid in the identification of anatomic plans. The left and right para-rectal spaces can then be dissected, with minimal dissection of the retrorectal space to decrease trauma of surrounding nerves and vessels [19]. Again, hydro-dissection of the retroperitoneal space creates buffer between the diseased peritoneal tissue and the underlying ureter and vascular structures. Areas that commonly undergo hydro-dissection include the anterior vesicouterine peritoneum and the peritoneum overlying the bilateral uterosacral ligaments. Endometrial lesions on the peritoneum can then be removed using the surgeon's instrument of choice, including but not limited to scissors, the CO_2 laser, electrosurgical knife, and monopolar or bipolar technology.

If the CO_2 laser is utilized, it can be set at 1 mm in diameter and a power of 40. The suction irrigator can be employed as a backstop for the laser to prevent damage of surrounding structures. Due to minimal thermal spread limited to 150 μm, the CO_2 laser or plasma energy is especially helpful in the treatment of bowel endometriosis. In comparison, bipolar cautery can cause up to 7500 μm of lateral thermal damage. The rectum adherent to the uterosacral ligaments and posterior lower uterine segment should be released. If rectal involvement is more extensive, a sigmoidoscope placed into

the rectum can help identify the plane in between the rectum itself and the fibrotic adhesions. After complete separation of the rectum from its pathologic adhesions to surrounding structures, lesions on the rectum or rectovaginal septum can be ablated or excised.

Care should be taken to excise lesions in the surrounding areas, including the parametria and right and left pelvic sidewall [17, 18, 53]. Low rectal lesions should be approached with caution. Experts operating at this level air on the side, leaving disease on the rectum rather than entering the bowel lumen, avoiding mechanical or thermal injury to the bowel mucosa whenever possible [54]. If the muscularis propria is disrupted, the surgeon should reinforce this defect to decrease risk of postoperative bowel perforation. Oftentimes, an assistant will perform a rectovaginal exam while the lead surgeon ablates and resects the disease from above. Ablation continues until the assistant is no longer able to palpate disease [55, 56].

At the completion of the dissection, the pelvis is filled with sterile normal saline or lactated ringers to observe the cul-de-sac and area of dissection under water. This magnification of the dissected tissue offered by the robotic camera helps identify any residual disease, as well as any potential remaining areas of bleeding. An air bubble test should be performed to ensure bowel integrity. If air bubbles are observed in the cul-de-sac fluid, perforation should be suspected and can be repaired with interrupted suture with or without a piece of omentum placed for reinforcement. This portion of the technique is akin to the approached taken via laparotomy [16].

Bowel Endometriosis: Operative Technique—Disc Excision

Video laparoscopic disc excision of bowel endometriosis was first described in 1989 [18], and this approach is now considered a well-established and feasible option [30, 51, 53, 57]. Lesions that qualify for this approach should infiltrate less than half the maximum circumference of the bowel [58] with several surgeons advocating for this approach instead of segmental resection as it has yielded comparable results with potentially fewer complications [14, 32, 59]. The extent of disease is first examined video laparoscopically. This can further be isolated using a sigmoidoscope at the time of robotic-assisted video laparoscopic survey. As with shave excision, the procedure begins with restoration of normal anatomy. This frees the bowel and allows for any subsequent repair to be performed in a tension-free manner. Following this, lesions smaller than 3 cm can typically be excised using scissors with the resultant defect repaired with suture or using a laparoscopic linear stapler or rectal stapler [60]. Careful inspection should be done prior to firing the stapler to ensure that the lesion is completely encased by the staple line to decrease risk of subsequent leakage. Similarly, the resultant staple line should be inspected carefully to verify that it can be seen past the entire length of transected bowel [32]. A robotic stapler can be used, or a laparoscopic stapler can be placed through the assistant port without needing to undock the robot.

If the use of the linear stapler is not feasible, for example, in cases of low rectal lesions, the bowel lumen can be entered using a variety of other methods, including laparoscopic scissors and/or the use of CO_2 laser [16]. If disc excision is performed using robotic scissors, all effort should be made to excise all diseased tissue until healthy, pink tissue is encountered [14, 52]. Opposing stay sutures can be placed at the residual defect using gentle tension to create a transverse, linear defect for subsequent robotic-assisted suturing [16, 18, 51, 53]. This can be performed in an interrupted fashion, with a spacing of approximately 5 mm in between sutures. It is recommended that the bowel be repaired in the transverse fashion to decrease risk of future stricture. The integrity of the closure should then be tested by performing a bubble test. Surgeons should be cautious when using electrical heat sources when performing these procedures as delayed necrosis and postoperative fistula or leak are potential complications.

Anterior disc excision can also be done via a natural orifice approach as well, including transrectal resection. This approach involves placing a trans-anal circular stapler to remove a full-thickness patch of the rectal wall after the bowel has been appropriately mobilized using the robotic platform. This approached is generally taken when lesions are less than 3 cm in diameter, but some experts have successfully performed disc excision in this fashion for lesions up to twice that size [29, 53, 61]. In our experience, we have found that the video laparoscopic approach with the linear stapler is more facile with minimal leakage complications [14]. However, for low rectal lesions which cannot be accessed by the linear stapler, the trans-anal stapler is an option. A randomized control trial is currently underway investigating the Rouen technique, a trans-anal disc excision approach, as compared with segmental resection [62].

Bowel Endometriosis: Operative Technique—Segmental Resection

Segmental bowel resection for treatment of endometriosis of the bowel has been described in the literature since the 1950s [63]. It involves the complete resection of the diseased bowel with the subsequent reanastomosis of the remaining healthy tissue. Indications for this approach include circumferentially diseased bowel or large and/or obstructive lesions of the bowel. Lesions on the small bowel are particularly

amenable to segmental resection. A multidisciplinary approach is encouraged for thorough and safe treatment of disease. Although once considered too difficult to perform without a laparotomy, the development of improved technology including the robotic platform and video laparoscopic stapling devices has enabled surgeons to utilize minimally invasive approaches to improve patient outcomes [29].

For lesions on the distal small bowel, ileocolic region, right hemi-colon, and appendix, segmental resection is a reasonable option [15, 20, 33, 64]. Appendectomy in conjunction with removal of disease elsewhere along the bowel is straightforward and reasonable due to the high frequency of concomitant disease found on the appendix at the time of endometriosis-related surgery [65, 66]. The surgical principle guiding the approach is maintenance of a well-vascularized, tension-free anastomosis to decrease risk of anatomic leak [33]. Pathologic adhesions attaching the involved bowel to the neighboring anatomy should be transected, with restoration of normal anatomy. A left tilt may be employed to help with visualization while patient is in the Trendelenburg position, and the right colon mesentery should be dissected in a medial to lateral fashion. Delicate structures here include the right ureter, right gonadal vessels, and second and third parts of the duodenum [54].

Once the bowel is adequately mobilized, it should be reexamined to clearly delineate the location of disease in relation to surrounding healthy bowel. This is to ensure that there is adequate tension-free healthy bowel for subsequent reanastomosis following complete resection of the diseased bowel. A laparoscopic linear stapler, introduced either robotically or through the assistant port, can then be applied and the diseased bowel transected. It is imperative that an expert trained in bowel surgery, such as a general surgeon or colorectal surgeon familiar with extragenital endometriosis, perform this procedure. The resultant closure helps to minimize spill of bowel contents. A side-to-side anastomosis is then performed by placing the proximal and distal bowel segments in parallel along their anti-mesenteric borders, with placement of a stay suture along this border to keep the orientation stable. A small defect should then be created to allow for the forks of the stapler to be introduced into each segment, and the laparoscopic linear stapler is then deployed. To complete the functional end-to-end anastomosis, the remaining enterotomy is regrasped and closed using either the linear stapler or suture with excess tissue trimmed sharply if needed [29, 49].

Lesions along the sigmoid colon which involve more than one-third of the bowel lumen can also be considered for segmental resection. After the sigmoid mesentery is mobilized, placement of patient in steep Trendelenburg position with a rightward tilt can help facilitate improved visualization of the posterior attachments of the mesocolon to the retroperitoneum. Here, the peritoneum of the mesocolon is then entered at level of the sacral promontory, and this incision is extended to the origin of the left colic artery. The superior rectal artery is then isolated proximal to the sigmoidal artery and secured using the device of choice, including but not limited to hemostatic clips, a vascular staple device, or thermal energy [54]. As the left ureter and left gonadal vessels are nearby, the use of thermal energy should be limited if possible. The descending colon should be mobilized to the level of the splenic flexure as to facilitate a tension-free reanastomosis to decrease with of postoperative anastomotic leak [54]. After the border between healthy and disease tissue is noted, a linear endo-stapler can be used as described above to transect and remove disease tissue, with subsequent performance of end-to-end primary reanastomosis. Proctoscopy should be performed to evaluate for potential defects, and an air leak test should be performed to ensure adequate closure. For low rectal lesions, treatment with less aggressive methods such as shave excision or disc excision is now advocated as the dissection of the retrorectal space requires extra caution. Dissection as this level may result in the disruption of the hypogastric plexus and can lead to autonomic dysfunction should the parasympathetic and sympathetic nervous be effected (see Photo 8.3) [20].

Ureteral Endometriosis: Operative Technique

The purpose of treatment is to free the ureter from its pathologic attachments, to avoid injury to the surrounding structures, and to preserve renal function [49, 67]. The video laparoscopic approach, with or without robotic assistance, is the recommended mode of surgery for improved patient outcomes [34, 42]. The magnification and clarity offered by the optics of robotic surgery creates the opportunity for thorough evaluation and treatment of endometriosis, which can be beneficial for subtle ureteral disease [36, 68]. The robotic-assisted modality also has the potential of expediting the learning curve of standard video laparoscopy, with the potential for improved dissection, possibility of decreased nerve interruption, and increased ease of suturing [52].

Intrinsic disease can involve the muscularis, lamina propria, or lumen of the ureter. Should proximal hydronephrosis be visible after ureterolysis is performed, infiltrative disease should be suspected and ureteral resection considered even if there is no visible stricture [36, 69]. Preoperatively, a physical exam reflective of deep infiltrative endometriosis should increase suspicion of possible ureteral disease. Intrinsic ureteral pathology is more common with the presence of deep infiltrative disease [67]. Imaging including MRI or IVP can be considered to assess for intrinsic disease. Renal function

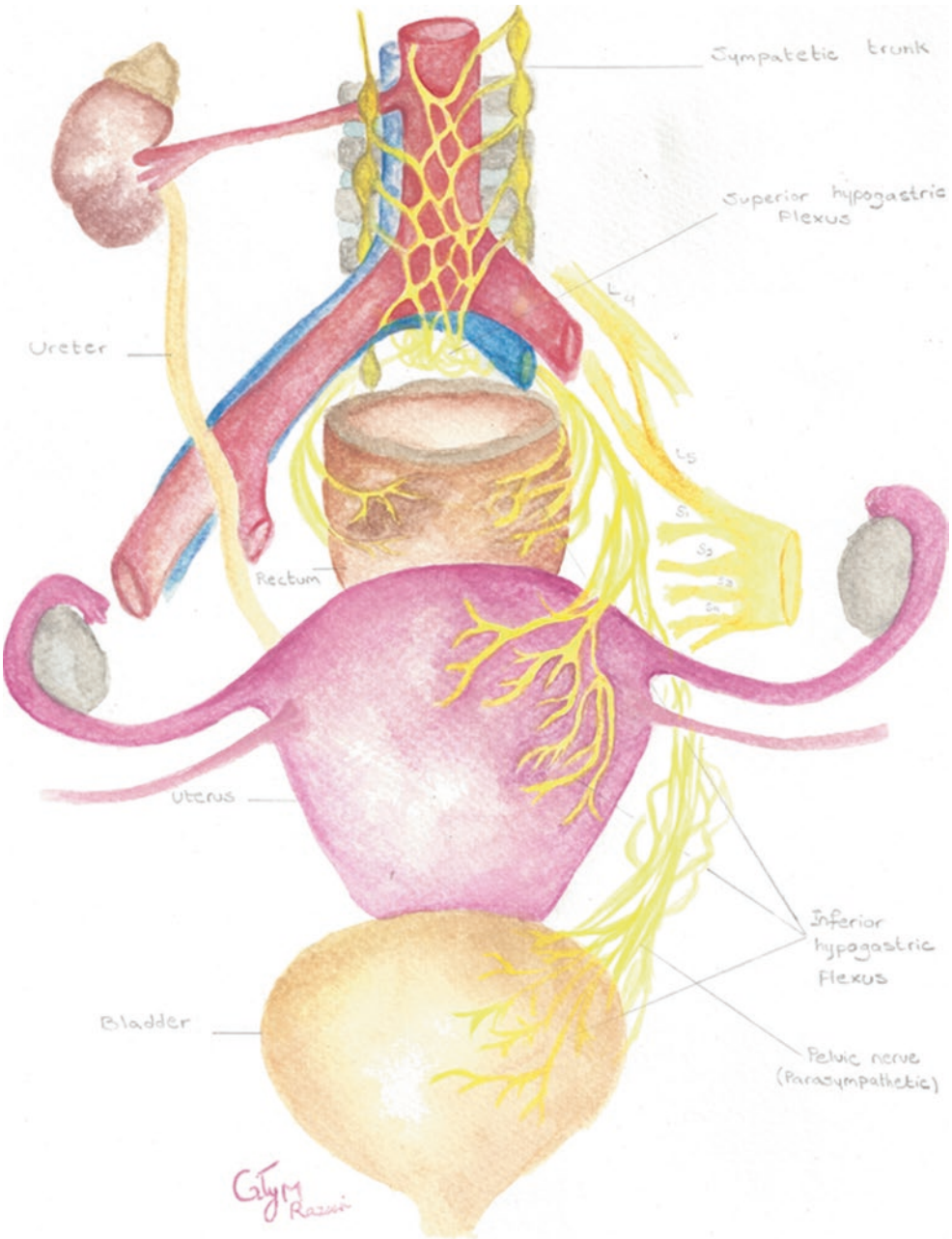

Photo 8.3 Course of the superior and inferior hypogastric plexus

can be evaluated with serum BUN and creatinine; however, a normal BUN/Cr may reflect chronic disease and silent kidney loss and should not negate the possibility of severe, intrinsic ureteral pathology. If there is preoperative concern for intrinsic disease, CT urogram with IV contrast should be considered and consultation with urology planned to prepare for a multidisciplinary approach.

Should the lesion be located on the proximal ureter, a uretero-ureteral anastomosis can be considered. If the disease is located on the distal ureter, a ureteroneocystostomy with or without a psoas hitch may be necessary. Larger areas of resection may require a Boari flap, ileal interposition, or autotransplantation [42, 43]. The principle behind reanastomosis is to create a tension-free connection between the ureter and bladder. Patients should be counseled regarding the possibility of recurrence, and regular physical exam with review of symptoms is recommended for surveillance. Imaging, including MRI, IVP, or CP, can be considered if there is suspicion of disease recurrence.

Bladder Endometriosis: Operative Technique

Endometriosis of the bladder can present subtly with genitourinary symptoms including but not limited to hematuria, dys-

uria, and urinary frequency [70]. A thorough history should be performed as the differential diagnosis is broad, including UTI, interstitial cystitis, stone, neoplasm, and endometriosis. Cystoscopy with biopsy is encouraged prior to definitive surgery if malignancy is of concern [70]. Endometriotic disease on the bladder can be fulgurated, but in our experience, we have found excision to be preferable. This is to both maximize complete removal of the disease and to have subsequent pathologic diagnosis to support the suspected disease process. If the detrusor muscle is involved, excision is the recommended approach. This should be performed in consultation with a surgeon, including urologists, trained in advance laparoscopic or robotic techniques [49, 52, 70]. One- or two-layer closures have been advocated, both associated with good results, as long as a tension-free repair in maintained [49, 71]. The bladder heals well following segmental resection as it is well vascularized. If the excised lesion was close to the trigone or ureteral meatus, placement of Double J® stents should be performed. In the rare case a lesion is located at the inter-ureteric ridge, a ureteroneocystostomy may be required. Postoperative cystogram is typically performed 7–14 days following surgery to ensure adequate healing prior to removing the Foley catheter [49, 71].

Surgical Treatment of Deep Infiltrative Endometriosis: Potential Complications

Perioperative complications following shave excision of endometriosis are the lowest among the surgical options, with favorable long-term outcomes. A series of 141 women who underwent shave excision of the bowel did not encounter any major complications, defined as postoperative rectovaginal fistula, anastomotic leakage, inadvertent ureteral damage, accidental bowel perforation, anastomotic leakage, or pelvic abscess [14]. A retrospective analysis following shave excision of 3298 cases of involving deep endometriotic nodule noted that bowel resection was required for only 1.1% (n = 37) cases. The complication rate was low, with only one case of rectal perforation, three cases of ureteral injury, and one case of fecal peritonitis [72, 73].

Beginning in 1989, Nezhat et al. described video laparoscopic segmental resection of bowel affected by endometriosis [29, 74]. Complications following this procedure can be considerable, and patients should be well informed regarding their risk associated with surgery [70]. Major postoperative complications reported include stricture, obstruction, infection, fistula/perforation, anastomotic leakage, and perioperative hemorrhage [75]. A systematic review of 34 articles described major complications in up to 11% of patients and suggested that the lower the anastomosis, the higher the probability of postoperative leakage [76]. Similarly, a cohort of 178 women who underwent various approaches for video laparoscopic treatment of bowel endometriosis encountered a higher proportion of major complications following segmental resection, with 6/48 (12.5%) major complications including ureterovaginal fistula (1/48, 2%), anastomotic stricture (2/48, 4%), intraoperative bladder perforation (1/48, 2%), rectal bleeding requiring transfusion (1/48, 2%), and anastomotic leak requiring temporary colostomy (1/48, 2%) [15]. Interestingly, of the 93 patients in the cohort who underwent shave excision, there were no major complications encountered [15]. Due to these observations, we advocate for shave excision to be performed whenever possible for the treatment of deep infiltrative endometriosis for lesions within 15 cm of the anal verge [17, 18].

On the contrary, segmental resection of bladder endometriosis is associated with excellent results [43, 71, 77]. Nezhat, Chamsy, and others observed no major complications following closure with monofilament suture or barbed suture and suggested several benefits of barbed suture including a more secure wound closure [78]. It is recommended to perform a cystoscopy 1–2 weeks postoperatively prior to Foley removal to assess for the integrity of closure [77, 78]. Generally, the video laparoscopic excision of endometriosis of the ureter is safe and effective. In a study of 80 patients with endometriosis involving the ureter who underwent ureterolysis and excision, postoperative complications were most commonly encountered in patients with disease involving more than 4 cm of the ureter [79]. The recurrence rate of disease was found to be 8.7% and, again, was more commonly seen in patients with extensive disease [79]. It is suggested that patients who have disease encompassing more than 4 cm of ureteral length consider ureteroneocystostomy versus ureterolysis alone [80]. Given the potential for perioperative and long-term complications, we only advocate surgical intervention for symptomatic patients [36].

Conclusions

Extragenital endometriosis should be considered in women who present with cyclic pelvic pain, bowel dysfunction, or urinary dysfunction. The decision to proceed with surgery should not be made lightly and is recommended, namely, for patients who are symptomatic. Should a patient require surgery, the robotic platform allows for improved visualization and increased dexterity, enabling surgeons to perform delicate and challenging surgeries in a minimally invasive fashion. Oftentimes medical management alone is not sufficient for the treatment of deeply infiltrative endometriosis. In these instances, a multidisciplinary surgical approach may be appropriate.

Regarding bowel endometriosis, segmental resection was previously advocated for any lesion along the bowel. However, new data suggests that there is an increased risk of perioperative and long-term morbidity associated with segmental resection of low rectal lesions due to the required extensive dissection of the retrorectal space [19]. Although lesions on the small bowel, ileocecal junction,

transverse colon, and even descending colon may be amenable to segmental resection, we advocate for shave excision for lesions within 15 cm of the anal verge to decrease risk of long-term morbidity to the patient.

In addition, the optimal approach for endometriosis located on the bladder or ureter often necessitates surgical excision. The key principle for surgical approach includes creating a tension-free reanastomosis if an excision is required. For disease that involves more than 4 cm of the ureter, a ureteroneocystostomy is recommended. Disease on the bladder can easily be excised, with the remaining defected sutured in a robotic fashion and Foley catheter left for 7–14 days. These procedures require significant skill and should be performed in collaboration with a surgeon trained in minimally invasive surgical techniques.

Bibliography

1. Dario P. Robotics for medical applications. IEEE Robot Autom Mag. 1996;3:44–56.
2. Davies BL, Hibberd RD, Coptcoat MJ, Wickham JE. A surgeon robot prostatectomy—a laboratory evaluation. J Med Eng Technol. 1989;13(6):273–7.
3. Davies BL, Hibberd RD, Ng WS, Timoney AG, Wickham JE. The development of a surgeon robot for prostatectomies. Proc Inst Mech Eng H. 1991;205(1):35–8.
4. Ajit Shah ES. A history of telepresence surgery. Nezhat's video-assisted and robotic-assisted laparoscopy and hysteroscopy. New York: Cambridge University Press; 2013. p. 628–41.
5. Talamini MA. Robotic surgery: is it for you? Adv Surg. 2002;36:1–13.
6. Giudice LC. Clinical practice. Endometriosis. N Engl J Med. 2010;362(25):2389–98.
7. Redwine DB. Ovarian endometriosis: a marker for more extensive pelvic and intestinal disease. Fertil Steril. 1999;72(2):310–5.
8. Weed JC, Ray JE. Endometriosis of the bowel. Obstet Gynecol. 1987;69(5):727–30.
9. Koninckx PR, Ussia A, Adamyan L, Wattiez A, Donnez J. Deep endometriosis: definition, diagnosis, and treatment. Fertil Steril. 2012;98(3):564–71.
10. Alabiso G, Alio L, Arena S, et al. How to manage bowel endometriosis: the ETIC approach. J Minim Invasive Gynecol. 2015;22(4):517–29.
11. Wu L, Wu Q, Liu L. Oral contraceptive pills for endometriosis after conservative surgery: a systematic review and meta-analysis. Gynecol Endocrinol. 2013;29(10):883–90.
12. Nezhat C, Crowgey SR, Garrison CP. Surgical treatment of endometriosis via laser laparoscopy. Fertil Steril. 1986;45(6):778–83.
13. Nezhat C, Crowgey SR, Garrison CP. Surgical treatment of endometriosis via laser laparoscopy and videolaseroscopy. Contrib Gynecol Obstet. 1987;16:303–12.
14. Nezhat C, Hajhosseini B, King LP. Laparoscopic management of bowel endometriosis: predictors of severe disease and recurrence. JSLS. 2011;15(4):431–8.
15. Mohr C, Nezhat FR, Nezhat CH, Seidman DS, Nezhat CR. Fertility considerations in laparoscopic treatment of infiltrative bowel endometriosis. JSLS. 2005;9(1):16–24.
16. Nezhat C, Nezhat F, Pennington E, Nezhat CH, Ambroze W. Laparoscopic disk excision and primary repair of the anterior rectal wall for the treatment of full-thickness bowel endometriosis. Surg Endosc. 1994;8(6):682–5.
17. Nezhat C, Nezhat F, Pennington E. Laparoscopic treatment of infiltrative rectosigmoid colon and rectovaginal septum endometriosis by the technique of videolaparoscopy and the CO_2 laser. Br J Obstet Gynaecol. 1992;99(8):664–7.
18. Nezhat C, Nezhat FR. Safe laser endoscopic excision or vaporization of peritoneal endometriosis. Fertil Steril. 1989;52(1):149–51.
19. Lewis LA, Nezhat C. Laparoscopic treatment of bowel endometriosis. Surg Technol Int. 2007;16:137–41.
20. Nezhat C, Nezhat C, Nezhat F, Ocampo J, Nutis M. Davalos et al. Outcome after rectum or sigmoid resection: a review for gynecologists. J. Minim. Invasive Gynecol. 2007;14(4):529–30. Author reply 530.
21. Darai E, Dubernard G, Coutant C, Frey C, Rouzier R, Ballester M. Randomized trial of laparoscopically assisted versus open colorectal resection for endometriosis: morbidity, symptoms, quality of life, and fertility. Ann Surg. 2010;251(6):1018–23.
22. Nezhat C, Nezhat F, Nezhat C. Operative laparoscopy (minimally invasive surgery): state of the art. J Gynecol Surg. 1992;8(3):111–41.
23. Revised American Society for Reproductive Medicine classification of endometriosis: 1996. Fertil Steril. 1997;67(5):817–21.
24. Johnson NP, Hummelshoj L, Adamson GD, et al. World Endometriosis Society consensus on the classification of endometriosis. Hum Reprod. 2017;32(2):315–24.
25. Daraï E, Dubernard G, Coutant C, Frey C, Rouzier R, Ballester M. Randomized trial of laparoscopically assisted versus open colorectal resection for endometriosis: morbidity, symptoms, quality of life, and fertility. Ann Surg. 2010;251(6):1018–23.
26. Moawad NS, Guido R, Ramanathan R, Mansuria S, Lee T. Comparison of laparoscopic anterior discoid resection and laparoscopic low anterior resection of deep infiltrating rectosigmoid endometriosis. JSLS. 2011;15(3):331–8.
27. Hudelist G, Oberwinkler KH, Singer CF, et al. Combination of transvaginal sonography and clinical examination for preoperative diagnosis of pelvic endometriosis. Hum Reprod. 2009;24(5):1018–24.
28. Bazot M, Darai E, Hourani R, et al. Deep pelvic endometriosis: MR imaging for diagnosis and prediction of extension of disease. Radiology. 2004;232(2):379–89.
29. Nezhat F, Nezhat C, Pennington E, Ambroze W Jr. Laparoscopic segmental resection for infiltrating endometriosis of the rectosigmoid colon: a preliminary report. Surg Laparosc Endosc. 1992;2(3):212–6.
30. Nezhat C, Nezhat F, Ambroze W, Pennington E. Laparoscopic repair of small bowel and colon. A report of 26 cases. Surg Endosc. 1993;7(2):88–9.
31. Mahajna A, Krausz M, Rosin D, et al. Bowel preparation is associated with spillage of bowel contents in colorectal surgery. Dis Colon Rectum. 2005;48(8):1626–31.
32. Landi S, Pontrelli G, Surico D, et al. Laparoscopic disk resection for bowel endometriosis using a circular stapler and a new endoscopic method to control postoperative bleeding from the stapler line. J Am Coll Surg. 2008;207(2):205–9.
33. Veeraswamy A, Lewis M, Mann A, Kotikela S, Hajhosseini B, Nezhat C. Extragenital endometriosis. Clin Obstet Gynecol. 2010;53(2):449–66.
34. Nezhat C, Nezhat F, Green B. Laparoscopic treatment of obstructed ureter due to endometriosis by resection and ureteroureterostomy: a case report. J Urol. 1992;148(3):865–8.
35. Nezhat C, Paka C, Gomaa M, Schipper E. Silent loss of kidney seconary to ureteral endometriosis. JSLS. 2012;16(3):451–5.
36. Bosev D, Nicoll LM, Bhagan L, et al. Laparoscopic management of ureteral endometriosis: the Stanford University hospital experience with 96 consecutive cases. J Urol. 2009;182(6):2748–52.
37. Comiter CV. Endometriosis of the urinary tract. Urol Clin North Am. 2002;29(3):625–35.
38. Sillou S, Poiree S, Millischer AE, Chapron C, Helenon O. Urinary endometriosis: MR imaging appearance with surgical and histological correlations. Diagn Interv Imaging. 2015;96(4):373–81.

39. Kinkel K, Frei KA, Balleyguier C, Chapron C. Diagnosis of endometriosis with imaging: a review. Eur Radiol. 2006;16(2):285–98.
40. Takeuchi M, Matsuzaki K, Harada M. Susceptibility-weighted MRI of extra-ovarian endometriosis: preliminary results. Abdom Imaging. 2015;40(7):2512–6.
41. Yohannes P. Ureteral endometriosis. J Urol. 2003;170(1):20–5.
42. Nezhat C, Modest AM, King LP. The role of the robot in treating urinary tract endometriosis. Curr Opin Obstet Gynecol. 2013;25(4):308–11.
43. Nezhat CH, Malik S, Nezhat F, Nezhat C. Laparoscopic ureteroneocystostomy and vesicopsoas hitch for infiltrative endometriosis. JSLS. 2004;8(1):3–7.
44. Spaczynski RZ, Duleba AJ. Diagnosis of endometriosis. Semin Reprod Med. 2003;21(2):193–208.
45. Nezhat C, Lewis M, Kotikela S, et al. Robotic versus standard laparoscopy for the treatment of endometriosis. Fertil Steril. 2010;94(7):2758–60.
46. Prystowsky JB, Stryker SJ, Ujiki GT, Poticha SM. Gastrointestinal endometriosis. Incidence and indications for resection. Arch Surg. 1988;123(7):855–8.
47. Schipper E, Nezhat C. Video-assisted laparoscopy for the detection and diagnosis of endometriosis: safety, reliability, and invasiveness. Int J Womens Health. 2012;4:383–93.
48. Nezhat C, Kho KA, Morozov V. Use of neutral argon plasma in the laparoscopic treatment of endometriosis. JSLS. 2009;13(4):479–83.
49. Nezhat C, Buescher E, Paka C, Nezhat C, Nezhat F. Video-assisted laparoscopic treatment of endometriosis. In: Nezhat C, Nezhat F, Nezhat C, editors. Nezhat's video-assisted and robotic-assisted laparoscopy and hysteroscopy. 4th ed. New York: Cambridge University Press; 2013. p. 265–96.
50. Orbuch IK, Reich H, Orbuch M, Orbuch L. Laparoscopic treatment of recurrent small bowel obstruction secondary to ileal endometriosis. J Minim Invasive Gynecol. 2007;14(1):113–5.
51. Nezhat C, Pennington E, Nezhat F, Silfen SL. Laparoscopically assisted anterior rectal wall resection and reanastomosis for deeply infiltrating endometriosis. Surg Laparosc Endosc. 1991;1(2):106–8.
52. Nezhat C, Hajhosseini B, King LP. Robotic-assisted laparoscopic treatment of bowel, bladder, and ureteral endometriosis. JSLS. 2011;15(3):387–92.
53. Nezhat F, Nezhat C, Pennington E. Laparoscopic proctectomy for infiltrating endometriosis of the rectum. Fertil Steril. 1992;57(5):1129–32.
54. Kopelman D, King LP, Nezhat C. Laparoscopic management of intestinal endometriosis. In: Nezhat C, Nezhat F, Nezhat C, editors. Nezhat's video-assisted and robotic-assisted laparoscopy and hysteroscopy. 4th ed. New York: Cambridge University Press; 2013. p. 303–9.
55. Donnez J, Nisolle M, Gillerot S, Smets M, Bassil S, Casanas-Roux F. Rectovaginal septum adenomyotic nodules: a series of 500 cases. Br J Obstet Gynaecol. 1997;104(9):1014–8.
56. Redwine DB. Laparoscopic en bloc resection for treatment of the obliterated cul-de-sac in endometriosis. J Reprod Med. 1992;37(8):695–8.
57. Wills HJ, Reid GD, Cooper MJ, Tsaltas J, Morgan M, Woods RJ. Bowel resection for severe endometriosis: an Australian series of 177 cases. Aust N Z J Obstet Gynaecol. 2009;49(4):415–8.
58. Kent A, Shakir F, Rockall T, et al. Laparoscopic surgery for severe rectovaginal endometriosis compromising the bowel: a prospective cohort study. J Minim Invasive Gynecol. 2016;23(4):526–34.
59. Slack A, Child T, Lindsey I, et al. Urological and colorectal complications following surgery for rectovaginal endometriosis. BJOG. 2007;114(10):1278–82.
60. Remorgida V, Ragni N, Ferrero S, Anserini P, Torelli P, Fulcheri E. How complete is full thickness disc resection of bowel endometriotic lesions? A prospective surgical and histological study. Hum Reprod. 2005;20(8):2317–20.
61. Roman H, Abo C, Huet E, et al. Full-thickness disc excision in deep endometriotic nodules of the rectum: a prospective cohort. Dis Colon Rectum. 2015;58(10):957–66.
62. Roman H, Tuech JJ, Slim K, Canis M. Functional outcomes of surgical management of deep endometriosis infiltrating the rectum (ENDORE). NCT01291576. http://clinicaltrials.gov/ct2/show/NCT01291576?term1/4NCT01291576&rank1/41. Accessed 24 Jan 2017.
63. Fleming WB. The management of endometriosis of the large intestine. Aust N Z J Surg. 1956;26(2):144–53.
64. Nezhat C, Nezhat F. Incidental appendectomy during videolaseroscopy. Am J Obstet Gynecol. 1991;165(3):559–64.
65. Gustofson RL, Kim N, Liu S, Stratton P. Endometriosis and the appendix: a case series and comprehensive review of the literature. Fertil Steril. 2006;86(2):298–303.
66. Berker B, Lashay N, Davarpanah R, Marziali M, Nezhat CH, Nezhat C. Laparoscopic appendectomy in patients with endometriosis. J Minim Invasive Gynecol. 2005;12(3):206–9.
67. Knabben L, Imboden S, Fellmann B, Nirgianakis K, Kuhn A, Mueller MD. Urinary tract endometriosis in patients with deep infiltrating endometriosis: prevalence, symptoms, management, and proposal for a new clinical classification. Fertil Steril. 2015;103(1):147–52.
68. Nezhat CH, Nezhat F, Seidman D, Nezhat C. Laparoscopic ureteroureterostomy: a prospective follow-up of 9 patients. Prim Care Update Ob Gyns. 1998;5(4):200.
69. Lusuardi L, Hager M, Sieberer M, et al. Laparoscopic treatment of intrinsic endometriosis of the urinary tract and proposal of a treatment scheme for ureteral endometriosis. Urology. 2012;80(5):1033–8.
70. Nezhat CH, Malik S, Osias J, Nezhat F, Nezhat C. Laparoscopic management of 15 patients with infiltrating endometriosis of the bladder and a case of primary intravesical endometrioid adenosarcoma. Fertil Steril. 2002;78(4):872–5.
71. Nezhat CR, Nezhat FR. Laparoscopic segmental bladder resection for endometriosis: a report of two cases. Obstet Gynecol. 1993;81(5(Pt 2)):882–4.
72. Donnez J, Jadoul P, Colette S, Luyckx M, Squifflet J, Donnez O. Deep rectovaginal endometriotic nodules: perioperative complications from a series of 3,298 patients operated on by the shaving technique. Gynecol Surg. 2013;10(1):31–40.
73. Roman H, Moatassim-Drissa S, Marty N, et al. Rectal shaving for deep endometriosis infiltrating the rectum: a 5-year continuous retrospective series. Fertil Steril. 2016;106(6):1438–45. e1432.
74. Nezhat C, Nezhat F. Evaluation of safety of videolaseroscopic treatment of bowel endometriosis. Scientific paper, 44th annual meeting of the American Fertility Society, Atlanta Hilton and Towers, Atlanta, Georgia, 8–13 Oct 1988.
75. De Cicco C, Corona R, Schonman R, Mailova K, Ussia A, Koninckx P. Bowel resection for deep endometriosis: a systematic review. BJOG. 2011;118(3):285–91.
76. Ret Davalos ML, De Cicco C, D'Hoore A, De Decker B, Koninckx PR. Outcome after rectum or sigmoid resection: a review for gynecologists. J Minim Invasive Gynecol. 2007;14(1):33–8.
77. Bourdel N, Cognet S, Canis M, et al. Laparoscopic ureteroneocystostomy: be prepared! J Minim Invasive Gynecol. 2015;22(5):827–33.
78. Chamsy D, King C, Lee T. The use of barbed suture for bladder and bowel repair. J Minim Invasive Gynecol. 2015;22(4):648–52.
79. Camanni M, Bonino L, Delpiano EM, et al. Laparoscopic conservative management of ureteral endometriosis: a survey of eighty patients submitted to ureterolysis. Reprod Biol Endocrinol. 2009;7:109.
80. Kolodziej A, Krajewski W, Dolowy L, Hirnle L. Urinary tract endometriosis. Urol J. 2015;12(4):2213–7.

Role of Robotics in the Management of Infertility

9

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Robot-Assisted Tubal Reversal

Background

The permanent female family planning option of tubal ligation is a safe, highly effective, and permanent form of contraception. Tubal ligation includes a number of different procedures and techniques. The idea behind the technique is to prevent pregnancy by disrupting the patency of the fallopian tubes [1].

Depending on the timing of the procedure, tubal ligation may be performed in one of the several ways. It may be performed immediately after childbirth (postpartum sterilization) or at a time unrelated to a pregnancy (interval sterilization). Postpartum sterilization procedures are performed following Cesarean section or vaginal delivery via minilaparotomy. For interval sterilization, laparoscopy is the most preferred option. Pomeroy, Parkland, Irving, and Madlener procedures, as well as fimbriectomy, are common open surgical methods. Laparoscopic tubal sterilization is disruption of tubal continuity through the use of loops, clips, or electrocautery.

Although tubal sterilization procedures are considered to be permanent, requests for reversal of the procedure (recanalization) are not infrequent (1–5%) [2]. The reversal procedure can be done either by open laparotomy or by minimally invasive surgery (laparoscopic or robotic approaches). The damaged part of the tube is excised, and the remaining patent ends are brought together and sutured, thus reestablishing tubal patency. The use of a microscope or loupes for magnification has been shown to be beneficial during open surgery [3] but is not necessary with a robotic approach since robotic surgical equipment provides magnification in addition to three-dimensional (3D) viewing.

The method of sterilization, remaining tube length following reversal, the length of time from the original sterilization procedure to reversal, and the woman's age are important factors that affect the success of reversal procedures [4]. Women's age older than 36 years, remaining tube length less than 4 cm, and sterilization for more than 5 years were found to negatively influence the success rate of the reversal procedure [5]. In terms of pregnancy rates, reversal procedures using clip or Falope ring sterilization have better results compared to coagulation or Pomeroy's technique. The use of operating loupes or a microscope, fine sutures, operator experience, and surgical techniques plays an important part in the success of reversal procedures [5]. The most reversible procedure is the placement of the Falope ring (83% term delivery), and the least reversible is fimbriectomy (29% term delivery) [3].

Description of the Intervention

The traditional approach has been to perform a laparoscopy to determine operability followed by an open laparotomy procedure using microsurgical techniques. Pregnancy rates of 70–80% have been achieved in women with a good prognosis [3, 5].

Because technology has developed and equipment has improved, laparoscopic surgeons are now recommending laparoscopic tubal reanastomosis with more confidence. Quicker recovery time and return to the job, early hospital discharge, and smaller incisions are the main advantages of this approach for the patients [6]. However, laparoscopic tubal anastomosis requires a high level of surgical expertise and proficiency. The laparoscopic method has a long learning curve for attaining proficiency in successful tubal reanastomosis compared to traditional open methods and is therefore only available only in selected centers. Safety and success are imperative in any surgery. According to some

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reports, laparoscopic tubal reanastomosis has more than 70% success for conception and ongoing pregnancy, a rate which is comparable to conventional open surgical techniques [6].

Robotic Surgery in Tubal Reversal

Robotic tubal reanastomosis marked the beginning of the era of robotic surgery in gynecology. In 1998, Margossian et al.'s work on porcine animal models concluded that a robotic approach to tubal surgery is a safe and feasible technique, with 100% immediate and 67% 4-week patency rates [7]. Two years later, Falcone et al. (ZEUS Robotic Surgical System, Computer Motion, now Intuitive Surgical, Sunnyvale, CA) and Degueldre et al. (da Vinci Surgical System, Intuitive Surgical) described bilateral tubal reanastomosis in ten and eight cases, respectively, completed with the robotic surgical systems [8, 9].

For the last decade, surgical sterilization has been the second most commonly used form of contraception overall in the United States and the most frequently used method among married women and women over 30 years old. Bilateral tubal ligation is the most effective and commonly used method of surgical sterilization [10]. While completion of childbearing and medical indications are the main reasons for undergoing tubal ligation, up to 30% of women will later regret their decisions. Change in a partner or marital status, young age, and nonwhite race are predictors for regret [2].

Microscopic tubal reanastomosis is generally recommended for women without a history of reproductive dysfunction [11]. Age is an important factor for prediction of pregnancy rates and pregnancy outcomes and should be considered along with other reproductive parameters as part of the preoperative workup.

Surgical Procedure

Several surgical techniques have been described for robotic tubal reanastomosis [11–13]. A commonly used protocol is to induce general anesthesia, place the patient in the dorsal lithotomy position, and apply intermittent pneumatic compression boots in both lower extremities. A uterine positioning system is used to ensure consistent intrauterine manipulation and chromopertubation. Pneumoperitoneum is created with a Veress needle followed by port placement and placement of a Visiport (US Surgical, Norwalk, CT) 5-mm trocar along with an orogastric tube in the suction mode to deflate stomach air. The da Vinci Si robot (Intuitive Surgical, Sunnyvale, CA) is docked obliquely, and the patient is placed in a Trendelenburg position. The surgical team insufflates the abdomen up to 11–14 mmHg and inserts three robotic ports under direct visualization. The 12-mm camera trocar is generally placed at the umbilicus. Two 8-mm robotic trocars are placed 8–12 cm lateral and slightly caudal to the umbilicus. An additional 12-mm assistant port is placed in the left upper quadrant, replacing the 5-mm initial trocar. The standard protocol allows for positioning of the robot between the patient's legs, although side docking is our preferred approach due to ease of vaginal access for chromopertubation and uterine manipulation [14].

After the robot is docked, scissors and bipolar forceps are used to immobilize the mesosalpinx and distal and amputate proximal tubal segments. The third robotic arm is used to improve exposure with robotic forceps. In most cases, the preferred hemostasis routine is dilute vasopressin injection into the proximal and distal segments of the mesosalpinx. Preferably, the surgeon should minimize the use of electrosurgery to avoid damage to the fallopian tube tissues. After amputating both sides of the stumps, chromopertubation is performed to assure tubal patency.

A catheter is used as a tubal stent to identify the distal tubal lumen and secure the anatomic orientation of the tube during the reanastomosis. Two Black Diamond Micro Forceps (EndoWrist; Intuitive Surgical) are utilized for suturing. Most centers prefer using 6-0 polyglycolic acid (reapproximate the mesosalpinx) and 8-0 polypropylene sutures (reapproximate the tube). At the end of the procedure, chromopertubation is performed to assure tubal patency, and an adhesive barrier is placed.

After Surgery

For the postoperative follow-up, patients are taken to the recovery room and observed for several hours. Nonsteroidal anti-inflammatory drugs and narcotic pain medication are used for postoperative pain control. Patients can discharge the same day if there is no other contraindication to discharge, but patient activity is limited for up to 14 days after surgery. Conception is not recommended until a hysterosalpingogram (HSG) at least 8 weeks after surgery confirms tubal patency.

After surgery, the risk of ectopic pregnancy is increased up to tenfold compared with the general population [15]. Therefore, patients should undergo a pregnancy test immediately following the first day of a missed menstrual period to exclude ectopic pregnancy.

In one study, the pregnancy rate was found to be 71% at 2-year follow-up after robotic tubal reanastomosis. The highest pregnancy rate, 91%, was observed in patients under 35 years old, and the lowest pregnancy rate, 33%, was in those over 43 years. Pregnancy rates among women aged 36–39 years were 75%; in those aged 40–42 years, the rate was 50% [16].

In two prospective studies evaluating surgical outcomes following robotic tubal reanastomosis (total of 95 patients),

authors found prolonged surgical times and increased cost for the robotic versus a classic open microsurgical approach to tubal reanastomosis [13, 17]. Hospitalization times and pregnancy and ectopic pregnancy rates were comparable between the two groups. Dharia Patel et al. reported shorter hospitalization times and decreased time for recovery in the robotic surgery group. The cost per delivery was similar between the two approaches.

In conclusion, robotic tubal reanastomosis is a safe and feasible technique with pregnancy rates on par with those achieved following in vitro fertilization (IVF) [13].

Robot-Assisted Reconstruction of Uterine Anomalies

Introduction

Müllerian duct anomalies are congenital malformations caused by altered development of the genital tract with a prevalence of 5–7% in the female patient population [18–20]. They are often asymptomatic and therefore unrecognized until they present with a variety of gynecological and obstetrical problems [21, 22]. A variety of surgical treatment modalities are performed to restore a normal uterine and/or vaginal architecture and preserve fertility. Since vascularization of anomalous organs and myometrial and cervical function may also be impaired, normal or near-normal architecture cannot always be achieved [23].

Surgical correction of these anomalies can be performed either by open abdominal/vaginal surgery or by endoscopic approaches including hysteroscopic, laparoscopic, or robot-assisted laparoscopic routes. The nature of the anomaly determines the most appropriate method.

In addition to a general outline of the classification, etiology, presentations, investigations, and available treatment options, this chapter will review robot-assisted laparoscopic surgery as a relatively new approach for correcting these congenital Müllerian anomalies.

Background/Etiology

A series of complex events including cellular differentiation, migration, fusion, and canalization are involved in the development of the female genital tract, and any failure of these processes at any step may lead to a congenital anomaly. Embryologically, Müllerian abnormalities arise mainly from four defective Müllerian duct steps with a sporadic occurrence and no evidence of familial inheritance [20, 24]:

- Unilateral maturation of one Müllerian duct with absent or incomplete development of the other side
- Either focal or whole-tube agenesis of both Müllerian ducts
- Absent or faulty midline fusion of the Müllerian ducts
- Defects of canalization

The most widely accepted classification of Müllerian duct anomalies is the American Fertility Society (AFS) classification which categorizes these anomalies into groups with similar clinical characteristics, pregnancy prognosis, and treatment. Reproductive tract abnormalities associated with the fetal exposure to diethylstilbestrol (DES) are also included in this classification as class VII [24].

The Class I defects caused by segmental Müllerian hypoplasia or agenesis may affect the vagina, cervix, uterine fundus, or fallopian tubes. These defects can occur in isolation or may be seen in association with other Müllerian defects. Class I vaginal abnormalities comprise vaginal agenesis and two types of congenital septa, arising from either a fusion, a resorption defect (longitudinal septum), or incomplete canalization/vertical fusion failure between the up-growing urogenital sinus and the down-growing Müllerian duct system (transverse septum). In Mayer-Rokitansky-Küster-Hauser (MRKH) syndrome, upper vaginal agenesis is typically associated with hypoplasia or uterine agenesis and may be accompanied by renal, skeletal, and auditory system abnormalities. Class I cervical developmental abnormalities are constituted of duplication, partial or complete agenesis, and longitudinal septa [24, 25].

Although they may be observed in a variety of forms, the more common uterine abnormalities may be categorized in AFS classification as uterine fundal hypoplasia or agenesis (Class I), unicornuate uterus (Class II), uterine didelphys (Class III), bicornuate uterus (Class IV), septate uterus (Class V), and arcuate uterus (class VI) [24]. In a review by Nahum, the most common uterine anomalies were bicornuate (39%) and septate (34%), while didelphic, arcuate, unicornuate, and hypo- or aplastic were observed as 11%, 7%, 5%, and 4%, respectively [26].

In unicornuate uterine anomaly, which develops in 1 in 4000 women [27], a rudimentary or underdeveloped horn may be present or absent. When it is present, there may or may not be communication with the other horn, and an endometrium-lined cavity may or may not exist [25].

A total lack of Müllerian duct fusion leads to uterine didelphys, which are characterized by two entirely separate cervices, hemi-uteri, and, usually, two vaginas or a longitudinal vaginal septum [28]. It can occur in isolation or may be part of a triad named shortly as OHVIRA (obstructed hemivagina and ipsilateral renal agenesis), which is also known as Herlyn-Werner-Wunderlich syndrome [29, 30].

The lack of fundal fusion may also result in two hemi-uteri, with only one cervix and vagina, which is called bicornuate uterus. A longitudinal vaginal septum may also accompany this anomaly [25].

When a defect in resorption results in a persistent partial or complete longitudinal septum within the uterine cavity, a septate uterus is formed. A complete vaginocervicouterine septum may be detected in rare cases [25].

The arcuate uterus is a kind of malformation which is regarded as a mild deviation from normal uterine development [25].

Hybrid anomalies are not described in AFS classification. For example, the combination of a septate uterus and bicornuate uterus is called "hybrid septate variety" and is not included in the classification [24, 31]. Nonuterine anomalies are also not included in AFS classification, but it allows additional descriptors of associated vaginal, tubal, and urinary abnormalities.

Presentation, Investigation, and Treatment Options

The presentation of Müllerian anomalies varies greatly, depending on the defect involved. Either cyclic or noncyclic pelvic pain and dysmenorrhea with increasing intensity, abnormal vaginal bleeding, or pain may be observed in adolescent girls after the start of menstrual periods. As for menstrual abnormalities, while minimal endometrium may lead to hypomenorrhea in some cases, amenorrhea may signify a vertical fusion defect or Mayer-Rokitansky-Küster-Hauser syndrome. A longitudinal vaginal septum, which may occur alone or accompany a didelphic or other form of double uterine anomaly, may lead to dyspareunia, leukorrhea, bleeding complaints despite the use of a tampon, and dystocia at delivery. In some cases, a mass may be detected on bimanual examination due to a hydrocolpos, and hematocolpos may be caused by a one-sided obstruction in the vagina, which may be complicated with microperforations leading to infection. If a noncommunicating functioning horn leads to retro menstruation, a woman may present with endometriosis and its associated symptoms. Obstetrical complications, such as recurrent pregnancy loss, cervical incompetence, antepartum and postpartum bleeding, intrauterine growth restriction, malpresentation, preterm delivery, pregnancy-associated hypertension, uterine rupture, and cesarean delivery, are also more common in women with uterine anomalies [32]. Women with or without uterine anomalies have similar clinical pregnancy rates when they undergo IVF [33, 34] since uterine abnormalities typically don't interfere with conception and implantation.

During the evaluation of common gynecologic and obstetric problems mentioned above, most congenital anomalies of the uterus and vagina are diagnosed incidentally. During infertility or reproductive loss workup, anomalies are discovered after a two-dimensional ultrasonography or hysterosalpingogram, which are the acceptable first-line screening tools favoring assessment of the adnexa and fallopian tube patency, respectively. Ultrasonography is also helpful to detect associated renal anomalies. The uterine cavity may be well delineated by both hysterosalpingography and saline infusion sonohysterography. Magnetic resonance imaging and/or three-dimensional ultrasonography are also the best noninvasive means to diagnose uterine anomalies [32]. Although they are less frequently required because of the radiologic advances described above, additional information may be obtained by examination with the patient under anesthesia, vaginoscopy, or laparoscopy alone or together with hysteroscopy in cases of complicated Müllerian anomalies [35, 36].

Among the various types of congenital uterine anomalies, uterine septa, bicornuate uteri, and obstructed hemiuteri, rather than unicornuate or arcuate uteri, are good candidates for surgical repair with the indications of pelvic pain and repetitive pregnancy loss after other causes are excluded [37].

The obstructed rudimentary noncommunicating uterine horn should be removed by laparoscopic or robot-assisted laparoscopic routes.

If medical therapy is ineffective, dysmenorrhea in women with septate uteri may be candidates for hysteroscopic metroplasty. In such cases, the possibility of coexistent endometriosis should also be evaluated by laparoscopy [23]. However, if the septum cannot be safely removed hysteroscopically or the uterine cervix cannot be dilated for introduction of the hysteroscope, then abdominal or laparoscopic approaches, such as the Jones metroplasty (a wedge resection of the portion of the uterine fundus containing the septum) or Tompkins metroplasty (a modified Jones metroplasty technique performed without removing any tissue) can be used [23]. As an acceptable alternative to abdominal metroplasty for uterine unification, robotic metroplasty with modified Jones metroplasty technique was reported for a patient with complete septated uterus with double cervix [38]. In a report by Gungor et al., a modified Tomkin's metroplasty procedure was performed with the use of robotic technology in a patient with hybrid septate variant anomaly [39].

For vaginal construction in patients with vaginal agenesis, androgen insensitivity syndrome, congenital adrenal hyperplasia, and gonadal dysgenesis, various nonsurgical and surgical techniques with different functional outcomes have been described [40]. As a first-choice treatment, nonsurgical vaginal dilation has been put forward. Although its functional results are good, keeping the neovagina patent requires mechanical dilatation with lubrication and periodically [41]. Among surgical techniques, the Abbe-McIndoe operation, the laparoscopic Davydov technique, the laparoscopic Vecchietti modified technique, and laparotomic and laparoscopic sigmoid vaginoplasty are the most widely used [42–46]. The first case of robot-assisted rectosigmoid vaginoplasty

performed on an adolescent with congenital vaginal atresia was reported by a pediatric surgeon group in 2008 [47]. Recently, Boztosun and Olgan presented a second case of a robotic approach to vaginal agenesis repair in an adolescent girl [48]. From India, Pushkar et al. reported a combined robotic and perineal approach for a 9-year-old girl with vaginal atresia in which the urogenital sinus (UGS) failed to contribute to the formation of the lower (distal) portion of the vagina [49].

For women with Müllerian agenesis and fusion defects, such as MRKH and congenital absence of the uterus, uterine transplant is a potential alternative to adoption or using a gestational carrier [23]. The robot-assisted approach has never been described for uterine transplantation, but it was recently proposed by Iavazzo and Gkegkes [50].

Surgical Technique

Initially, Kim et al. presented their technique for a completely robotic approach for the abdominal portion of a sigmoid vaginoplasty operation performed on a 17-year-old patient with 46,XY with androgen insensitivity syndrome [47]. Later, Boztosun and Olgan described their technique for robotic sigmoid vaginoplasty in an adolescent girl with MRKH. After the patient was positioned in a modified lithotomy position with PAS stockings with legs apart and secured to the bed with tape across the chest, four ports were used. The port placement was guided from prior reports of robotic sigmoid resection and the expected range needed to work in the patient's pelvis [51, 52]. Intraumbilically, a 12-mm trocar was placed, and two 8-mm robotic ports were placed in the left upper quadrant along the anterior axillary line and in the right lower quadrant lateral to the inferior epigastric vessels. As an accessory port, a fourth 5-mm laparoscopic port was placed just below the umbilicus and lateral to the inferior epigastric vessel port to provide additional retraction and expedite suture passage. After the table was rotated with the right side down approximately 30° for the small intestine to fall out of the surgical field, the robot was docked from the patient's left side [47]. After mobilization of the sigmoid colon, a 15-cm segment was measured with a piece of suture material and divided via a laparoscopic endovascular stapler introduced through the 12-mm umbilical port under temporary viewing with a 5-mm laparoscopic camera. With the robotic arms, the colon was reanastomosed, and the mesentery was reapproximated using a freehand technique. The isolated sigmoid segment was brought to the true pelvis without tension on its blood supply. A metal dilator was introduced from the perineum, posterior to the bladder and anterior to the rectum, to identify a path to position the sigmoid segment. By using electrocautery from a robotic working arm, an access into the peritoneum was made, and the distal end of the sigmoid was brought out the perineum. Additional tacking sutures were placed from the abdomen to secure the serosa of the sigmoid to the peritoneum in the pelvis [47].

To alleviate dysmenorrhoea, prevent an intracornual pregnancy, and possibly prevent endometriosis in cases of a rudimentary horn, a robotic-assisted laparoscopic approach can be used to perform a hemi-hysterectomy. In such cases, it is better to insert a uterine manipulator via the cervix to enable lateralization and identification of the communicating hemiuterus. If the cystic mass is large, the trocars are placed higher, but equally distributed, with an aim to facilitate surgery in the upper abdomen, as used for standard robot-assisted surgery in the pelvis [53, 54].

Results

Robotic vaginoplasty provides an opportunity for healthy adolescent patients with vaginal agenesis to benefit from the satisfying functional and relatively cosmetic results [48]. Performing a vaginal reconstruction by using a sigmoid colon in a minimally invasive approach, a colon-colon anastomosis without using a stapling device in laparoscopy, or an extracorporeal reconstruction through an additional incision of 3–4 cm necessitates extra surgical skills and training. However, with the advent of robotic surgery, the articulating instruments of the robot may provide complete wrist dexterity, which combines fine control with precision when performing cutting and intracorporeal suturing [55]. Therefore, a robotic vaginoplasty performed with a robot-sewn anastomosis might avoid additional laparoscopic techniques and laparotomy, resulting in a reduced risk of anastomotic complications [56] and a hospitalization time approximately 3 days shorter than for laparotomy [48]. In a recent report of robotic sigmoid vaginoplasty technique [48], the docking, surgeon console (including both abdominal and vaginal procedures), and total operative times (from docking to undocking) were reported as 50, 180, and 240 min, respectively. In the first report by Kim et al., the total time in the operating room was 9 h and 45 min, more than 90 min of which was used for access issues [47].

Robotic metroplasty is reported to be a safe, feasible, and successful surgical option [38, 39]. In addition to the technologic advantages of ergonomics, magnified high-definition (HD) three-dimensional (3D) optics, the autonomy of camera control, and wristed instrumentation, robotics may simplify the operation by allowing a delicate dissection of the uterus with minimal injury to the uterine wall, which might be more difficult with a traditional laparoscopic approach.

The robotic system also facilitates minimally invasive surgery even in rare and complex conditions which may be encountered during the corrective surgeries of various anom-

alies. As demonstrated by Anderberg et al., the meticulous retroperitoneal vessel dissection and subsequent step-by-step mapping and coagulation of the atypical blood vessels supplying the hemi-uterus and adnexa were successfully achieved with a robot-assisted laparoscopic approach during a hemi-hysterectomy procedure for a rare genitourinary malformation with associated duplication of the inferior vena cava [53]. The main disadvantages of a robot-assisted approach are the high cost for the health centers and the patients, the requirement for a larger operating room because of the bulky machinery, and the necessity of specific training for the surgical team. The need for more and larger ports may be a relative disadvantage for some patients who are highly worried about the cosmetic results.

Complications

The limited number of case reports related to corrective surgeries for female reproductive tract anomalies showed good results with no postoperative complications. The estimated blood loss was minimal, usually less than 100 mL [39, 47, 48, 57]. There is an increased risk of uterine rupture with procedures requiring fundal hysterotomy, and cesarean delivery is recommended for these women [23].

Conclusion/Personal Review

A steep learning curve is inevitable for reconstructive laparoscopic procedures. Robot-assisted laparoscopy may offer an avenue for overcoming some of the technical limitations of traditional laparoscopic surgery. The feasibility of robotic sigmoid vaginoplasty and robotic metroplasty with various corrective surgery techniques for female genital tract anomalies has been well explored, and the robotic approach gives hope for a possible role in uterine transplantation, too. However, we should keep in mind the fact that with the refinement of the technology, the issues of cost and training need to be addressed for the full acceptance of these robotic-assisted laparoscopic techniques in the future.

Robotic Surgery in Cervical Insufficiency

Cervical insufficiency is also known as incompetent cervix, which is characterized classically by painless cervical dilatation in the second trimester. It can be followed by prolapse and ballooning of membranes into the vagina, which leads to loss of otherwise normal pregnancies or preterm birth, with an incidence of 0.1–1.0% of all pregnancies. If not effectively treated, this sequence may repeat in future pregnancies. The term has also been applied to women with one or two such losses/births or those at risk for second-trimester pregnancy loss or preterm birth [58].

Risk Factors

Risk of cervical insufficiency is increased with congenital and acquired cervical abnormalities; acquired risk factors are more common.

Acquired abnormalities include:

- Cervical trauma during labor or delivery (spontaneous, forceps- or vacuum-assisted, cesarean) [59]
- Rapid mechanical cervical dilation before a gynecologic procedure (e.g., uterine evacuation) [60] or treatment of cervical intraepithelial neoplasia

Congenital abnormalities include:

- Genetic disorders affecting collagen (e.g., Ehlers-Danlos syndrome) [61],
- Uterine anomalies [62, 63]
- In utero diethylstilbestrol (DES) exposure [64]
- Biologic variation

How Can We Make Diagnosis of Cervical Insufficiency?

In our clinical practice, two main diagnoses of cervical insufficiency are present:

- Based on historic factors, diagnosis is made in women with two- or more consecutive prior second-trimester pregnancy losses associated with relatively painless early cervical dilation or three or more early (<34 weeks) preterm births in which other causes of pregnancy loss or preterm birth have been excluded.
- Diagnosis is also made on a combination of historic factors and transvaginal ultrasound measurement of cervical length. Having one or two prior second-trimester pregnancy losses or preterm births and cervical length ≤25 mm on transvaginal ultrasound examination or advanced cervical changes on physical examination before 24 weeks of gestation may be risk factors for cervical insufficiency that support the diagnosis.

Treatment

Nonsurgical and surgical modalities have been defined to treat cervical insufficiency.

Nonsurgical approaches. Unfortunately, nonsurgical approaches, such as activity restriction, bed rest, and pelvic rest, have not been proven effective for treating cervical

insufficiency, and their use is discouraged [65, 66]. Vaginal pessary, which is another nonsurgical option, is considered in patients at risk for cervical insufficiency. Evidence is limited for potential benefit of pessary placement in select high-risk patients [67–69].

Surgical approaches. Transvaginal and transabdominal routes are identified procedures for cervical cerclage. More proximal placement of the stitch, decreased risk of suture migration, absence of a foreign body in the vagina that could promote infection, and the ability to leave the suture in place for future pregnancies are the main advantages of the transabdominal over transvaginal cerclage [70]. A disadvantage of this approach is the potential need for two laparotomies during pregnancy (one to place the cerclage and potentially another to remove it).

How Can We Treat the Patient Surgically?

Transvaginal cerclage. Modifications of the McDonald and Shirodkar techniques are the standard methods currently used. The superiority of one surgical technique or suture type over another has not been proven [71, 72]. In the McDonald procedure, a simple purse-string suture of nonresorbable material is inserted at the cervicovaginal junction [73]. The Shirodkar procedure involves dissection of the vesicocervical mucosa in an attempt to place the suture as close to the cervical internal os as might otherwise be possible. Dissection is necessary for the bladder and rectum from the cervix in a right plane through the cephalic line. Then the suture is placed and tied, and the mucosa is resutured over the knot [74, 75]. As in the McDonald procedure, nonresorbable sutures are preferred for cerclage placement in the Shirodkar procedure, too.

Transabdominal cerclage. Abdominal cerclage procedures are usually performed in the late first trimester or early second trimester (10–14 weeks of gestation) or in the nonpregnant state [76, 77]. The stitch can be left in place between pregnancies with subsequent cesarean delivery.

Transabdominal placement of a cerclage at the cervicoisthmic junction appears to be a safe and effective procedure for reducing the incidence of spontaneous pregnancy loss in selected patients with cervical insufficiency [78, 79].

Cervicoisthmic cerclage is generally reserved for when anatomical limitations (e.g., after a trachelectomy) prevent cerclage placement or when previous failed transvaginal cervical cerclage procedures have resulted in second-trimester pregnancy loss [80]. Two options available for transabdominal cerclage are open (laparotomy) or minimally invasive (laparoscopy/robotic).

The preferred route can depend on physician experience or patient preference. In a systematic literature review, no evidence exists to suggest that laparoscopically performed surgical approach for cervicoisthmic cerclage placement has an advantage over the laparotomic surgical approach [76]. Nevertheless, in a recent review of 14 studies of abdominal cerclage, high rates of third-trimester delivery and live birth after abdominal cerclage via laparoscopy were comparable to those via laparotomy [81]. Because cervical incompetence treated with transabdominal cerclage can carry significant morbidity with the need for sequential laparotomies and prolonged postoperative recovery, preference for minimally invasive procedures is an increasing trend.

Laparoscopic transabdominal cerclage placement has been described but has significant limitations with only two-dimensional depth perception and limited dexterity. Robotic-assisted cervical cerclage (RACC) is rapidly gaining acceptance in gynecologic surgery [82]. RACC has reportedly been used for placement of an interval transabdominal cerclage. RACC is less invasive and is effective not only as an interval procedure but also during pregnancy, offering the patient an alternative to the traditional laparotomy but with quicker recovery time [83].

Robot-Assisted Cervical Cerclage Procedure

Abdominal cerclage in pregnancy. In this section, we will describe the steps for uterine cerclage performed during pregnancy. In our clinic, the robot-assisted abdominal cervical cerclage procedure is usually performed between 12 and 14 gestational weeks after evaluating the first-trimester genetic screening data. According to the American College of Obstetricians and Gynecologist guidelines, there is insufficient evidence to recommend perioperative antibiotic prophylaxis; even so, we administer a single dose of cefazolin 2 g preoperatively [84].

In our clinic, after inducing general anesthesia, the patient is placed in the dorsal lithotomy position with intermittent pneumo-pressure boots on both lower extremities. The initial trocar entrance is from the Palmer point, which is left of the midclavicular line, 3 cm under the left coastal margin. The Visiport 5-mm trocar placement is synchronized with an orogastric tube in suction mode to deflate the stomach air. The SI robot is docked obliquely, and the patient is placed in a shallow Trendelenburg p (<25°) to be compliant with pregnancy-related hemodynamic changes. We insufflate the abdomen up to 11 mmHg and insert three robotic ports under direct visualization. The 12-mm camera trocar is generally placed 10 cm superior to the umbilicus. Two 8-mm robotic trocars are placed bilaterally 10 cm from the camera port (Fig. 9.1). An additional 12-mm assistant port is placed on the left upper quadrant, replacing the 5-mm initial trocar. A 0-degree camera allows visualization of the uterus (both anteriorly and posteriorly) while maintaining a wide view. The option of using a 30-degree scope interchangeably during the procedure when needed is always a possibility. Intraabdominal pressure is maintained at about 11 mmHg

throughout the case to give sufficient insufflation for visualization while not compromising uterine perfusion.

The peritoneum is incised at the vesicouterine reflection, and a bladder flap is created. The cervix is gently elevated by an assistant's fingers, which allows direct feedback to the surgeon for identifying the margins of the cervicoisthmic junction. After identifying landmarks, a sterile-covered transvaginal probe (M-Turbo; SonoSite, Bothell, WA) is inserted. Using the TilePro multi-input display feature, the ultrasound is connected to the da Vinci Si system (Intuitive Surgical, Sunnyvale, CA), allowing the surgeon to view both the operative field and the real-time ultrasound images capture by a transvaginal probe. An open fan retractor placed through the laparoscopic port allows the distribution of any pressure over a larger area, avoiding point pressure on the gravid uterus. Dissection continues until the cervicoisthmic junction, uterine arteries, and parametrial vessels are exposed bilaterally.

The curved needles of a 30-cm long, double-swaged, 5-mm-wide Mersilene suture (RS20; Ethicon, Inc., Somerville, NJ) are straightened and introduced through the assistant port. A robotic needle driver is placed. Ultrasound is used to identify the endocervix and gestational sac in longitudinal views and the cervical edges and lateral structures in transverse images (Figs. 9.2 and 9.3). The tip of one needle is placed at the cervicouterine junction posteriorly medial to the uterine vessels. The split-screen ultrasound images allow constant visualization of the needle. Once visualized on the anterior aspect of the uterus, the needle is pulled through. Similarly, the second needle transfixes the cervicouterine junction on the opposite side (Fig. 9.4). Ultrasound verifies the proper Mersilene tape placement and fetal heart tones. Needles pass in a posterior-to-anterior fashion in the cervical isthmus area bilaterally to avoid the possibility of damaging presacral and pelvic vessels located posteriorly to the pelvis. Another technique for placing the Mersilene tape is to introduce the tape into the intraperitoneal cavity without the needles. Using a long, pointy tip grasper, the ligamentum latum is opened with a spreading, dissecting technique. After creating the passages bilaterally on both sides of the cervical isthmus, the mesh is introduced. An advantage of this technique is avoiding the use of needles, but precision in creating the surgical field is not as good as the needle technique. At this point, the literature shows a similar success rate with both techniques [82].

Care is then taken to ensure that the cerclage is lying flat against the cervix and the knot is tied anteriorly (Fig. 9.5). Adjustment of the knot will be guided by the assistant's manual exam to leave the cervical os at 0.5 cm, allowing us to monitor for premature rupture of membranes during the pregnancy and menstrual bleeding (in case the patient chooses to keep the mesh after delivery). Cervical length is measured again after the procedure.

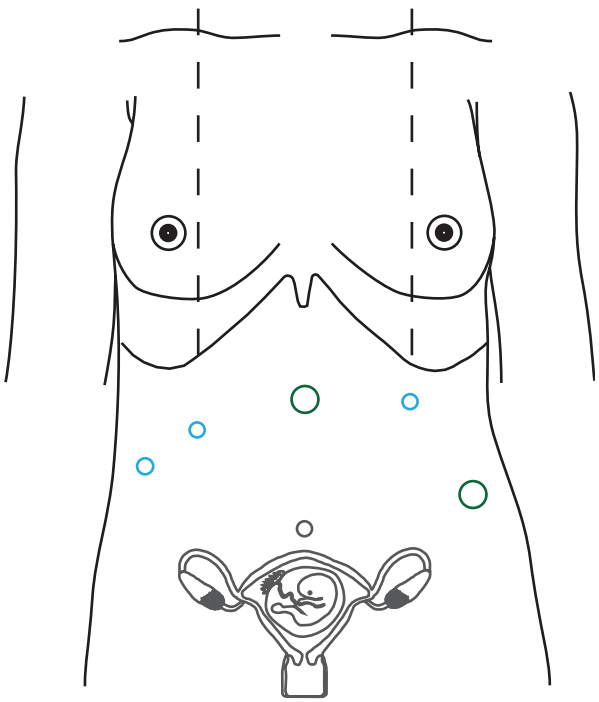

Fig. 9.1 Trocar distribution for pregnant uterine abdominal cerclage. The da Vinci Si robot is docked obliquely

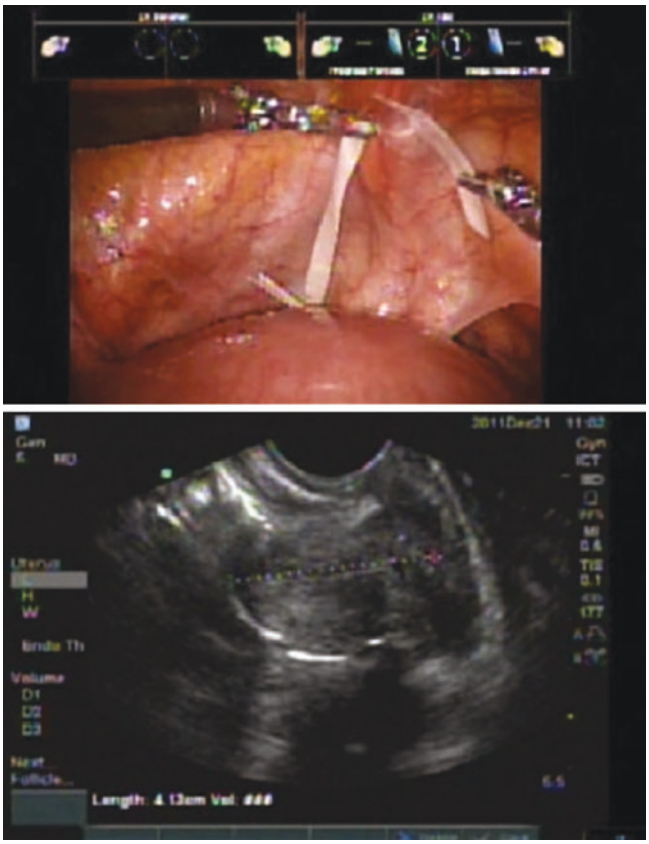

Fig. 9.2 Simultaneously showing a transvaginal ultrasound image of the cervical length and anteriorly placed cerclage stitch

Robot-assisted cerclage performed during pregnancy—with the advantages of 3D visualization and endowristed instrumentation—has the potential to improve safety for the patient and the fetus. As we described earlier, the TilePro feature allows the ultrasound view to be projected with the surgical view on the same screen simultaneously [85]. Another feature is the option to utilize indocyanine green dye (Fig. 9.6) to identify the vascularity before you pass the needles [86].

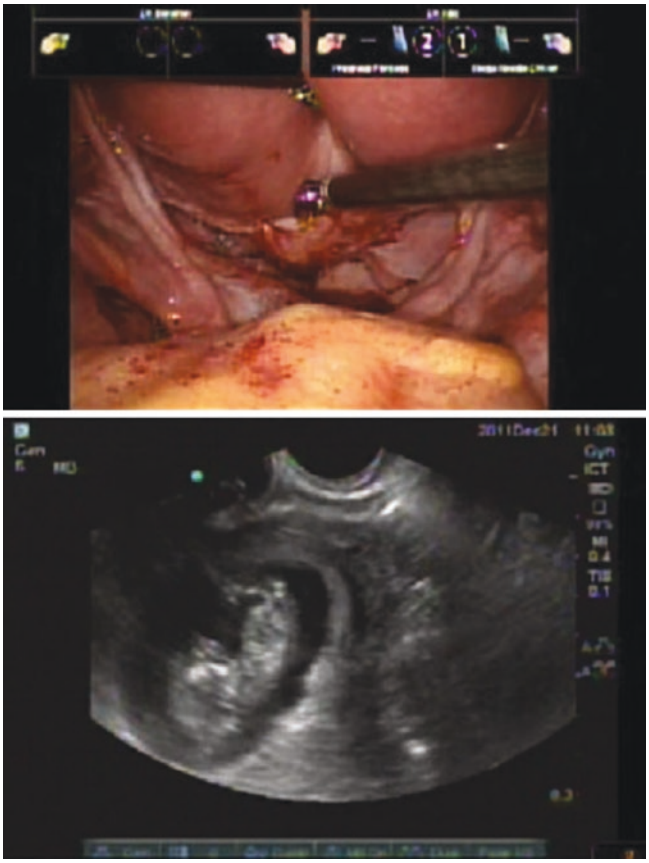

Fig. 9.3 Simultaneously showing transvaginal ultrasound image of the fetus at the completion of the case and intraoperative image of robotic cerclage placement

Nonpregnant Uterine Cerclage. For nonpregnant cerclage, the steps will differ as follows compared to the technique for pregnant patients.

Preconceptual counseling is important, especially for discussing possible cerclage placement, and its potential impact on conception is critical to discuss. A few studies directly compare the insertion of a preconceptual transabdominal cerclage with insertion in early pregnancy [81, 87]. The most recent one concluded that preconceptual transabdominal cerclage is more successful in preventing pregnancy loss and preterm labor and is associated with less surgical and pregnancy-related morbidity compared to first-trimester transabdominal cerclage insertion [87]. Tulandi et al., however, found that the efficacy of the procedure performed either before or during pregnancy is similar [81]. Even so, preconceptual insertion should be considered when possible because of the technical advantage of operating on the uterus of a woman who is not pregnant. Furthermore, there is no evidence that preconceptual transabdominal cerclage has any detrimental impact on fertility or management of an early miscarriage [88]. Abdominal cerclage can be safely left in place if a further pregnancy is a possibility.

A pregnancy test is critical before beginning the procedure. Initial trocar entrance is the same as for pregnant patients. Enter from the Palmer point, which is left of the midclavicular line and 3 cm under the left coastal margin. Placement of a 5-mm Visiport (US Surgical, Norwalk, CT) is to be synchronized with an orogastric tube in the suction mode to deflate stomach air. We insufflate the abdomen up to

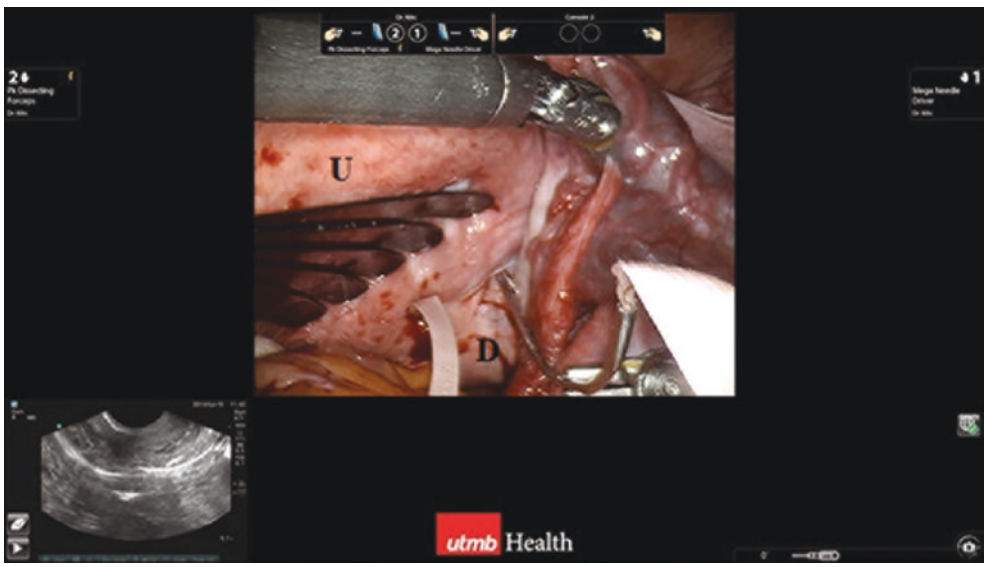

Fig. 9.4 Second needle passing from posterior to anterior in avascular area. *U* Uterus, *D* Douglas Pouch

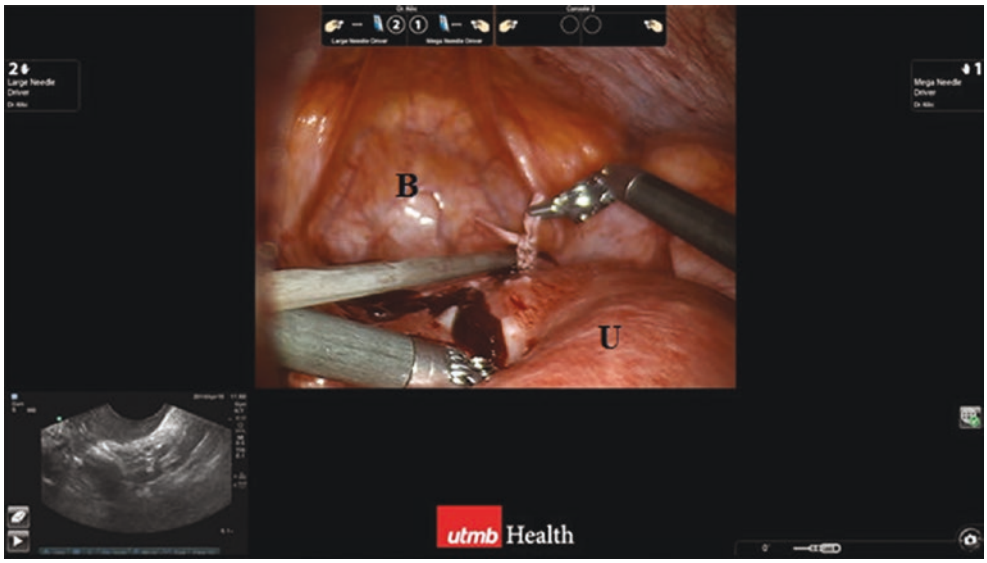

Fig. 9.5 The Mersilene tape is tied anteriorly. *B* Bladder, *U* Uterus

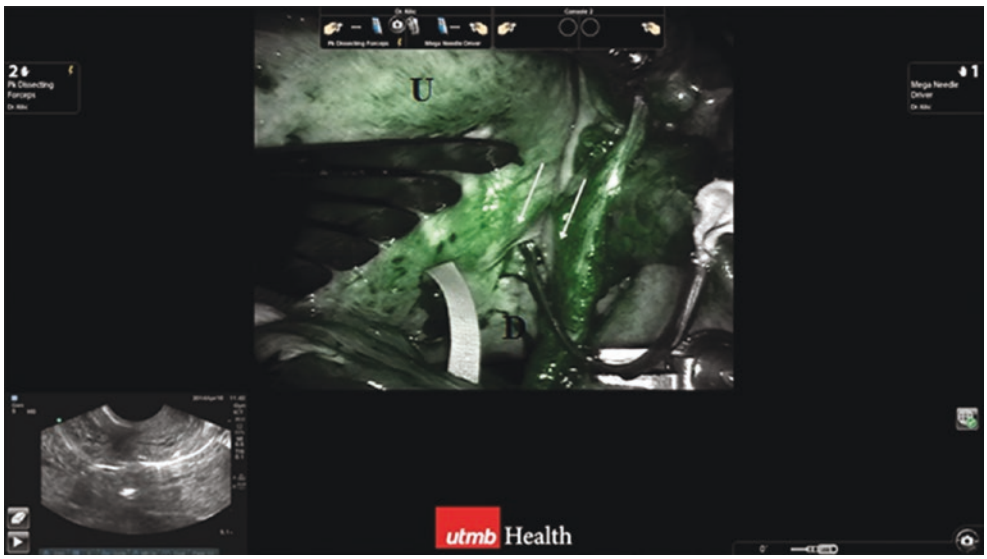

Fig. 9.6 Passing the suture in avascular space

14 mmHg and insert three robotic ports under direct visualization. Trocar placement for nonpregnant women is more advantageous in terms of number of variations. Umbilical camera placement is an option. Generally, the 12-mm camera trocar is placed closer to the umbilicus than in pregnant patients (6–8 cm). Two 8-mm robotic trocars are placed bilaterally 10 cm from the camera port (Fig. 9.7). An additional 12-mm assistant port is placed in the left upper quadrant, replacing the 5-mm initial trocar. If no assistant side trocar is placed, mesh can be introduced either from one robotic trocar side or through the camera port with the needle attached at the beginning of the procedure.

Place a uterine manipulator in the intrauterine cavity. We use VCare (ConMed) due to the fact that it helps to turn the manipulator 180° during the bladder flap to gain better counter tension, which will facilitate bladder dissection. In addition, the uterine manipulator will facilitate moving the uterus toward the bladder and rectum during the needle passage. Another difference for the nonpregnant cerclage procedure in our practice is that only one needle is attached to the Mersilene tape introduced into the intraperitoneal cavity instead of two. The first pass can be done from posterior to anterior (Fig. 9.8). After making the loop around the cervix anteriorly, it can be passed from anterior to posterior using the same needle (Fig. 9.9). This technique provides an option to place the knot on the posterior cervix to avoid the potential risk of having it irritate the bladder (Fig. 9.10). However, in our experience, an anteriorly placed knot did not cause bladder irritation, either. The biggest advantage of nonpregnant cerclage is easy exposure of the surgical field, especially with the help of a uterine manipulator. The manipulator is kept intrauterine during knot placement, thus providing a small opening on the cervical os for monitoring premature rupture of the membranes during pregnancy and menstrual flow after pregnancy.

In conclusion, robotic abdominal cerclage is found to have a success rate of 85% with lower incidence of preterm delivery and preterm premature rupture of membranes compared to the vaginal approach [82].

Robotic cerclage is currently a safe and effective technique, yet it is still open for new adaptations to make it even more safe and effective as technology evolves.

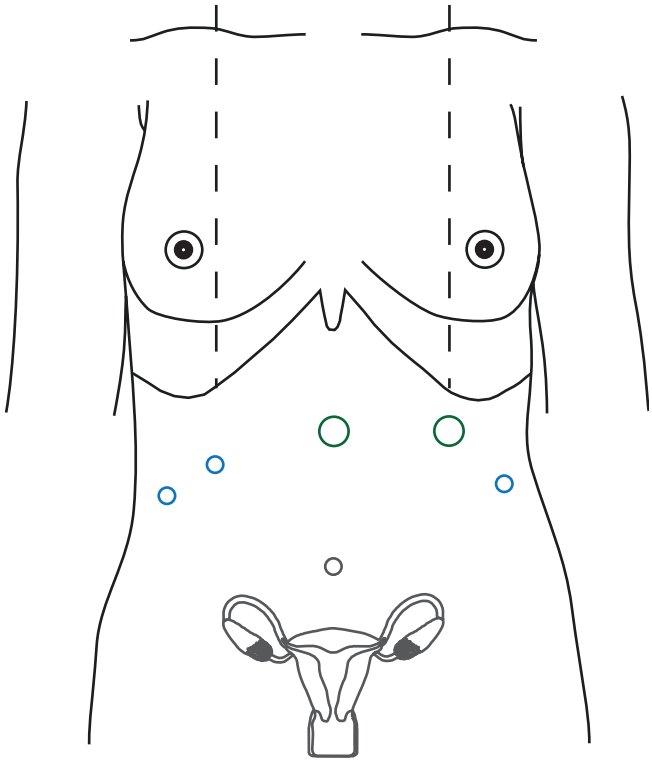

Fig. 9.7 Trocar distribution for nonpregnant uterine abdominal cerclage. The da Vinci Si robot is docked obliquely

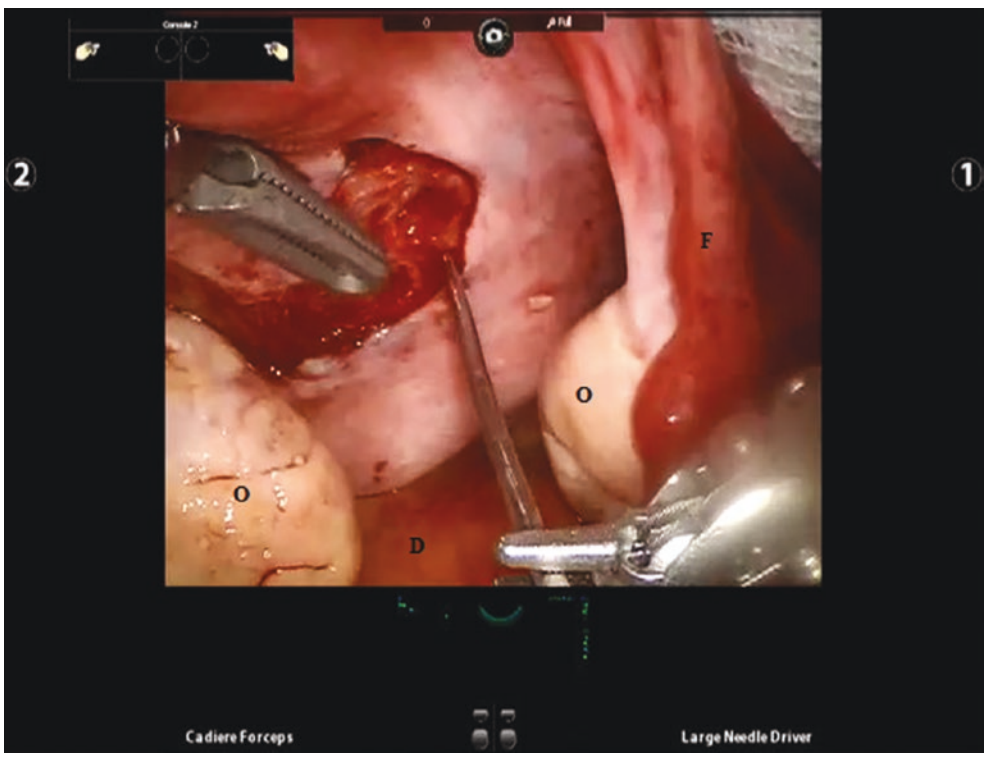

Fig. 9.8 Needle attached to Mersilene tape first passing from posterior to anterior. *D* Douglas Pouch, *O* Ovary, *F* Fallopian Tube

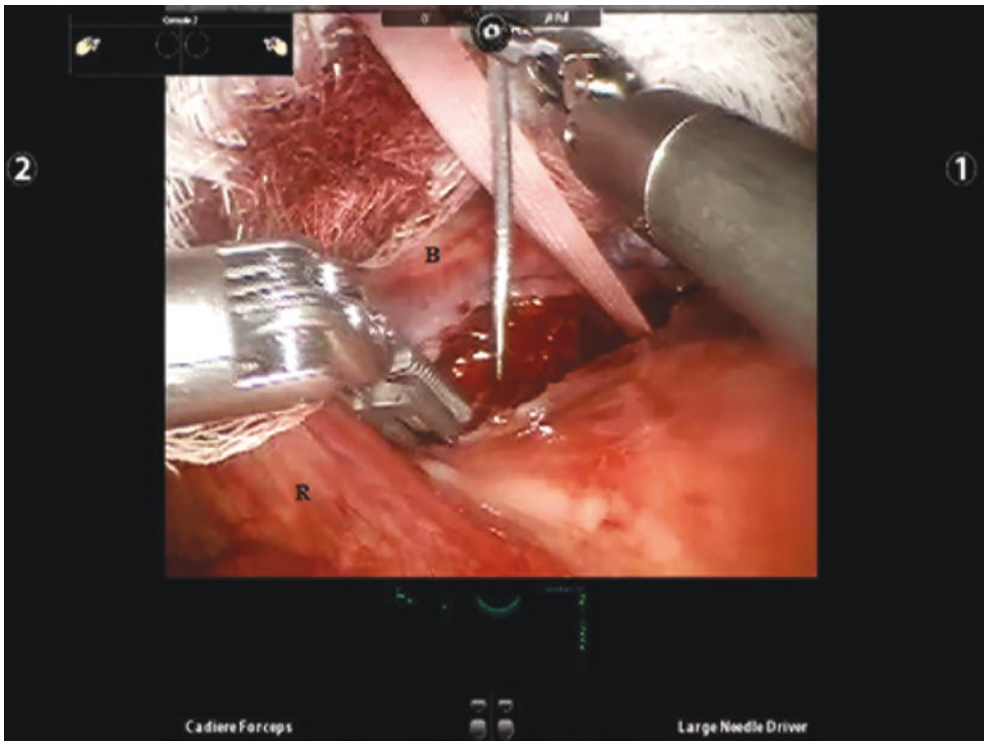

Fig. 9.9 The same needle attached to Mersilene tape then passing from anterior to posterior. *B* Bladder, *R* Round Ligament

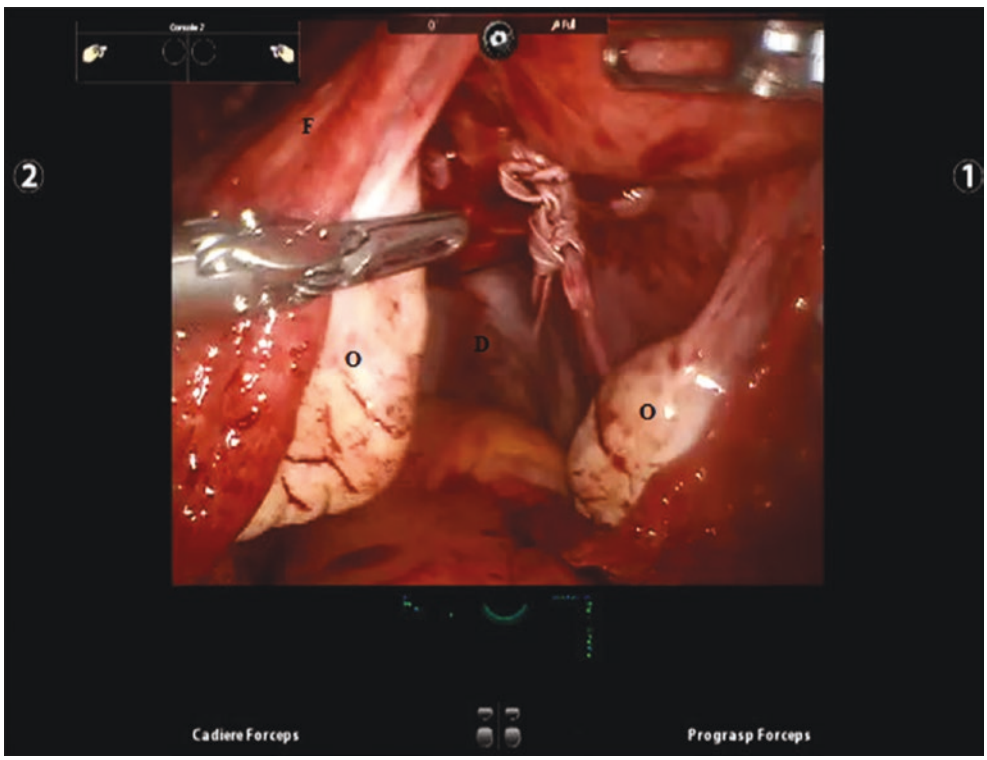

Fig. 9.10 The Mersilene tape is tied posteriorly. *D* Douglas Pouch, *O* Ovary, *F* Fallopian Tube

References

1. Moss C, Isley MM. Sterilization: a review and update. Obstet Gynecol Clin N Am. 2015;42(4):713–24.
2. Hillis SD, Marchbanks PA, Tylor LR, et al. Poststerilization regret: findings from the United States collaborative review of sterilization. Obstet Gynecol. 1999;93(6):889–95.
3. Henderson SR. The reversibility of female sterilization with the use of microsurgery: a report on 102 patients with more than one year of follow-up. Am J Obstet Gynecol. 1984;149(1):57–65.
4. Hanafi MM. Factors affecting the pregnancy rate after microsurgical reversal of tubal ligation. Fertil Steril. 2003;80(2):434–40.
5. Gordts S, Campo R, Puttemans P, et al. Clinical factors determining pregnancy outcome after microsurgical tubal reanastomosis. Fertil Steril. 2009;92(4):1198–202.

6. Yoon TK, Sung HR, Kang HG, et al. Laparoscopic tubal anastomosis: fertility outcome in 202 cases. Fertil Steril. 1999;72(6):1121–6.
7. Margossian H, Garcia-Ruiz A, Falcone T, et al. Robotically assisted laparoscopic tubal anastomosis in a porcine model: a pilot study. J Laparoendosc Adv Surg Tech A. 1998;8(2):69–73.
8. Degueldre M, Vandromme J, Huong PT, et al. Robotically assisted laparoscopic microsurgical tubal reanastomosis: a feasibility study. Fertil Steril. 2000;74(5):1020–3.
9. Falcone T, Goldberg JM, Margossian H, et al. Robotic-assisted laparoscopic microsurgical tubal anastomosis: a human pilot study. Fertil Steril. 2000;73(5):1040–2.
10. Zite N, Borrero S. Female sterilisation in the United States. Eur J Contracept Reprod Health Care. 2011;16(5):336–40.
11. Gargiulo AR. Fertility preservation and the role of robotics. Clin Obstet Gynecol. 2011;54(3):431–48.
12. Bedaiwy MA, Barakat EM, Falcone T. Robotic tubal anastomosis: technical aspects. JSLS. 2011;15(1):10–15. PMC3134681.
13. Dharia Patel SP, Steinkampf MP, Whitten SJ, et al. Robotic tubal anastomosis: surgical technique and cost effectiveness. Fertil Steril. 2008;90(4):1175–9.
14. Einarsson JI, Hibner M, Advincula AP. Side docking: an alternative docking method for gynecologic robotic surgery. Rev Obstet Gynecol. 2011;4(3–4):123–5. PMC3252883.
15. Schippert C, Soergel P, Staboulidou I, et al. The risk of ectopic pregnancy following tubal reconstructive microsurgery and assisted reproductive technology procedures. Arch Gynecol Obstet. 2012;285(3):863–71.
16. Caillet M, Vandromme J, Rozenberg S, et al. Robotically assisted laparoscopic microsurgical tubal reanastomosis: a retrospective study. Fertil Steril. 2010;94(5):1844–7.
17. Rodgers AK, Goldberg JM, Hammel JP, et al. Tubal anastomosis by robotic compared with outpatient minilaparotomy. Obstet Gynecol. 2007;109(6):1375–80.
18. Lima M, Cantone N, Destro F, et al. Combined laparoscopic and hysteroscopic approach for the treatment of a hybrid Mullerian duct anomaly: a case report. J Laparoendosc Adv Surg Tech A. 2013;23(11):960–4.
19. Saygili-Yilmaz E, Yildiz S, Erman-Akar M, et al. Reproductive outcome of septate uterus after hysteroscopic metroplasty. Arch Gynecol Obstet. 2003;268(4):289–92.
20. Vallerie AM, Breech LL. Update in Mullerian anomalies: diagnosis, management, and outcomes. Curr Opin Obstet Gynecol. 2010;22(5):381–7.
21. Grimbizis GF, Gordts S, Di Spiezio Sardo A, et al. The ESHRE/ESGE consensus on the classification of female genital tract congenital anomalies. Hum Reprod. 2013;28(8):2032–44. PMC3712660.
22. Arleo EK, Troiano RN. Complex Mullerian duct anomalies defying traditional classification: lessons learned. J Fertil. 2013;1:115.
23. Iverson R, Decherney A, Laufer M. Surgical management of congenital uterine anomalies. In: Barbieri R, editor. UpToDate. Waltham: Wolters Kluwer; 2016.
24. AFS. The American Fertility Society classifications of adnexal adhesions, distal tubal occlusion, tubal occlusion secondary to tubal ligation, tubal pregnancies, Mullerian anomalies and intrauterine adhesions. Fertil Steril. 1988;49(6):944–55.
25. Cunningham FG, Leveno KJ, Bloom SL, et al. Congenital genitourinary abnormalities. In: Williams obstetrics. New York: McGraw-Hill Education; 2014. p. 36–45.
26. Nahum GG. Uterine anomalies. How common are they, and what is their distribution among subtypes? J Reprod Med. 1998;43(10):877–87.
27. Reichman D, Laufer MR, Robinson BK. Pregnancy outcomes in unicornuate uteri: a review. Fertil Steril. 2009;91(5):1886–94.
28. Heinonen PK. Uterus didelphys: a report of 26 cases. Eur J Obstet Gynecol Reprod Biol. 1984;17(5):345–50.
29. Smith NA, Laufer MR. Obstructed hemivagina and ipsilateral renal anomaly (OHVIRA) syndrome: management and follow-up. Fertil Steril. 2007;87(4):918–22.
30. Tong J, Zhu L, Lang J. Clinical characteristics of 70 patients with Herlyn-Werner-Wunderlich syndrome. Int J Gynaecol Obstet. 2013;121(2):173–5.
31. El Saman AM, Shahin AY, Nasr A, et al. Hybrid septate uterus, coexistence of bicornuate and septate varieties: a genuine report. J Obstet Gynaecol Res. 2012;38(11):1308–14.
32. Iverson R, Decherney A, Laufer M. Clinical manifestations and diagnosis of congenital anomalies of the uterus. In: Barbieri R, editor. UpToDate. Waltham: Wolters Kluwer; 2016.
33. Guirgis RR, Shrivastav P. Gamete intrafallopian transfer (GIFT) in women with bicornuate uteri. J In Vitro Fert Embryo Transf. 1990;7(5):283–4.
34. Marcus S, Al-Shawaf T, Brinsden P. The obstetric outcome of in vitro fertilization and embryo transfer in women with congenital uterine malformation. Am J Obstet Gynecol. 1996;175(1):85–9.
35. Markham SM, Waterhouse TB. Structural anomalies of the reproductive tract. Curr Opin Obstet Gynecol. 1992;4(6):867–73.
36. Pellerito JS, Mccarthy SM, Doyle MB, et al. Diagnosis of uterine anomalies: relative accuracy of MR imaging, endovaginal sonography, and hysterosalpingography. Radiology. 1992;183(3):795–800.
37. Acien P, Acien M, Sanchez-Ferrer M. Complex malformations of the female genital tract. New types and revision of classification. Hum Reprod. 2004;19(10):2377–84.
38. Chen YJ, Twu NF, Horng HC, et al. Robotic modified Jones metroplasty for uterine unification. J Minim Invasive Gynecol. 2010;17(6):S11–2.
39. Gungor M, Afsar S, Ozbasli E, et al. The robotic metroplasty in a patient with hybrid septate variant anomaly. J Robot Surg. 2016;10(3):271–4.
40. Wright C, Hanna MK. Thirty-six vaginal constructions: lessons learned. J Pediatr Urol. 2014;10(4):667–71.
41. Committee on Adolescent Health Care. Committee opinion: no. 562: Mullerian agenesis: diagnosis, management, and treatment. Obstet Gynecol. 2013;121(5):1134–7.
42. Dargent D, Marchiole P, Giannesi A, et al. Laparoscopic Davydov or laparoscopic transposition of the peritoneal colpopoeisis described by Davydov for the treatment of congenital vaginal agenesis: the technique and its evolution. Gynecol Obstet Fertil. 2004;32(12):1023–30.
43. Gauwerky JF, Wallwiener D, Bastert G. An endoscopically assisted technique for construction of a neovagina. Arch Gynecol Obstet. 1992;252(2):59–63.
44. Mcindoe A. The treatment of congenital absence and obliterative conditions of the vagina. Br J Plast Surg. 1950;2(4):254–67.
45. Popp LW, Ghirardini G. Creation of a neovagina by pelviscopy. J Laparoendosc Surg. 1992;2(3):165–73.
46. Urbanowicz W, Starzyk J, Sulislawski J. Laparoscopic vaginal reconstruction using a sigmoid colon segment: a preliminary report. J Urol. 2004;171(6 Pt 2):2632–5.
47. Kim C, Campbell B, Ferrer F. Robotic sigmoid vaginoplasty: a novel technique. Urology. 2008;72(4):847–9.
48. Boztosun A, Olgan S. Robotic sigmoid vaginoplasty in an adolescent girl with Mayer-Rokitansky-Kuster-Hauser syndrome. Female Pelvic Med Reconstr Surg. 2016;22(5):e32–5.
49. Pushkar P, Rawat SK, Chowdhary SK. Robotic approach to vaginal atresia repair in an adolescent girl. Urol Ann. 2015;7(3):396–8. PMC4518385.
50. Iavazzo C, Gkegkes ID. Possible role of DaVinci robot in uterine transplantation. J Turk Ger Gynecol Assoc. 2015;16(3):179–80. PMC4560477.
51. Braumann C, Jacobi CA, Menenakos C, et al. Computer-assisted laparoscopic colon resection with the Da Vinci system: our first experiences. Dis Colon Rectum. 2005;48(9):1820–7.
52. Denoto G, Rubach E, Ravikumar TS. A standardized technique for robotically performed sigmoid colectomy. J Laparoendosc Adv Surg Tech A. 2006;16(6):551–6.
53. Anderberg M, Bossmar T, Arnbjornsson E, et al. Robot-assisted laparoscopic hemihysterectomy for a rare genitourinary malformation

with associated duplication of the inferior vena cava—a case report. Eur J Pediatr Surg. 2010;20(3):206–8.
54. Persson J, Reynisson P, Borgfeldt C, et al. Robot assisted laparoscopic radical hysterectomy and pelvic lymphadenectomy with short and long term morbidity data. Gynecol Oncol. 2009;113(2):185–90.
55. Liu XX, Jiang ZW, Chen P, et al. Full robot-assisted gastrectomy with intracorporeal robot-sewn anastomosis produces satisfying outcomes. World J Gastroenterol. 2013;19(38):6427–37. PMC3801313.
56. Uyama I, Sugioka A, Fujita J, et al. Completely laparoscopic extraperigastric lymph node dissection for gastric malignancies located in the middle or lower third of the stomach. Gastric Cancer. 1999;2(3):186–90.
57. Sheyn D, Abouassaly R, Paspulati R, et al. Multidisciplinary approach for management of obstructed hemivagina and ipsilateral renal anomaly (OHVIRA) syndrome and rectal prolapse. Int Urogynecol J. 2015;26(7):1079–81.
58. Cunningham FG, Leveno KJ, Bloom SL, et al. Abortion, early pregnancy. In: Williams obstetrics. New York: McGraw-Hill Education; 2014. p. 350–76.
59. Vyas NA, Vink JS, Ghidini A, et al. Risk factors for cervical insufficiency after term delivery. Am J Obstet Gynecol. 2006;195(3):787–91.
60. Saccone G, Perriera L, Berghella V. Prior uterine evacuation of pregnancy as independent risk factor for preterm birth: a systematic review and metaanalysis. Am J Obstet Gynecol. 2016;214(5):572–91.
61. Warren JE, Silver RM, Dalton J, et al. Collagen 1Alpha1 and transforming growth factor-beta polymorphisms in women with cervical insufficiency. Obstet Gynecol. 2007;110(3):619–24.
62. Chan YY, Jayaprakasan K, Tan A, et al. Reproductive outcomes in women with congenital uterine anomalies: a systematic review. Ultrasound Obstet Gynecol. 2011;38(4):371–82.
63. Rackow BW, Arici A. Reproductive performance of women with Mullerian anomalies. Curr Opin Obstet Gynecol. 2007;19(3):229–37.
64. Kaufman RH, Adam E, Hatch EE, et al. Continued follow-up of pregnancy outcomes in diethylstilbestrol-exposed offspring. Obstet Gynecol. 2000;96(4):483–9.
65. Grobman WA, Gilbert SA, Iams JD, et al. Activity restriction among women with a short cervix. Obstet Gynecol. 2013;121(6):1181–6. PMC4019312.
66. Sciscione AC. Maternal activity restriction and the prevention of preterm birth. Am J Obstet Gynecol. 2010;202(3):232.e1–5.
67. Abdel-Aleem H, Shaaban OM, Abdel-Aleem MA. Cervical pessary for preventing preterm birth. Cochrane Database Syst Rev. 2013;5:Cd007873.
68. Dharan VB, Ludmir J. Alternative treatment for a short cervix: the cervical pessary. Semin Perinatol. 2009;33(5):338–42.
69. Goya M, Pratcorona L, Merced C, et al. Cervical pessary in pregnant women with a short cervix (PECEP): an open-label randomised controlled trial. Lancet (London, England). 2012;379(9828):1800–6.
70. Herron MA, Parer JT. Transabdominal cerclage for fetal wastage due to cervical incompetence. Obstet Gynecol. 1988;71(6 Pt 1):865–8.
71. Berghella V, Szychowski JM, Owen J, et al. Suture type and ultrasound-indicated cerclage efficacy. J Matern Fetal Neonatal Med. 2012;25(11):2287–90.
72. Harger JH. Comparison of success and morbidity in cervical cerclage procedures. Obstet Gynecol. 1980;56(5):543–8.
73. Mcdonald IA. Suture of the cervix for inevitable miscarriage. J Obstet Gynaecol Br Emp. 1957;64(3):346–50.
74. Shirodkar V. A new method of operative treatment for habitual abortions in the second trimester of pregnancy. Antiseptic. 1955;52:299–300.
75. Toaff R, Toaff ME, Ballas S, et al. Cervical incompetence: diagnostic and therapeutic aspects. Isr J Med Sci. 1977;13(1):39–49.
76. Burger NB, Brolmann HA, Einarsson JI, et al. Effectiveness of abdominal cerclage placed via laparotomy or laparoscopy: systematic review. J Minim Invasive Gynecol. 2011;18(6):696–704.
77. Wolfe L, Depasquale S, Adair CD, et al. Robotic-assisted laparoscopic placement of transabdominal cerclage during pregnancy. Am J Perinatol. 2008;25(10):653–5.
78. Fick AL, Caughey AB, Parer JT. Transabdominal cerclage: can we predict who fails? J Matern Fetal Neonatal Med. 2007;20(1):63–7.
79. Umstad MP, Quinn MA, Ades A. Transabdominal cervical cerclage. Aust N Z J Obstet Gynaecol. 2010;50(5):460–4.
80. Davis G, Berghella V, Talucci M, et al. Patients with a prior failed transvaginal cerclage: a comparison of obstetric outcomes with either transabdominal or transvaginal cerclage. Am J Obstet Gynecol. 2000;183(4):836–9.
81. Tulandi T, Alghanaim N, Hakeem G, et al. Pre and postconceptional abdominal cerclage by laparoscopy or laparotomy. J Minim Invasive Gynecol. 2014;21(6):987–93.
82. Zeybek B, Hill A, Menderes G, et al. Robot-assisted abdominal cerclage during pregnancy. JSLS. 2016;20(4):e2016.00072. PMC5118107.
83. Estape RE, Schroeder ED, Estape RA, et al. Robotic abdominal cerclage: a case series with pregnancy outcomes. J Minim Invasive Gynecol. 2015;22(6s):S235.
84. ACOG. ACOG Practice Bulletin No.142: cerclage for the management of cervical insufficiency. Obstet Gynecol. 2014;123(2 Pt 1):372–9.
85. Walsh TM, Borahay MA, Fox KA, et al. Robotic-assisted, ultrasound-guided abdominal cerclage during pregnancy: overcoming minimally invasive surgery limitations? J Minim Invasive Gynecol. 2013;20(3):398–400.
86. Zeybek B, Borahay M, Kilic GS. Overcoming the obstacles of visualization in robotically assisted abdominal cerclage using indocyanine green. J Robot Surg. 2016;10(4):361–4.
87. Dawood F, Farquharson RG. Transabdominal cerclage: preconceptual versus first trimester insertion. Eur J Obstet Gynecol Reprod Biol. 2016;199:27–31.
88. Pundir J, Coomarasamy A. Preterm labour (PTL). In: Obstetrics: evidence-based algorithms. London: Cambridge University Press; 2016.

Robot-Assisted Laparoscopic Myomectomy (RALM)

10

Sandra Madeuke Laveaux and Arnold P. Advincula

Introduction

Uterine fibroids are the most common solid pelvic tumor in women. Seventy percent of white women and 80% of black women will be diagnosed with uterine fibroids by age 50 [4]. Uterine fibroids are the leading indication for hysterectomy in the USA [5]. However, myomectomy is the surgery of choice for symptomatic women who desire fertility preservation [6]. Also, infertility patients undergoing in vitro fertilization (IVF) often require myomectomy to optimize the uterus and potentially improve fertility outcomes.

The route of myomectomy—abdominal, laparoscopic, robotic, or hysteroscopic—depends on the location, size, and number of the uterine fibroids and to a certain extent, the indication for the myomectomy. In some cases multiple routes need to be employed for optimal results, and sometimes these procedures have to be staged. For the purpose of this chapter, we will focus on the role of robotic surgery in myomectomy. We will review some of the available literature, discuss our surgical technique for performing a robot-assisted laparoscopic myomectomy (RALM), and review some clinical pearls in the surgical management of uterine fibroids.

Background

Historically, myomectomy via laparotomy was the surgical route of choice for fibroid removal. This surgery was associated with long hospital stays, high rates of blood transfusions, postoperative pain, and long recovery periods. With the advent of minimally invasive surgery, laparoscopic myomectomy (LM) became more commonly performed and accepted by many as the "gold standard" approach for myomectomy [7]. Conventional LM is technically challenging for most laparoscopic surgeons and as a result is performed by a select group of highly specialized laparoscopic surgeons. The challenges with conventional LM include enucleation of the fibroid along the correct plane and multiple layer hysterotomy closure [8]. The devastating consequence of a poor hysterotomy closure, uterine rupture, is of utmost concern when pregnancy occurs after myomectomy. Accordingly, recommendations for more strict selection criteria that excluded patients with fibroids >5 cm, multiple fibroids, and deep intramural fibroids were introduced after reports of several cases of uterine rupture in the second and third trimesters of pregnancy following laparoscopic myomectomy [9].

In efforts to overcome the difficulties of conventional LM as well as to broaden the patient pool candidacy for the minimally invasive approach to myomectomy, robot-assisted laparoscopic myomectomy (RALM) was developed. In 2004, Advincula et al. introduced the use of the da Vinci robot for RALM in their first case series of 35 women [10]. Since this report, multiple retrospective studies have verified the safety, feasibility, and efficacy of RALM.

When compared to traditional abdominal myomectomy (AM), RALM is associated with less blood loss, shorter hospital stay, quicker recovery time, fewer complications, and higher costs. A review of the literature provides sufficient evidence in favor of RALM over AM [6, 11, 12]. However, this is not the case with the literature comparing RALM to conventional LM. In a 2016 systematic review and meta-analysis by Lavazzo et al. comparing RALM to conventional LM or AM, there was no significant difference between RALM and LM [13]. Although the available evidence strongly suggests a role for RALM [14–16] including broadening the laparoscopists' surgical armamentarium [17] and resulting in less conversion rates to laparotomy, 0–3% (RALM) vs. 11.3% (conventional LM) [18, 19] more comparative studies need to be conducted to clearly identify the role of RALM.

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At our institution the majority of the myomectomies (non-hysteroscopic) are performed robotically. Our goal when selecting RALM candidates is twofold: to ensure a successful procedure and to minimize the risk of conversion. Fibroid location, size and number, the patient's body habitus, and the relative size of the uterus to the length of the patient's torso are the factors we consider when selecting candidates for RALM. A preoperative MRI is routinely obtained for the mapping of fibroids and to exclude the presence of adenomyosis. Although RALM is performed by 4 high-volume providers with slightly different patient selection criteria and thresholds for robotic candidacy, in general we do not offer robotic surgery to patients with >15 leiomyomas, a single leiomyoma >12–15 cm, or when the uterus is more than 2–3 finger breadths above the umbilicus.

Presentations, Investigations, and Treatment Options

The majority of women with uterine fibroids are asymptomatic. However, when symptoms exist they typically include abnormal uterine bleeding (AUB) with resultant anemia and bulk symptoms such as urinary frequency, pelvic pressure, and constipation. Uterine fibroids are also strongly associated with pregnancy and reproductive complications, and their role in infertility remains heavily debated [20]. Uterine fibroids are diagnosed based on a combination of patient history, physical examination, and imaging studies: transvaginal ultrasound, saline infusion sonography, and/or MRI [21].

Medical management is usually the first line of treatment for patients with symptomatic uterine fibroids. Combination oral contraceptives (pills, patches, vaginal inserts) and nonsteroidal anti-inflammatory drugs (NSAIDs) are typically offered first. Although there is no data to support the efficacy of oral contraceptive pills and nonsteroidal anti-inflammatory pills in women whose symptoms are caused by uterine fibroids, the data is clear that these therapies work for non-fibroid-related heavy menstrual bleeding and dysmenorrhea [22]. Progesterone-only options include pills, implants, injectables, and intrauterine devices (IUDs) [23]. Hysteroscopic resection can be performed prior to IUD placement to decrease expulsion rates. Other medical options include leuprolide acetate [24], antifibrinolytics such as tranexamic acid, androgens (danazol, gestrinone), and progesterone modulators such as mifepristone [25].

A few medications are currently undergoing clinical trials for use in management of uterine fibroids. Ulipristal acetate a selective progesterone receptor modulator, which is currently approved for use in medical management of uterine fibroids in Europe and Canada, is being studied in the USA. The Venus I trial was a multicenter randomized double-blind placebo-controlled clinical trial comparing ulipristal acetate 5 mg, 10 mg, and placebo. It is the first completed pivotal study of ulipristal acetate for uterine fibroids in the US population [26]. Elagolix, an orally active, non-peptide GnRH antagonist, is another investigational treatment of uterine fibroids. The phase III clinical trials commenced in the first quarter of 2016 [27].

Surgical management of uterine fibroids is indicated when medical management fails in patients with AUB and/or when patients have bulk predominant symptoms. Surgical options include hysteroscopic resection for submucosal fibroids, fertility/uterine preserving myomectomy performed via abdominal, laparoscopic or robot-assisted approaches, and definitive management with hysterectomy.

In some patients with bulk symptoms who do not desire future fertility and/or are poor surgical candidates, uterine artery embolization and magnetic resonance guided focused ultrasound are options. A new and more recent alternative is the FDA-approved Acessa® system which is indicated for use in percutaneous, laparoscopic coagulation and ablation of uterine fibroids [28].

From this point forward, the remaining portion of this chapter will focus on the conservative surgical management of fibroids with robot-assisted laparoscopy. Our preferred systematic approach to set up and utilization of robotics will be highlighted. Although two current robotic surgical platforms (Xi & Si) exist within the da Vinci Surgical System, a description of technique will be made using the Si system.

Robot-Assisted Laparoscopic Myomectomy (RALM) Procedure

Patient Positioning

Patients are placed in modified dorsal lithotomy position using Allen Yellofins stirrups (Allen Medical Systems, Acton, Massachusetts). Extreme joint flexion, extension, and abduction are avoided to prevent nerve compression injuries. A standard motorized operating room table with maximum tilt of at least 30° is used. Antiskid is achieved using the Pink Pad-Pigazzi positioning system (Xodus Medical, New Kensington, PA, USA) in order to avoid slippage while in steep Trendelenburg as well as to protect the arms, which are tucked by the patients' sides (Fig. 10.1).

Abdominal Entry and Port Placement

After placement of the Advincula Arch uterine manipulator (Cooper Surgical, Trumbull, CT), the umbilicus is infiltrated with 0.5% Marcaine, and the abdominal wall stabilized using

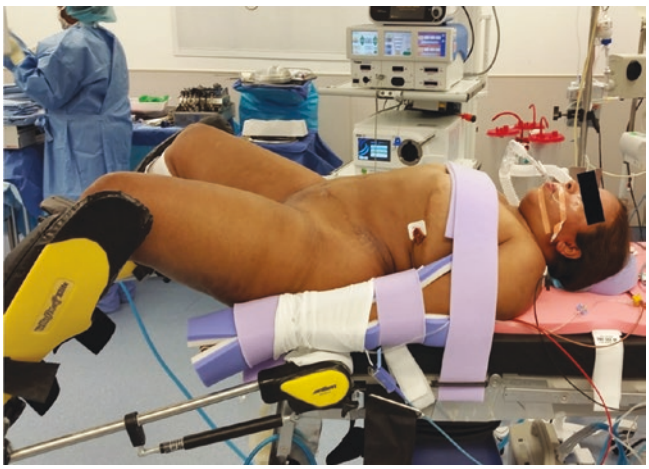

Fig. 10.1 Modified low dorsal lithotomy position with the Pink Pad-Pigazzi system

penetrating towel clamps. The abdominal cavity is entered at the base of the umbilicus using the Veress needle. Pneumoperitoneum is established to 20 mmHg. Next, the 5-mm AirSeal® IFS (SurgiQuest, Milford, CT, USA) accessory trocar is placed in the right or left upper quadrant (depending on surgeon preference), about 2–3 fingerbreadths below the costal margin and along the midclavicular line. The AirSeal® IFS technology allows for a stable pneumocavity and constant smoke evacuation [29]. At this juncture the abdominal cavity is surveyed, and the absence of any peritoneal or vascular injury with the Veress needle is verified. Also the feasibility of the case is ascertained and confirmed. The patient is then placed in Trendelenburg position, and a long, 12-mm non-robotic port is introduced through the umbilicus. Three additional 8-mm robotic ports are then placed strategically as seen in Fig. 10.2 ensuring at least a handbreadth or 8–10 cm between each port.

Robot Docking/EndoWrist® Instrumentation

The da Vinci Surgical System can be docked centrally or on the patients' side. We perform either left- or right-side docking (depending on surgeon preference) in order to allow unobstructed access to the perineum. As seen in Fig. 10.3, the left leg of the Si patient side cart is oriented at a 30°–45° angle to the left corner of the patients' bed. For all of our left-side docked RALM procedures, the da Vinci instrument placement is as follows: monopolar Hot Shears (arm1), Bipolar PK™ dissecting forceps (arm2), and EndoWrist® Tenaculum (arm 3).

Control of Blood Loss

Myomectomy is associated with significant risk of blood loss and need for transfusion. A range of options, both pre-

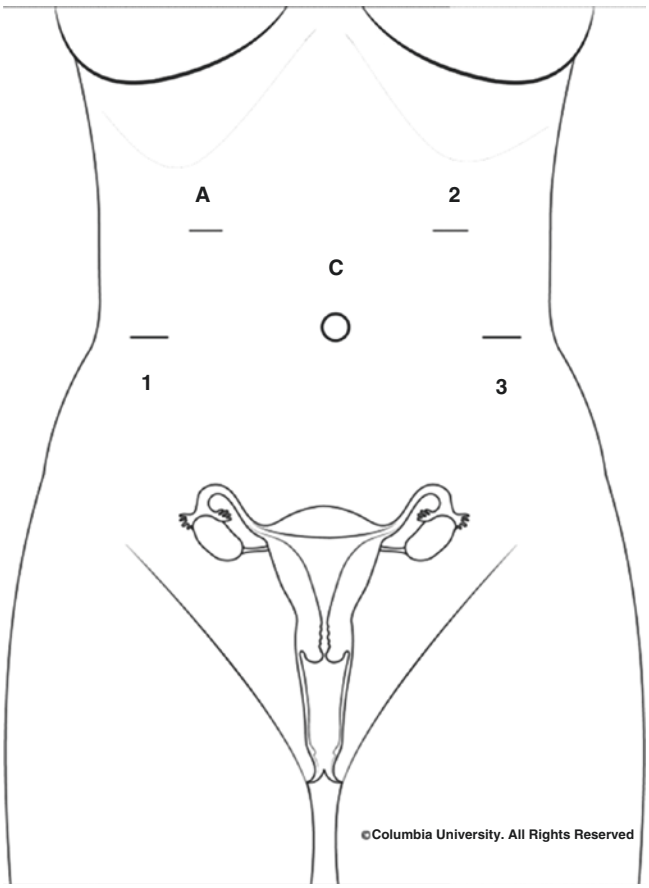

Fig. 10.2 Four-arm robotic port placement (for left-sided docking with da Vinci Si)

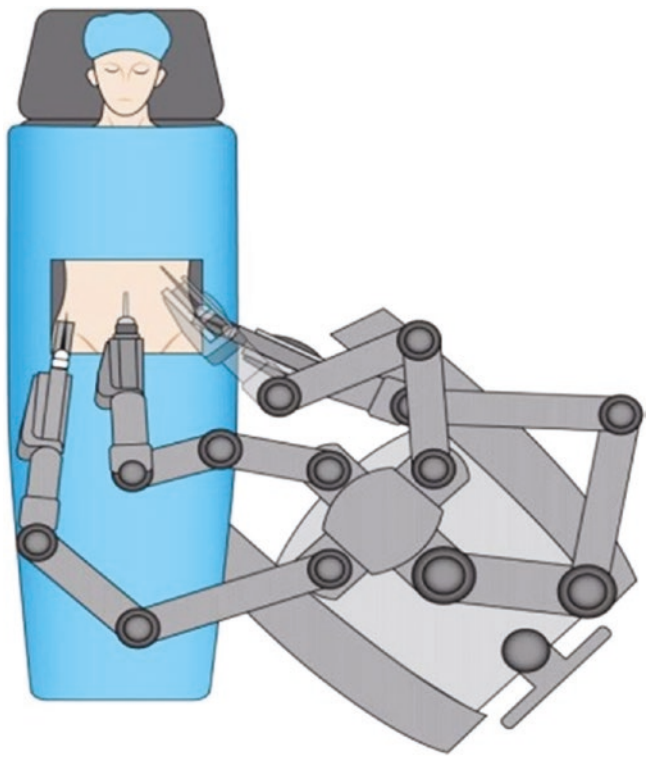

Fig. 10.3 Left-side docking of the da Vinci Si robot

operative and intraoperative, is available to help decrease this risk. A 2015 Cochrane Review of interventions to reduce hemorrhage during myomectomy included 18 studies with a total of 1250 women. All studies compared an intervention to reduce blood loss during myomectomy with either a placebo or no treatment. The review concluded that there is moderate-quality evidence to suggest that with a laparotomy, vasopressin reduces blood loss by 392.51–507.49 mL and with laparoscopy by 121.73–172.17 mL. Other interventions such as dinoprostone, gelatin-thrombin matrix, tranexamic acid, vitamin C, bupivacaine + epinephrine, fibrin sealant, and tourniquet use were found to be supported by low-quality evidence. In this review, misoprostol use was also supported by moderate-quality evidence to decrease blood loss by 70.24–125.52 mL. In our practice, we use infiltration of dilute vasopressin (20 units in 50 mL of normal saline) into the myometrium surrounding the targeted fibroids at the start of the case. This is facilitated by a 7-in. 22 gauge spinal needle placed directly through the anterior abdominal wall. Prior to infiltration with vasopressin, care is taken to withdraw the syringe to ensure no intravascular infiltration occurs. The use of vasopressin, pneumoperitoneum, and electrosurgery are factors that contribute to hemostasis and thus improved visualization of the operative field [30]. Vasopressin should be used cautiously as there have been reports of healthy patients with cardiopulmonary complications resulting from vasopressin use [31] (Fig. 10.4).

Uterine Incisions

Once the myometrium overlying the fibroid is adequately blanched, a hysterotomy incision is made using the monopolar device. Any heavy bleeding encountered is controlled with electrosurgery using the Bipolar PK™ dissecting forceps. In general, the least number of incisions possible should be used to perform myomectomies. With fewer incisions, less bleeding is encountered. Incisions are made strategically so that multiple fibroids may be removed from a single incision, if feasible. However, it is important to balance this with the depth of the incision, particularly because adequate closure can be more difficult with deeper hysterotomies. Transverse, vertical, or oblique incisions can be made. Despite the advantages of robotic suturing, transverse incisions are preferable and easier to close; therefore, this should be taken into consideration when planning a hysterotomy. When making uterine incisions, it is important to always be aware of the locations of the cornua, adnexa, and uterine vasculature in order to avoid injury to these structures. Also a keen awareness of these locations will help guide the decision about incisions in order to avoid inadvertent entry into the endometrial cavity (Fig. 10.5).

Enucleation of Fibroids

Once the fibroid capsule is identified and exposed adequately, it is grasped with a robotic tenaculum. It is important to place enough traction on the fibroid in order to allow separation of tissues along their natural planes during the enucleation process. Just as in open cases, with adequate traction on the fibroid, the surrounding myometrium is peeled away using a blunt and sharp technique with judicious use of electrosurgery. Adequate traction-countertraction is imperative during enucleation. Once in the right plane, the fibroids typically "shell out" easily and with minimal blood loss. In all our RALM cases, the EndoWrist® tenaculum is used in the fourth robotic arm (Fig. 10.2). Alternatively an assistant can provide traction on the fibroid

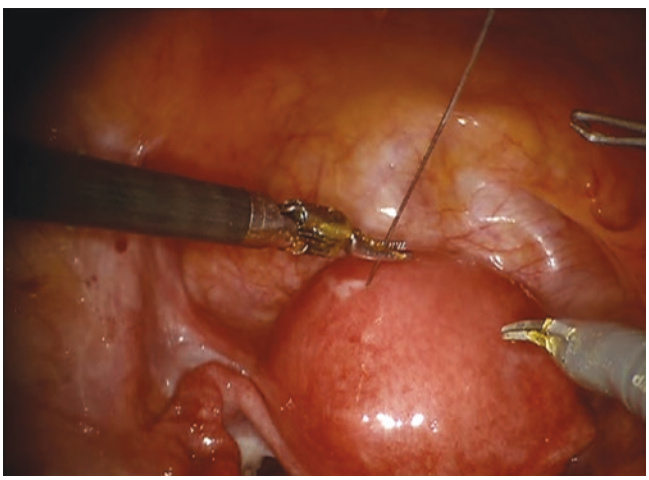

Fig. 10.4 Administration of vasopressin

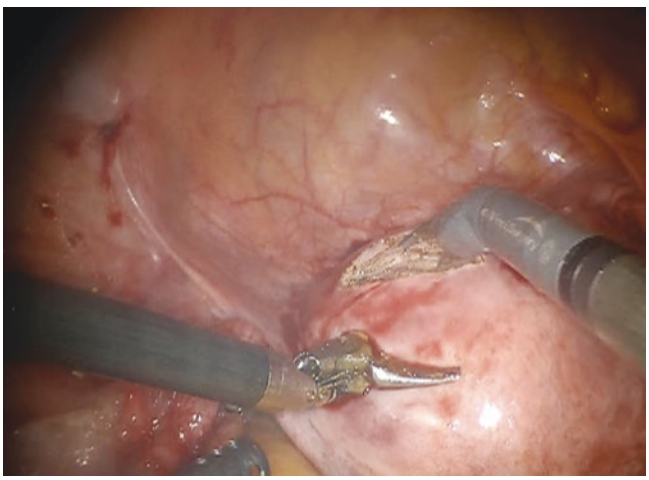

Fig. 10.5 Anterior lower uterine segment hysterotomy

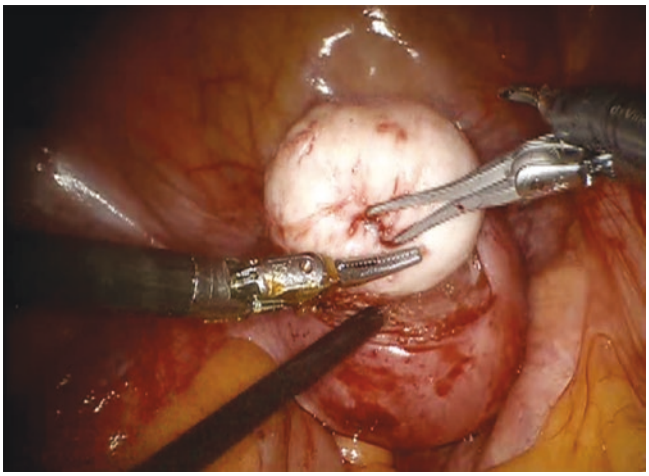

Fig. 10.6 Enucleation facilitated with robotic tenaculum

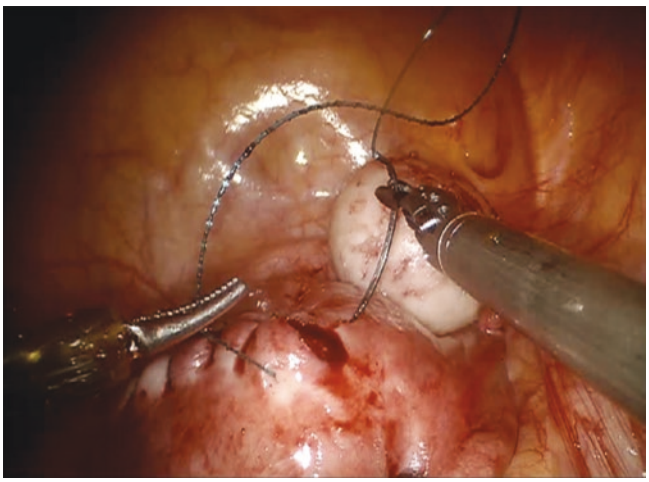

Fig. 10.7 Hysterotomy closure with barbed suture

using a conventional laparoscopic tenaculum through the accessory trocar. In a study comparing a three-arm to four-arm robotic technique for RALM, Sanderson et al. concluded that the four-arm robotic technique has a significantly shorter operative time [32]. For intramural or transmural fibroids that may abut the cavity, it is important not to place excessive traction in order to avoid avulsing the endometrial cavity. Regarding breaching the endometrial cavity, in some cases, this is done purposefully to retrieve large submucosal fibroids. When this is not the case, every effort is made to avoid injury to the endometrial cavity. If entry to the cavity does occur, this area can be repaired separately using fine suture. Diluted methylene blue can be used to identify the cavity in cases where entry is unclear. Of note, when multiple fibroids are removed, it is important to keep track of the number of fibroids. One tip to facilitate tissue extraction and prevent misplacing fibroids is to fasten them together in "string-of-pearls" fashion with either a braided or barbed suture (Fig. 10.6).

Closure of Myometrium and Serosa

Once enucleation is complete, the fibroids are placed either in the posterior cul-de-sac or the paracolic gutters. The monopolar hot shears is then replaced with a mega needle driver for hysterotomy closure. A multilayered closure is routinely performed for deep hysterotomies. The more superficial ones may be closed in one layer. Adequate closure is critical and fundamental in decreasing the risk of uterine rupture. We use either an absorbable braided or barbed suture for our closures. In a 2016 meta-analysis by Zhang et al., a clear clinic advantage of time saving and reduction in blood loss was demonstrated when using barbed suture versus conventional suture [33]. Any endometrial cavity defects are closed with 3-0 or 4-0 non-barbed suture without penetrating into the cavity if possible to reduce intracavitary adhesion formation (Fig. 10.7).

Adhesion Prevention

Myomectomy is associated with a high risk of adhesion formation [34]. The use of adhesion barriers to decrease or prevent adhesion formation has been advocated for many years. The efficacy of these adhesion barriers has been demonstrated in many studies. A 2008 Cochrane database review of barrier agents for adhesion prevention in gynecologic surgery concluded that Interceed (Ethicon, Somerville, NJ), an oxidized cellulose, reduces the incidence of adhesion formation following laparoscopy and laparotomy. In this analysis, Gore-Tex was found to be superior to Interceed as an adhesion barrier, but the need for suturing and later removal was felt to counteract its superiority. Interestingly, Seprafilm and Fibrin sheets had no evidence of effectiveness in adhesion prevention [35]. This Cochrane Review was updated in 2015, and the conclusions were quite different. In the update, the evidence that Interceed, Gore-Tex, and Seprafilm were more effective than no treatment in reducing the incidence of adhesion formation following pelvic surgery was low. There was also no evidence on the effects of barrier agents on pain and fertility outcomes in women of reproductive age. The overall quality of all available literature on this subject was very low to moderate, and this was felt to be due to imprecise and poor reporting of study methods [36].

Recently, a concern about immediate postoperative complications with the use of adhesion barriers in myomectomy and hysterectomy has gained the interest of many gynecologic surgeons. Tulandi et al. published a retrospective cohort study evaluating this concern and found the use of adhesion

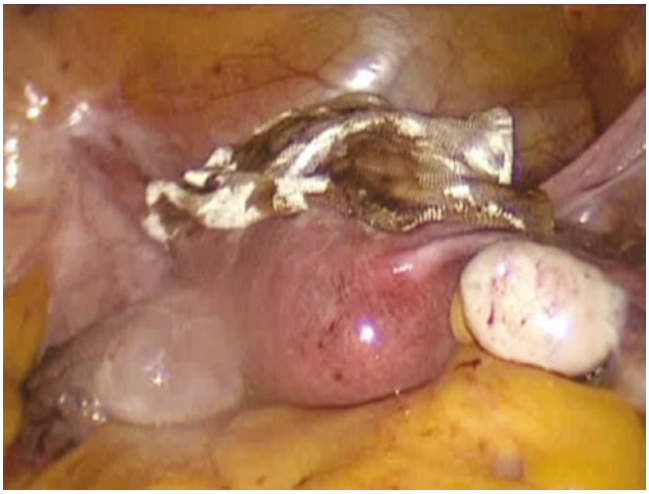

Fig. 10.8 Placement of Interceed

barriers to be associated with increased risk of postoperative fever and ileus after myomectomy or hysterectomy via laparotomy. In addition, the risk of small bowel obstruction in the immediate postoperative period was increased with its use in open hysterectomy [37]. There was no increased risk of complications with the use of adhesion barriers during robotic myomectomy.

In our practice we use Interceed over the suture lines of our hysterotomy closures. This being so, it is important to remember that the best method for prevention of adhesions is optimal surgical technique and closure and meticulous hemostasis (Fig. 10.8).

Tissue Extraction

In the current post power morcellation era, the technique for tissue extraction has become so much more critical and continues to evolve. Like many institutions, we have adapted an extracorporeal tissue extraction technique, coined as the ExCiTE (Extracorporeal C-incision Tissue Extraction) technique. After the robot is undocked, the specimen is placed into an appropriate sized specimen retrieval bag and brought up through the umbilicus. The umbilical port site is extended to ~2.5–3 cm, and a small Alexis wound retractor (Applied Medical, Rancho Santa Margarita, CA) is placed inside the bag. Using an 11-in. blade scalpel, the specimen is "cored out" and extracted, with care taken not to disrupt the containment bag. Once extraction is complete, the fascia of the extended umbilical port site is closed using 0-Vicryl suture. The surgical field is inspected for hemostasis, Interceed is placed over the hysterotomy incisions if not already done and the case

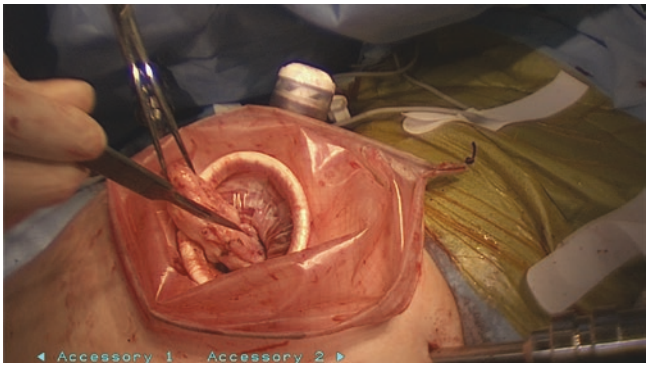

Fig. 10.9 ExCiTE technique

concluded. All instruments and ports are removed, pneumoperitoneum released, and skin incisions closed (Fig. 10.9).

Results

At our institution, our patient outcomes are generally favorable, and this is consistent with the available literature on surgical outcomes of RALM. Bedient et al. in their 81 patient retrospective study comparing RALM to LM concluded that short-term surgical outcomes were comparable between both groups [38]. Gargiulo et al. also found similar operative outcomes between RALM and LM patient groups. With regard to long-term outcomes of RALM, there are a handful of retrospective studies reporting pregnancy outcomes after RALM. One such study by Pitter et al. included a cohort of 872 women who underwent RALM between October 2005 and November 2010 at three centers. Of the 872 women, 107 conceived resulting in 127 pregnancies and 92 deliveries through 2011. The mean age at myomectomy was 34.8 ± 4.5 year, and the average number of myomas removed was 3.9 ± 3.2 with a mean size of 7.5 ± 3.0 cm and mean weight of 191.7 ± 145 g. Preterm delivery rates were higher with greater number of fibroids removed and anterior location of the largest incision. Overall the pregnancy outcomes in this study were comparable to those reported in the literature for conventional LM. Cela et al. had similar outcomes in a review of 48 patients who underwent RALM between the years 2007 and 2011 [39].

Complications

Complication rates with RALM are generally low. When compared to AM, RALM is associated with less of a drop in hematocrit concentration on postoperative day 1, less number of days to regular diet, decreased length of hospital stay, less

febrile morbidity, and longer operating times [11]. RALM patients in a study by Nash et al. were found to require less IV hydromorphone and had shorter hospital stays and equivalent clinical outcomes compared to AM patients [6]. In contrast, when compared to LM, blood transfusion risk and costs were higher with RALM. However, no significant differences were noted in estimated blood loss, operating time, length of hospital stay, and complications [14].

Conclusion

Although there is not enough evidence to support the superiority of RALM over conventional approaches, it is fair to conclude that robotic surgery is a game changer for the minimally invasive management of uterine fibroids. The underutilization of conventional LM in spite of the strong evidence to suggest its clear superiority over AM must be due to the technical demand in performing conventional LM. As Gargiulo and Nezhat stated in a 2015 book chapter, "Robot-assisted Myomectomy: Broadening the Laparoscopist's Armamentarium," despite the lack of level 1 evidence to support the role of robotic surgery for myomectomies, adapting this technology can raise the threshold for AM [17]. Ultimately, larger and ideally prospective studies are needed. Furthermore, future studies comparing these two modalities should be performed by surgeons who are skilled in both techniques and beyond their learning curves [40].

Clinical Pearls

1. Determine criteria for selecting appropriate candidates for RALM.
2. Preoperative imaging with MRI is recommended for fibroid mapping and to exclude adenomyosis.
3. For RALM candidates, determine if there is a need for multiple routes, e.g., hysteroscopy for a submucosal fibroid and discuss this with the patient including the possibility of needing a staged procedure.
4. Be generous while maintaining caution with the use of dilute vasopressin prior to myomectomy.
5. Be strategic when deciding on the location and trajectory of the hysterotomy incisions.
6. Remain cognizant of the cornua in order to be sure about the orientation of the uterus and location of the endometrial cavity.
7. Streamline your tissue extraction technique and select the appropriate size extraction bag for the pathology.

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References

1. Rosero EB, Kho KA, Joshi GP, Giesecke M, Schaffer JI. Comparison of robotic and laparoscopic hysterectomy for benign gynecologic disease. Obstet Gynecol Surv. 2014;69(1):18–9.
2. Advincula AP, Song A. The role of robotic surgery in gynecology. Curr Opin Obstet Gynecol. 2007;19(4):331–6.
3. Nieboer TE, Hendriks JC, Bongers MY, Vierhout ME, Kluivers KB. Quality of life after laparoscopic and abdominal hysterectomy: a randomized controlled trial. Obstet Gynecol. 2012;119(1):85–91.
4. Baird DD, Dunson DB, Hill MC, Cousins D, Schectman JM. High cumulative incidence of uterine leiomyoma in black and white women: ultrasound evidence. Am J Obstet Gynecol. 2003;188:100–7.
5. Management of uterine fibroids. Summary, evidence report/technology assessment: number 34. AHRQ Publication No. 01-E051, January 2001. Agency for Healthcare Research and Quality, Rockville, MD, USA.
6. Nash K, Feinglass J, Zei C, Lu G, Mengesha B, Lewicky-Gaupp C, Lin A. Robotic-assisted laparoscopic myomectomy versus abdominal myomectomy: a comparative analysis of surgical outcomes and costs. Arch Gynecol Obstet. 2012;285:435–40.
7. Herrmann A, De Wilde RL. Laparoscopic myomectomy—the gold standard. Gynecol Minim Invasive Ther. 2014;3(2):31–8.
8. Pluchino N, Litta P, Freschi L, et al. Comparison of the initial surgical experience with robotic and laparoscopic myomectomy. Int J Med Robot. 2014;10:208–12.
9. Parker WH, Iacampo K, Long T. Uterine rupture after laparoscopic removal of a pedunculated myoma. J Minim Invasive Gynecol. 2007;14(3):362–4.
10. Advincula AP, Song A, Burke W, et al. Preliminary experience with robot-assisted laparoscopic myomectomy. J Am Assoc Gynecol Laparosc. 2004;11:511–8.
11. Ascher-Walsh CJ, Capes TL. Robot-assisted laparoscopic myomectomy is an improvement over laparotomy in women with a limited number of myomas. J Minim Invasive Gynecol. 2010;17:306–10.
12. Hanafi MM, Hsu Y-S, Fomo AN. Comparative study between robotic laparoscopic myomectomy and abdominal myomectomy and factors affecting short-term surgical outcomes. J Reprod Med Endokrinol. 2010;7:258.
13. Lavazzo C, Mamais I, Gkegkes ID. Robotic assisted vs laparoscopic and/or open myomectomy: systematic review and meta-analysis of the clinical evidence. Arch Gynecol Obstet. 2016;294:5. DOI 10.1007/s00404-016-4061-6.
14. Pundir J, Pundir V, Walavalkar R, Omanwa K, Lancaster G, Kayani S. Robotic-assisted laparoscopic vs abdominal and laparoscopic myomectomy: systematic review and meta-analysis. J Minim Invasive Gynecol. 2013;20(3):335–45.
15. Barakat EE, Bedaiwy MA, Zimberg S, Nutter B, Nosseir M, Falcone T. Robotic-assisted, laparoscopic, and abdominal myomectomy: a comparison of surgical outcomes. Obstet Gynecol. 2011;117:256–65.
16. Pitter MC, Srouji SS, Gargiulo AR, et al. Fertility and symptom relief following robot-assisted laparoscopic myomectomy. Obstet Gynecol Int. 2015;2015:967568., 9 pages. DOI 10.1155/2015/967568.

17. Gargiulo AR, Nezhat C. Robot-assisted myomectomy: broadening the laparoscopists's armamentarium. In: Tinelli AA, Malvasi A, editors. Uterine myoma, myomectomy and minimally invasive treatments. Cham: Springer; 2015. p. 193. DOI 10.1007/978-3-319-10305-1_13.
18. Unger CA, Lachiewicz MP, Ridgeway B. Risk factors for robotic gynecologic procedures requiring conversion to other surgical procedures. Int J Gynaecol Obstet. 2016;135:299–303.
19. Dubuisson JB, Fauconnier A, Fourchotte V, et al. Laparoscopic myomectomy: predicting the risk of conversion to an open procedure. Hum Reprod. 2001;16:1726e31.
20. Stewart EA. Uterine fibroids. Lancet. 2001;357:293–8.
21. Uptodate. Uterine leiomyomas diagnostic evaluation. www.uptodate.com
22. ACOG practice bulletin. Alternatives to hysterectomy in the management of leiomyomas, August 2008, reaffirmed in 2012.
23. Marjoribanks J, Lethaby A, Farquhar C. Surgery versus medical therapy for heavy menstrual bleeding. Cochrane Database Syst Rev. 2006; (2). Art. No.: CD003855. DOI 10.1002/14651858.CD003855.pub2. (Level III).
24. Olive DL, Lindheim SR, Pritts EA. Non-surgical management of leiomyoma: impact on fertility. Curr Opin Obstet Gynecol. 2004;16:239–43. (Level III).
25. Fiscella K, Eisinger SH, Meldrum S, Feng C, Fisher SG, Guzick DS. Effect of mifepristone for symptomatic leiomyomata on quality of life and uterine size: a randomized controlled trial. Obstet Gynecol. 2006;108:1381–7. (Level I).
26. Karon A. MdEdge. Ulipristal acetate meets primary endpoint in pivotal uterine fibroids trial. http://www.mdedge.com/obgynnews/article/117334/gynecology/ulipristal-acetate-meets-primary-endpoint-pivotal-uterine. Accessed 13 Feb 2017.
27. Neurocrine Biosciences. Clinical trials. Elagolix: clinical trials in uterine fibroids. http://www.neurocrine.com/pipeline/elagolix-gnrh-antagonist/uterine-fibroids/clinical-trials. Accessed 13 Feb 2017.
28. Galen DI, Pemueller RR, Leal J. Laparoscopic radiofrequency fibroid ablation: phase II and phase III results. JSLS. 2014;18(2):182–90.
29. AirSeal® surgical system. http://www.conmed.com/advanced-surgical.php
30. Senapati S, Advincula AP. Surgical techniques: robot-assisted laparoscopic myomectomy with the da Vinci® surgical system. J Robot Surg. 2007;1:69. DOI 10.1007/s11701-007-0014-1.
31. Tulandi T, Beique F, Kimia M. Pulmonary edema: a complication of local injection of vasopressin at laparoscopy. Fertil Steril. 1996;66(3):478–80.
32. Derrick S, Rohnn S, Ali G. Robot-assisted laparoscopic myomectomy: a comparison of techniques. J Gynecol Surg. 2016;32(6):329–34. DOI 10.1089/gyn.2016.0058.
33. Zhang Y, Ma D, Xiong L. Role of barbed sutures in repairing uterine wall defects in laparoscopic myomectomy: a systemic review and meta-analysis. JMIG. 2016;23(5):684–91.
34. Tulandi T, Murray C, Guralnick M. Adhesion formation and reproductive outcome after myomectomy and second-look laparoscopy. Obstet Gynecol. 1993;82:213–5.
35. Ahmad G, Duffy JM, Farquhar C, Vail A, Vandekerckhove P, Watson A, Wiseman D. Barrier agents for adhesion prevention after gynaecological surgery. Cochrane Database Syst Rev. 2008;2:CD000475. DOI 10.1002/14651858.CD000475.pub2.
36. Ahmad G, O'Flynn H, Hindocha A, Watson A. Barrier agents for adhesion prevention after gynaecological surgery. Cochrane Database Syst Rev. 2015;4:CD000475. DOI 10.1002/14651858.CD000475.pub3.
37. Tulandi T, Closon F, Czuzoj-Shulman N, Abenhaim H. Adhesion barrier use after myomectomy and hysterectomy: rates and immediate postoperative complications. Obstet Gynecol. 2016;127(1):23–8.
38. Bedient CE, Magrina JF, Noble BN, et al. Comparison of robotic and laparoscopic myomectomy. Am J Obstet Gynecol. 2009;201:566.e1–5.
39. Cela V, Freschi L, Simi G, Tana R, Russo N, Artini PG, Pluchino N. Fertility and endocrine outcome after robot-assisted laparoscopic myomectomy (RALM). Gynecol Endocrinol. 2013;29(1):79–82.
40. Quaas AM, Einarsson JI, Srouji S, Gargiulo AR. Robotic myomectomy: a review of indications and techniques. Rev Obstet Gynecol. 2010;3(4):185–91.

Robotic Management of Pelvic Organ Prolapse

11

Johnny Yi

Introduction

Surgical management of uterovaginal and vaginal vault prolapse historically started with the vaginal approach, typically including a vaginal hysterectomy, with apical and compartmental repair. Unfortunately, population studies show that up to 30% of patients undergo reoperation for these conditions [1]. Due to risk of recurrence, more durable approaches have been sought out, including the utilization of synthetic materials to augment repair. Abdominal sacrocolpopexy thus developed and became the gold standard approach to reconstruct the vagina for patients with symptomatic prolapse. Multiple studies have shown durable outcomes, with safety and efficacy of abdominal mesh augmentation. With the advent of robotic and laparoscopic surgery, there has been a shift away from laparotomy, and the sacrocolpopexy procedure is now commonly performed in a minimally invasive fashion. Robotic surgery has also allowed the surgeon to evaluate the upper abdomen and address other intra-abdominal and pelvic issues which vaginal surgery cannot address. Furthermore, improved dexterity with the robotic instrumentation has led to ease in dissection of delicate surgical planes, along with generalized adoption of suturing, which is often difficult with laparoscopy. This had led to the rapid adoption of robotic technology in the repair of uterovaginal and vaginal vault prolapse.

Background

Different techniques for surgical repair of uterovaginal and vaginal prolapse have been described. Since the early twentieth century, two key approaches have been well studied and found to be durable approaches to addressing this common medical condition. The vaginal approach incorporated apical suspension to the uterosacral ligaments, described in the McCall's culdoplasty procedure [2]. Later, the sacrospinous ligament suspension developed and became an alternative apical suspension procedure [3]. Abdominally, the sacrocolpopexy evolved over time with the development of mesh augmentation materials. Initial attempts at vaginal apical suspension abdominally included attaching the uterine fundus to the anterior abdominal wall, utilizing a fascial augmentation [4]. This surgical technique was described to lead to lower abdominal pain and recurrence of prolapse. In 1961, Lane recommended a technique of attaching the vaginal apex and posterior vaginal wall to the sacral promontory and anterior longitudinal ligament initially with staples and then silk suture. This technique was thought to improve durability with a synthetic material that does not degrade over time, utilizing a surgical dissection that was not difficult to employ via laparotomy [5].

Further evolution of this technique then developed, including moving the sacral attachment site lower to mimic the natural vaginal axis. When moving this site to S3–S4, significant risk of hemorrhage was noted, and finally open sacrocolpopexy was performed with sacral attachment at S1–S2 level. Furthermore, mesh was distributed not only on the posterior vaginal wall and apex but completely surrounding the vagina. This approach led to more mesh complications and currently, two strips of mesh are attached to the vagina, at the anterior and posterior walls of the vagina.

Endoscopic surgery had a slow adoption with this procedure, due to the amount of suturing involved, along with the limitation of visualization over the sacral promontory. Early reports of laparoscopic sacrocolpopexy were reported, but long-term follow-up was limited. Studies demonstrated feasibility of the operation, but despite this, laparoscopic approach to sacrocolpopexy did not flourish due to difficulty with technical aspects of the operation [6, 7]. Following the introduction of the robotic surgical platform and approval for use in gynecologic surgery in 2004, sacrocolpopexy was quickly adopted by reconstructive pelvic surgeons. The da Vinci robotic platform (Intuitive Surgical, Sunnyvale, CA)

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offered improved visualization and wristed instrumentation, which allowed for improved ergonomics with laparoscopic suturing, while maintaining a laparoscopic approach in a minimally invasive fashion. Initial studies show safety and efficacy with promising short-term outcomes [8]. Initially, the bulky robotic platform was docked between the legs, limiting access to the vagina, which is critical for manipulation during surgery. However, with development of the da Vinci Si and subsequently the Xi generation, side docking has been optimized, which allows an assistant to manipulate the vagina from below, while allowing the surgeon up to three operative ports for which instruments can be utilized, in addition to the camera.

While sacrocolpopexy is the most common operation for prolapse performed utilizing the robotic platform, apical suspension of the uterosacral ligaments can also be performed, utilizing the McCall's culdoplasty or high uterosacral ligament suspension approach. While this procedure is performed more commonly vaginally, there are potential benefits to a robotic approach due to optimized visualization of the uterosacral ligaments and their relationship to the ureter. Furthermore, in this manner, uterosacral suspension can be performed without graft material and also can be performed prophylactically with any robotic hysterectomy in hopes to prevent cuff prolapse in the future.

Presentations, Investigations, and Treatment Options

Evaluation of Patient with Uterovaginal and Vaginal Vault Prolapse

Evaluation of a patient with complaints of uterovaginal and vaginal vault prolapse should start with a thorough history and physical examination. Most patients with symptomatic prolapse will identify with complaints of a bulge outside of the vagina, which can be physically confirmed on examination. Oftentimes, patients may have been symptomatic for years without discussing these sensitive issues with their physician. Risk factors for developing prolapse include vaginal parity and hysterectomy, although those without such risk factors can still present with symptoms of prolapse. Epidemiologic studies have shown that a laxity in the pelvic musculature and vaginal sidewalls is a common occurrence, with up to 40% of women showing evidence of POP-Q Stage 2 prolapse on an evaluation of asymptomatic outpatient gynecology patients [9]. However, this does not specifically correlate with a need for pelvic reconstructive surgery. Gutman et al. observed that women with leading edge of their prolapse 1 cm past the hymen are more likely to be bothered by prolapse symptoms [10]. Pelvic organ prolapse can often coexist with other pelvic floor disorders affecting the bowels and bladder, and these symptoms should be elucidated during history. Urinary incontinence is the most common coexisting condition, and failure to characterize a patient's bother with urinary symptoms can lead to suboptimal pelvic floor repair. Patient history should gather whether they have symptoms of stress and urgency urinary incontinence. Helpful questions include "Do you have leakage of urine with coughing, laughing, sneezing, exercise, etc.?" or "Do you have leakage of urine with a strong urge, or on the way to the bathroom?" Other important information includes fluid intake, urinary frequency, and number of incontinence episodes per day. Urodynamic evaluation may assist if the patient's history is unclear, the patient has a history of prior reconstructive surgery, especially for urinary incontinence, or if there is a concern for neurogenic component to their urinary symptoms. Urinalysis, spontaneous voided volume and post-void residual are all part of our standardized evaluation for patients with pelvic organ prolapse.

Studies have shown that pelvic organ prolapse does not cause pain, and pain is not typically a presenting symptom of prolapse unless there is pain due to ulceration from a severe prolapse [11]. If a patient presents with pain that is disproportionate to their degree of prolapse, other considerations should be investigated, such as pelvic floor tension myalgia, mesh complications, or other visceral and musculoskeletal etiologies of pelvic pain.

Physical examination of the prolapse patient should include a thorough abdominopelvic examination along with a musculoskeletal examination. Inspection of the abdomen will show prior surgical scars, which can help the surgeon anticipate surgical adhesive disease. Palpation can rule out other visceral processes and abdominopelvic masses.

Musculoskeletal examination should include evaluation of hip mobility and lower extremity strength. Pelvic floor surgery requires positioning in stirrups, whether low or high lithotomy positions, and limitations in hip mobility may limit surgical positioning. Furthermore, given that prolapse is a disorder associated with aging, the surgeon may discover other coexisting maladies that can be addressed to best treat the patient completely.

Pelvic examination is performed in the lithotomy position and can be confirmed in the standing position. The severity of prolapse can be described using the POP-Q or Baden-Walker Halfway system [12, 13]. Benefits to the POP-Q system include understanding of the anterior and posterior along with apical involvement along with standardization for future research purposes. Provocative maneuvers, such as cough or Valsalva, are then performed with and without prolapse reduction to evaluate for inducible stress urinary incontinence. Occult incontinence is demonstrated in a patient without clinical complaints of stress incontinence but has demonstrable stress incontinence with prolapse reduction.

A online calculator is available to determine risk of de novo stress incontinence after surgery for prolapse in which case a concomitant midurethral sling should be considered [14].

Robotic approach to prolapse repair can be offered to all patients with pelvic organ prolapse. Sacrocolpopexy is a mesh-augmented procedure and is well studied to be the gold standard and most durable repair for pelvic organ prolapse. Unique risks of mesh, along with the FDA notification regarding transvaginal mesh for prolapse placement, are important in complete informed consent for a patient undergoing this surgery. Patients that decline mesh augmentation can still undergo uterosacral ligament suspension and native tissue repair and hysterectomy along with apical suspension can be performed vaginally or endoscopically depending on the surgeon's preference. Robotic approach is ideal for patients that have had prior hysterectomy, have shortened vagina, or need the most durable approach to repair due to anticipated repetitive high-impact exercises.

Surgical Technique and Postoperative Rehabilitation

Robotic-Assisted Sacrocolpopexy

Robotic-assisted sacrocolpopexy starts with the typical entry approach for any endoscopic procedure. We prefer to place our initial incision trans-umbilically using an open laparoscopy technique. Utilizing this approach, we have avoided major vessel injury as compared to utilizing the Veress approach [15]. Once initial entry is obtained, CO_2 pneumoperitoneum is obtained up to 15 mmHg. For the Si model, we then utilize an "M" configuration for the remainder of our trocars. During the sacrocolpopexy procedure, the sigmoid colon is retracted to the left side, exposing the presacral space, so we choose to dock the robotic platform at a 45° angle on the patient's left side, utilizing our side docking template (Fig. 11.1). Arms 2 and 3 are docked on the left side

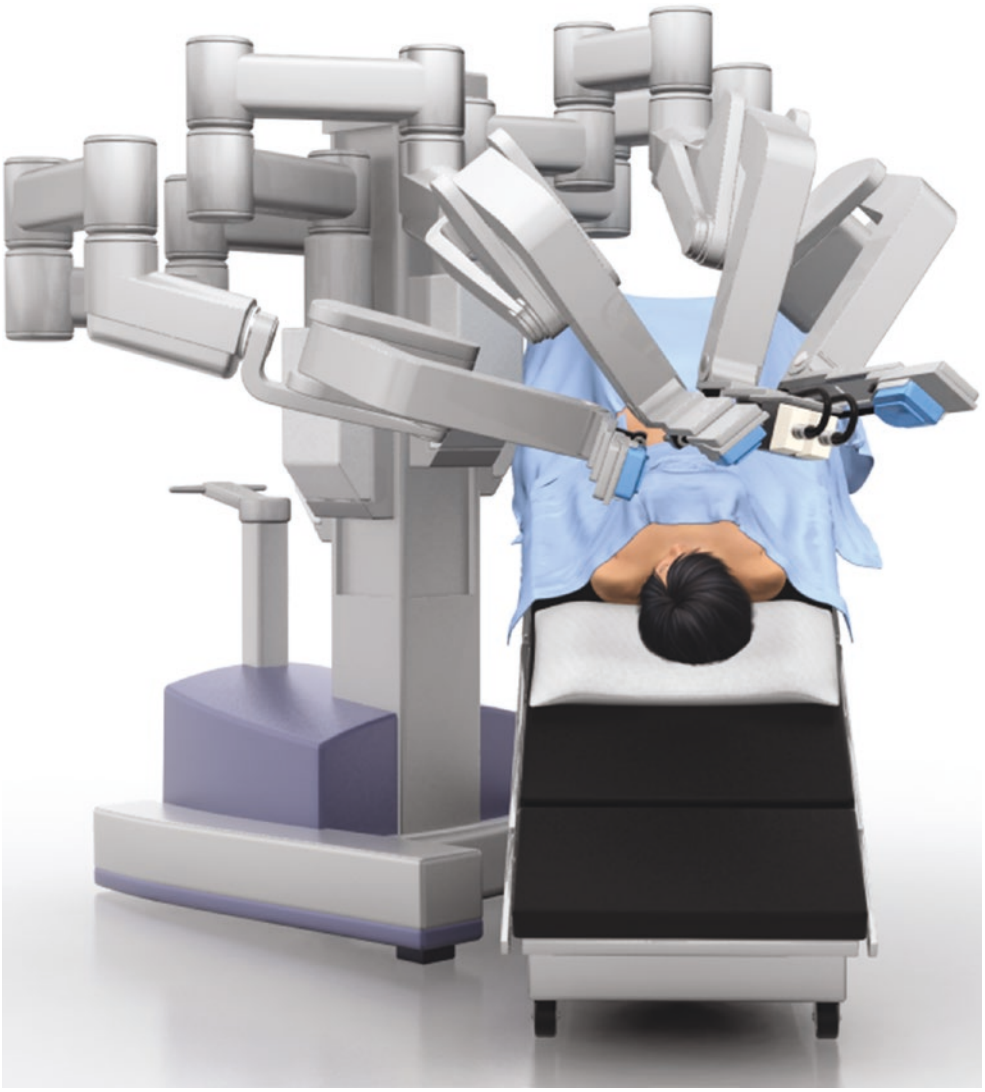

Fig. 11.1 Left side robotic position—head of bed (© 2017 Intuitive Surgical, Inc)

of the abdomen, while Arm 1 is docked on the right side. The assistant port, either an 8 or 12 mm port is placed between the umbilicus and right lower quadrant port, in the right mid-abdomen. For the Xi model, instead of an "M" configuration, the ports are placed at the level of the umbilicus, with the exception of the assistant port, which can be deviated cephalad. Once the robotic arms are docked, atraumatic grasper and bipolar device are placed in the left operating arms, while monopolar scissors or spatula is utilized on the right.

If the uterus is in situ, a supracervical hysterectomy has been shown to decrease the risk of mesh erosion and would be considered over a total hysterectomy. If the cervix must be removed, care should be taken to perform a two-layer vaginal cuff closure, with consideration of an interposition layer such as the bladder peritoneum, which can be easily mobilized.

In the case of significant blood loss requiring conversion to laparotomy, the presacral space is the most likely anatomic location, and therefore, the presacral dissection is performed first (Fig. 11.2). The peritoneum over the sacral promontory is lifted and entered using monopolar cautery. Starting this dissection at or below the level of the promontory allows safe access away from the common iliac vessels. Cadaveric studies show a mean distance of the sacral promontory to the left common iliac vein being 27 mm cephalad and distance to the sacral venous plexus being 34 mm caudad [16]. With pneumoperitoneum, left common iliac vein may be compressed, and care should be taken to identify this structure to avoid catastrophic hemorrhage. Once peritoneal entry is obtained, this can be extended caudal, and areolar space is opened. If there is significant bleeding encountered at this space, or obscured visualization of the anterior longitudinal ligament (ALL), sigmoid retraction should be assessed again to make sure sigmoid mesentery is sufficiently retracted laterally. Once this dissection is complete, the white shine of the ALL should be clearly visualized, along with the middle sacral artery, which is usually found medial to the mesh attachment site.

If mesh is retroperitonealized, then the presacral peritoneum should be followed deep and caudal, to the level of the posterior vaginal peritoneum incision. At this level, several critical anatomic structures exist. The ureter is lateral and anterior to this incision, and the inferior hypogastric plexus is found lateral at the level of the uterosacral ligaments. Avoidance of these structures will minimize intraoperative and postoperative complications.

The posterior rectovaginal space is dissected next (Fig. 11.3). The avascular space can be identified 1–2 cm caudal to the vaginal apex or cervix. Incision is made horizontally with monopolar scissors, developing the rectovaginal space, with a sweeping motion in the horizontal fashion. This area typically is void of surgical adhesions unless patient has undergone prior bowel resection or sacrocolpopexy in the past. This dissection can be carefully taken down to the level of the perineal body. As the dissection is carried distally, care must be taken to avoid rectal injury, which would likely preclude placement of a synthetic mesh material. Posterior dissection should be taken down to the appropriate level, taking into consideration several anatomic points. POP-Q points Ap and Bp can guide posterior dissection. With advanced prolapse, consideration should be made to more distal attachment. POP-Q measurement Gh may guide the surgeon as to whether a posterior colpoperineorrhaphy will be necessary. If so, we avoid vaginal and abdominal incisions overlapping and posterior attachment may stop higher along the posterior vaginal wall.

The anterior dissection is then performed (Fig. 11.4). Vesicovaginal space is carefully created using short bursts of monopolar energy. This area is more likely to have significant adhesive disease, either due to prior hysterectomy or

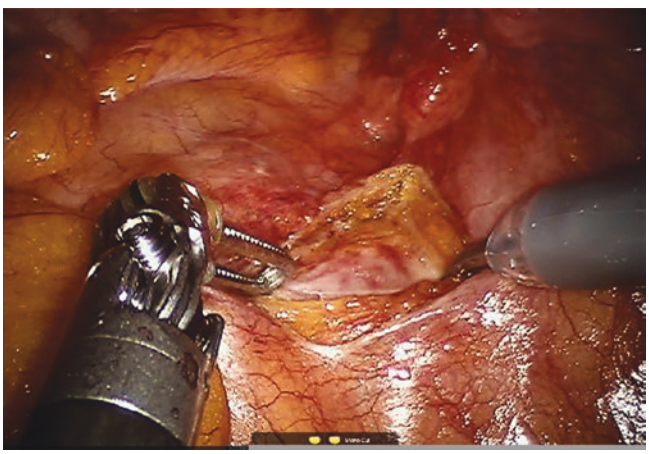

Fig. 11.2 Dissection of the presacral space. Anterior longitudinal ligament visible

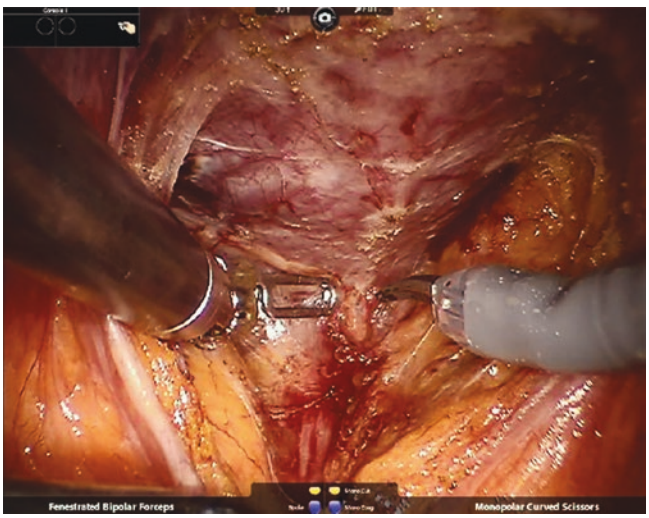

Fig. 11.3 Posterior dissection of rectovaginal space

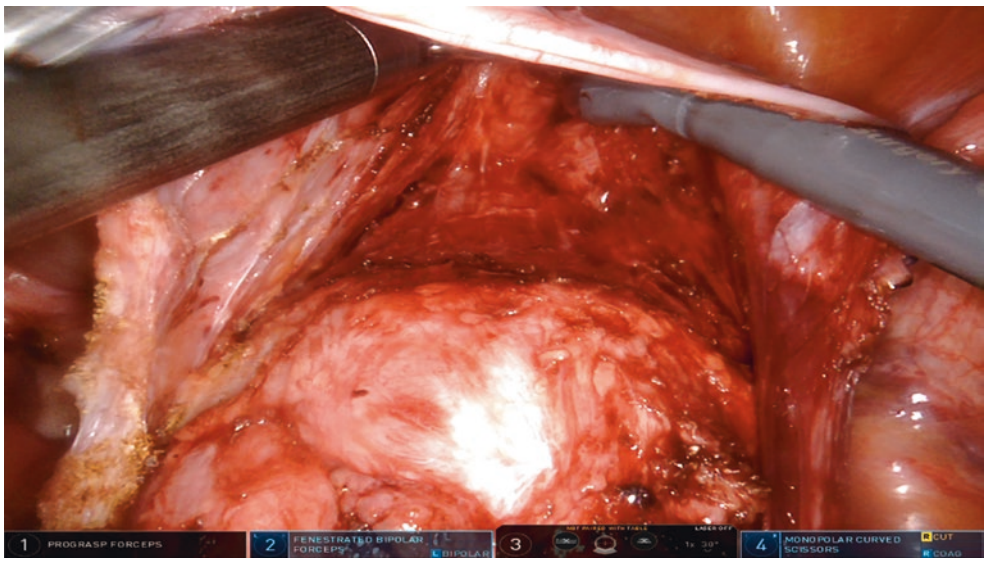

Fig. 11.4 Anterior vesicovaginal dissection

cesarean section. Again, dissection should be guided by the POP-Q points Aa and Ba. Dissection can be taken down to the level of the bladder neck and usually concomitant anterior colporrhaphy can be avoided. Adhesions of the bladder to the vagina are oftentimes encountered, and cystotomy is a risk of the procedure. If this complication is encountered, the ends of the injury should be tagged, dissection and colpopexy completed, prior to repair of the cystotomy, to avoid tension on the cystotomy repair iatrogenically. While a bladder injury would not preclude completion of the case, these patients should be closely followed to ensure no mesh erosion develops into the bladder. An interposition of bladder peritoneum or biologic graft can be considered between the two-layer closure and the mesh.

Once the dissection is complete, mesh attachment is performed. As discussed above, type I polypropylene mesh has shown improved outcomes with minimized complications when compared to other types of synthetic mesh and biologic materials. This type of polypropylene mesh is now widely available in either a free sheet that can be constructed into two separate strips of mesh or a Y-mesh that is preconstructed. In consideration of cost containment, we prefer to use two separate strips of mesh or construct our own Y-mesh for this procedure. Suture material is based on surgeon preference, but small studies show that absorbable suture, along with absorbable barbed suture, appear to have good short-term outcomes. We prefer to use synthetic monofilament Gore-Tex® (Gore, Flagstaff, AZ) suture with at least 6–8 points of attachment on each segment of the vaginal wall. This allows even distribution of force over the anterior and posterior vaginal wall. The stem of the mesh is then tensioned appropriately, with consideration that the patient is in steep Trendelenburg position (Fig. 11.5). Excessive tension can lead to postoperative stress urinary incontinence and pain, while inadequate tension can lead to continued symptomatic vaginal prolapse. Two horizontally placed Gore-Tex sutures are placed to attach the mesh to the ALL. Tacking or stapling devices are avoided as they may be inadvertently placed into the intervertebral disc spaces and predispose patients to degenerative disc disease or, rarely, discitis [17].

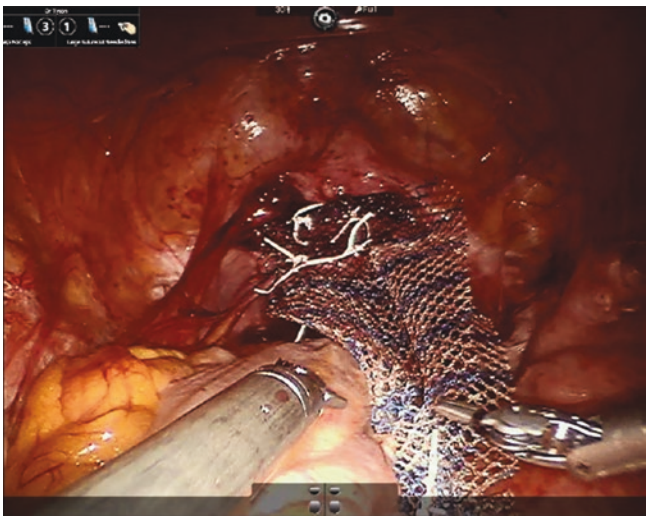

Fig. 11.5 Mesh attachment to anterior and posterior vagina. Along with sacral attachment

Once the mesh is completely attached, the peritoneum can be oversewn to retroperitonealize the mesh completely. This is usually performed with a rapidly absorbable suture (Fig. 11.6). The right ureter should be clearly identified and avoided as ureteral injury or kinking can occur during this portion of the operation. Following this portion of the case, a vaginal examination is performed, ideally with the patient out of Trendelenburg position, to determine if any

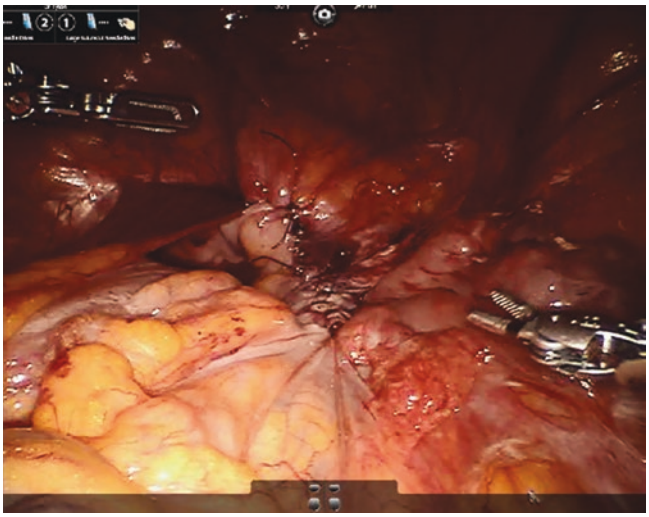

Fig. 11.6 Mesh is retroperitonealized with absorbable suture

concomitant vaginal repairs are necessary. Once this is completed, cystourethroscopy should be performed to ensure no injury to the bladder or compromise of the ureters.

Robotic-Assisted Uterosacral Ligament Suspension

In a patient needing a total hysterectomy or desiring a reconstructive procedure free of synthetic materials that requires an endoscopic approach, we prefer a robotic-assisted uterosacral ligament suspension. Once the uterus and cervix are removed through the vagina, the vaginal cuff is inspected. Additional hemostasis can be achieved with cautery but can also be achieved with suture closure of the vaginal cuff. The uterosacral ligament is identified by grasping the posterior vaginal cuff and deviating it anteriorly. This anterior tension usually delineates the uterosacral ligament clearly. We prefer to use a delayed absorbable suture, such as 0 polydioxanone. The suture is passed through the anterior and posterior vaginal cuff, and the intermediate uterosacral ligament is incorporated as this is the most robust portion of the ligament. Care is taken to avoid deep structures if sutures are placed cephalad to the ischial spine to avoid neurovascular injury. This suspension is performed in an ipsilateral fashion, with each suture placed medial is placed higher on the uterosacral ligament. By placed three sutures on each side, this suspension also essentially obliterates any existing enterocele and posterior cul-de-sac. If the ureter is deviated medially or there is concern for ureteral kinking, relaxing incisions can be made on the peritoneum between the ureter and the uterosacral ligament, to separate and distance the two anatomic structures. Due to clear visualization of the intra-abdominal anatomy, there may be less risk of ureteral compromise with the robotic approach as compared to the vaginal approach. Best practices would still suggest that diagnostic cystourethroscopy be performed after this procedure as with any hysterectomy to ensure no bladder or ureteral compromise.

Postoperative Rehabilitation

As with most of our robotic procedures, patients undergoing robotic repair of vaginal prolapse are considered for outpatient stay. If the patient prefers, or if medical comorbidities are present, overnight observation is considered. In this scenario, a urinary catheter is left in place overnight, and a voiding trial is performed in the morning. With a backfill of the empty bladder of 300 cm^3, if the patient voids more than 150 cm^3, the urinary catheter is removed, and patient is given precautions for signs and symptoms of urinary retention. If they are unable to void at least 150 cm^3, the Foley catheter is left in place for 3–5 days, and the patient returns for outpatient voiding trial in the ambulatory clinic. Upon discharge from the hospital, patients are given moderate activity and lifting restrictions. Of utmost importance is aggressive prevention of constipation due to the significant amount of intra-abdominal pressure that can be applied with Valsalva defecation. Narcotics, nonsteroidal anti-inflammatory medications, and laxative are provided for patients upon discharge. Typically, patients recover quickly due to the minimally invasive approach to this surgery. However, we recommend lifting and activity restrictions for 6 weeks, along with pelvic rest for 6 weeks. Postoperative evaluation is performed at 6 weeks prior to clearing patients to normal activity. Postoperative counseling is reiterated at this visit regarding synthetic mesh materials and the signs and symptoms of mesh complications, most commonly mesh erosion into the vagina.

Results

Abdominal sacrocolpopexy is a well-studied approach to treatment of pelvic organ prolapse. There has been a rapid transition and implementation of robotic technology, especially for the sacrocolpopexy procedure. As compared to traditional laparoscopic approach, robotics has allowed for ease of dissection and suturing, with a more rapid learning curve. Early during the adoption of minimally invasive sacrocolpopexy, Nezhat reported a series of 12 patients that underwent laparoscopic sacrocolpopexy [6]. This was considered for women that had reported contraindication to vaginal approach to prolapse surgery. His technique utilized Mersilene or Gore-Tex mesh either stapled or sutured to the anterior longitudinal ligament at the level of S3–S4. Only one patient required conversion. Cosson et al. describes a

larger series of 83 patients with successful laparoscopic approach in 77 patients [7]. Similarly, Mersilene mesh was utilized, and sacral fixation was at the level of the sacral promontory. One patient required reoperation due to cystocele. Cosson described the learning curve with decreasing operative time and decreasing complications as experience was gained.

When compared to open sacrocolpopexy, robotic approach showed increased operative time but decreased estimated blood loss and length of stay in the hospital. Similar to laparoscopic approach, and with all types of surgery, operative time for the robotic approach decreases with experience, with reported times ranging from 75 to 537 min. Median operative time reported by Serati et al. in their systematic review was 194 min [18]. Our early experience showed a short learning curve. Operative times after the first ten cases decreased by 25%. Mean operative time of the last 30 cases of our reported case series was 167.3 min. This experience was with the da Vinci S version. Improvements in the robotic technology and increased experience have optimized our approach in the last 10 years [8].

Currently, only two randomized controlled trials exist comparing laparoscopy to robotic-assisted laparoscopic sacrocolpopexy [19, 20]. While long-term outcomes are limited, anatomic and functional outcomes did not show differences. An earlier study by Paraiso reported shorter operative times with laparoscopy with a difference of about 67 min. Anger et al. recently published a randomized controlled trial which also showed increased times with robotic approach but with less difference of about 24 min. Total surgery times in this study did not show a significant difference. This implies that with improved optimization of robotic surgery, efficiency can be achieved and may help minimize the cost difference between the two approaches. Both studies showed an increase in cost of utilizing robotic technology as opposed to laparoscopic approach. Currently, Intuitive Surgical (Intuitive Surgical Corporation, Sunnyvale, CA) is the only FDA approved robotic surgical platform available for abdominal and pelvic surgery. As technology improves and other options develop, cost differences between robotic and laparoscopic approaches will likely diminish as well. In terms of anatomic and functional outcomes, robotic approach to sacrocolpopexy appears to be similar to open laparotomic approach. Both Paraiso and Anger followed patients for 12 months and reported postoperative outcomes with significant improvement in both arms showing no patients with recurrent POP-Q Stage 3-4 prolapse and significant improvement in validated pelvic floor questionnaires.

There are many variables to consider when evaluating sacrocolpopexy in terms of surgical technique, results, and complications. Large prospective randomized trials are lacking evaluating many of these variables, and further research is needed to understand the best approach to sacrocolpopexy. Variables of interest include different mesh materials, suture attachment materials, and peritonealization of the mesh.

There are a variety of mesh products that are commercially available for augmentation in pelvic floor surgery. While other types have been used in the past, currently, only Amid type I polypropylene mesh is utilized when discussing synthetic materials [21]. The pore size of type I mesh has been shown to allow best integration into the surrounding vaginal tissue. Utilization of autologous fascia for sacrocolpopexy has not been shown to be a durable alternative to synthetic mesh [22]. Other types of mesh have had increased risk of complication, including mesh erosion and infection. Not all type I meshes are created equal. Animal studies show that increased stiffness of type I polypropylene mesh has a negative impact on the vaginal cellular environment [23]. An ideal implant would provide strength and support to the vaginal apex and allow regeneration of the extracellular matrix that is found to be abnormal in patients with pelvic organ prolapse.

Suture choice of the mesh to the vagina and anterior longitudinal ligament are also variable. Common options include absorbable, delayed absorbable, barbed, and permanent suture. There are also staplers or tacking devices that can be used to attach the mesh to the ligament. Tan-Kim et al. reported a randomized controlled trial comparing barbed suture with non-barbed, delayed absorbable suture [24]. They found barbed suture had shorter operative times and easier suture placement. This was performed in even numbers between laparoscopic and robotic approaches. Patients were followed for 12 months, and there were no difference in anatomic outcomes. Linder et al. published their long-term follow-up of 132 robotic sacrocolpopexies performed with only polyglactin suture at both vaginal and sacral mesh fixation sites [25]. Median follow-up was 33 months with repeat surgeries avoided in 93% of patients at 3 years. The risk of suture erosion must be weighed against the risk of recurrent prolapse when deciding to use absorbable or permanent sutures; however, existing literature shows short- and medium-term outcomes to be favorable in the use of absorbable and delayed absorbable sutures.

Complications

Complications associated with robotic approach to pelvic organ prolapse carry the same risks as any endoscopic approach. Multiple studies have shown the decrease morbidity, improved recovery, and minimized blood loss associated with robotic surgery. All surgical approaches include the risk of bleeding, infection, and damage to surrounding organs. Given the synthetic mesh augmentation, there are unique risks associated with mesh procedures, most commonly mesh erosion into the vagina. As with any surgical

procedure, higher volume surgeons will have less complications, and privileging at most hospitals requires a consistent number of cases to be performed to maintain robotic surgical privileges. Overall, studies have shown that the robotic sacrocolpopexy is a safe procedure, with low risk of complications.

When evaluating complications between robotic and laparoscopic sacrocolpopexy, both groups are found to have low risks of overall complications. Estimated blood loss is typically low for this procedure with Anger et al. reporting mean blood loss less than 100 cm^3 [20]. However, Unger et al. reported robotic cases had more patients that had blood loss greater than 500 cm^3 as compared to laparoscopic approach [26]. In this study, robotic cases were less likely to undergo hysterectomy. The reason for higher blood loss with robotic approach was not clearly identified. With expert laparoscopists, robotic surgery may be reserved for the most difficult cases such as expected severe adhesive disease. It is possible that this may be a reason for such findings. Intraoperative complications can include visceral injury with the most common injury to the bladder. This risk is likely increased in posthysterectomy patients and patients with prior C-sections. We utilize careful sharp dissection, along with placement of a three-way urinary catheter to allow filling of the bladder when the bladder edges are not clearly demarcated. Injury to the bladder should be repaired in a two-layer fashion, and if available, bladder peritoneum can be mobilized as an interposition layer. Intraoperative bowel injury is also of low risk. Prior sigmoid or rectal surgery, obliteration of the posterior cul-de-sac and deep dissection to perform perineopexy increase the risk of bowel injury. In the scenario of bowel injury, there is significant concern to contamination of the mesh, and conversion to a different approach of apical suspension would be recommended. In this scenario, although rare, we would choose to avoid mesh procedure and perform robotic uterosacral ligament suspension.

Vascular complications are of significant consideration when performing sacrocolpopexy. With open procedures, mesh attachment to the sacrum was much lower at the S3–S4 level. However, due to catastrophic bleeding complications, attachment site migrated toward S1–S2. With the advent of robotic and laparoscopic approaches, it was found to be more difficult to attach beyond the sacral promontory and attachment site again migrated cephalad. With attachment at the promontory, this brought the dissection plane closer to a different set of significant vasculature, specifically the left common iliac vein and also the middle sacral artery and vein. Care must be taken to avoid vascular injury to these structures. Overall rates of significant vascular injury are found to be less than 1% [19, 26]. These can be avoided by mobilizing the sigmoid mesentery to the left and lifting the peritoneum off of the promontory. Starting at or beyond the promontory and dissecting caudal allows the surgeon to visualize the anterior longitudinal ligament at the level of S1–S2. A 30° scope pointing down can assist in visualizing past the angle of the promontory.

Postoperative bowel complications are often a concern as well, especially when debating whether the sacrocolpopexy mesh should be reperitonealized or not. Hypothetically, reperitonealization should protect adhesion formation of bowel to the synthetic mesh and subsequently lower the risk of bowel complications. No prospective trials have been performed to show this is of benefit. Mueller et al. performed a retrospective evaluation of outcomes in 450 women who underwent minimally invasive sacrocolpopexy [27]. Of this cohort, 86% did not have reperitonealization of the mesh. While follow-up was short, 13 weeks, there were only 2.6% of women who had bowel complications, which included ileus, small bowel obstruction and port site hernia. Overall bowel complications were no different whether the mesh was reperitonealized or not. The surgeon should consider the risks of further surgical dissection, which can disrupt the autonomic nerves and compromise the ureter, although this risk is likely very low as well. Future prospective studies should be performed to identify best practices.

Mesh complications are of significant concern to the surgeon, the patient, and the public. Due to increased risks of transvaginal mesh for prolapse, the FDA has published a health notification warning patients that risks with the use of transvaginal mesh for prolapse may have complications that are not rare [28, 29]. Following this notification, there has been significant public awareness, including class action lawsuits against companies who produce mesh for pelvic reconstruction. Patients are often unaware of the differences between transvaginal mesh and abdominally placed mesh and require careful informed consent prior to any mesh procedure. Despite significant counseling, some patients may feel uncomfortable with a mesh procedure despite the safety and increased durability. Given that other durable approaches to vaginal reconstruction exist, a patient and her surgeon should together choose the most appropriate route of treatment.

Mesh complications associated with sacrocolpopexy have been very well studied, with rates of mesh erosion typically reported less than 5% [26, 30]. The highest long term mesh complication rate was published in the E-CARE follow-up study are noted to be 9.9% [31]. Factors that may contribute include total hysterectomy with concomitant sacrocolpopexy along with certain mesh qualities (i.e., m-icroporous pore size). Given the long-term follow-up of the E-CARE study, this may also suggest that due to the permanent nature of mesh, new cases of mesh erosion can occur long after initial surgery and careful counseling should be provided to patients about symptoms of mesh erosion. Consideration should be made to annual or other regular long-term follow-up for these patients as well.

Conclusion/Personal Review

Robotic sacrocolpopexy is the most commonly performed robotic treatment for pelvic organ prolapse. This remains the most durable approach to vaginal reconstructive surgery and is safe and effective with low risk of complications. The pelvic reconstructive surgeon should understand the development of this procedure and how conversion to robotics has changed the procedure over time. As technology continues to advance in surgical instrumentation, including mesh and suture materials available, continued evaluation of these products should be considered prior to immediate implementation into common practice. Careful evaluation of the patient with pelvic organ prolapse along with understanding multiple modalities of treatment is necessary to offer the best care for these patients. Surgeons should also be familiar with the common complications that can occur with sacrocolpopexy and should be able to offer alternative procedures to patients if such complications prohibit completion of the intended procedure, such as uterosacral ligament suspension. Finally, given the utilization of mesh augmentation for sacrocolpopexy, surgeons should offer extensive informed consent to the patient so they understand the permanent nature of polypropylene mesh and also clearly understand the signs and symptoms of mesh erosion which is often best understood and treated by those who implanted the material.

References

1. Olsen AL, et al. Epidemiology of surgically managed pelvic organ prolapse and urinary incontinence. Obstet Gynecol. 1997;89(4):501–6.
2. Mc CM. Posterior culdeplasty; surgical correction of enterocele during vaginal hysterectomy; a preliminary report. Obstet Gynecol. 1957;10(6):595–602.
3. Randall CL, Nichols DH. Surgical treatment of vaginal inversion. Obstet Gynecol. 1971;38(3):327–32.
4. Arthure HG. Vault-suspension. Proc R Soc Med. 1949;42(6):388–90.
5. Lane FE. Repair of posthysterectomy vaginal-vault prolapse. Obstet Gynecol. 1962;20:72–7.
6. Nezhat CH, Nezhat F, Nezhat C. Laparoscopic sacral colpopexy for vaginal vault prolapse. Obstet Gynecol. 1994;84(5):885–8.
7. Cosson M, et al. Laparoscopic sacrocolpopexy, hysterectomy, and burch colposuspension: feasibility and short-term complications of 77 procedures. JSLS. 2002;6(2):115–9.
8. Akl MN, et al. Robotic-assisted sacrocolpopexy: technique and learning curve. Surg Endosc. 2009;23(10):2390–4.
9. Swift S, et al. Pelvic Organ Support Study (POSST): the distribution, clinical definition, and epidemiologic condition of pelvic organ support defects. Am J Obstet Gynecol. 2005;192(3):795–806.
10. Gutman RE, et al. Is there a pelvic organ prolapse threshold that predicts pelvic floor symptoms? Am J Obstet Gynecol. 2008;199(6):683.e1–7.
11. Heit M, et al. Is pelvic organ prolapse a cause of pelvic or low back pain? Obstet Gynecol. 2002;99(1):23–8.
12. Bump RC, et al. The standardization of terminology of female pelvic organ prolapse and pelvic floor dysfunction. Am J Obstet Gynecol. 1996;175(1):10–7.
13. Baden WF, Walker TA, Lindsey JH. The vaginal profile. Tex Med. 1968;64(5):56–8.
14. Jelovsek JE, et al. A model for predicting the risk of de novo stress urinary incontinence in women undergoing pelvic organ prolapse surgery. Obstet Gynecol. 2014;123(2 Pt 1):279–87.
15. Long JB, et al. Open laparoscopic access technique: review of 2010 patients. JSLS. 2008;12(4):372–5.
16. Wieslander CK, et al. Vascular anatomy of the presacral space in unembalmed female cadavers. Am J Obstet Gynecol. 2006;195(6):1736–41.
17. Propst K, et al. Pyogenic spondylodiscitis associated with sacral colpopexy and rectopexy: report of two cases and evaluation of the literature. Int Urogynecol J. 2014;25(1):21–31.
18. Serati M, et al. Robot-assisted sacrocolpopexy for pelvic organ prolapse: a systematic review and meta-analysis of comparative studies. Eur Urol. 2014;66(2):303–18.
19. Paraiso MF, et al. Laparoscopic compared with robotic sacrocolpopexy for vaginal prolapse: a randomized controlled trial. Obstet Gynecol. 2011;118(5):1005–13.
20. Anger JT, et al. Robotic compared with laparoscopic sacrocolpopexy: a randomized controlled trial. Obstet Gynecol. 2014;123(1):5–12.
21. Cosson M, et al. Mechanical properties of synthetic implants used in the repair of prolapse and urinary incontinence in women: which is the ideal material? Int Urogynecol J Pelvic Floor Dysfunct. 2003;14(3):169–78. Discussion 178.
22. FitzGerald MP, Edwards SR, Fenner D. Medium-term follow-up on use of freeze-dried, irradiated donor fascia for sacrocolpopexy and sling procedures. Int Urogynecol J Pelvic Floor Dysfunct. 2004;15(4):238–42.
23. Jallah Z, et al. The impact of prolapse mesh on vaginal smooth muscle structure and function. BJOG. 2016;123(7):1076–85.
24. Tan-Kim J, et al. A randomized trial of vaginal mesh attachment techniques for minimally invasive sacrocolpopexy. Int Urogynecol J. 2015;26(5):649–56.
25. Linder BJ, et al. Outcomes of robotic sacrocolpopexy using only absorbable suture for mesh fixation. Female Pelvic Med Reconstr Surg. 2017;23(1):13–6.
26. Unger CA, et al. Perioperative adverse events after minimally invasive abdominal sacrocolpopexy. Am J Obstet Gynecol. 2014;211(5):547.e1–8.
27. Mueller MG, Jacobs KM, Mueller ER, Abernethy MG, Kenton KS. Outcomes in 450 women after minimally invasive abdominal sacrocolpopexy for pelvic organ prolapse. Female Pelvic Med Reconstr Surg. 2016;22(4):267–71.
28. FDA. UPDATE on serious complications associated with transvaginal placement of surgical mesh for pelvic organ prolapse: FDA safety communication. 13 July 2011; 2011.
29. FDA. FDA public health notification: serious complications associated with transvaginal placement of surgical mesh in repair of pelvic organ prolapse and stress urinary incontinence. 2008.
30. Nygaard IE, et al. Abdominal sacrocolpopexy: a comprehensive review. Obstet Gynecol. 2004;104(4):805–23.
31. Nygaard I, et al. Long-term outcomes following abdominal sacrocolpopexy for pelvic organ prolapse. JAMA. 2013;309(19):2016–24.

Sentinel Lymph Node Mapping for Uterine and Cervical Cancers

12

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Introduction

Endometrial (uterine) cancer is the most common malignancy of the female genital tract in the United States with an estimated 60,050 new cases and 10,470 deaths in 2016. In contrast, there were 12,990 new cases of invasive cervical cancer and 4120 deaths in 2016 [1]. Worldwide, there were an estimated 320,000 new cases of endometrial cancer and 528,000 cases of cervical cancer in 2012.

Lymph node (LN) metastases are uniformly considered one of the important determinants of prognosis and adjuvant treatment in endometrial and cervical cancers [2, 3]. The incidence of pelvic lymph node metastasis varies from 0 to 28% in stage I cervical cancers and apparent uterine-confined endometrial cancers, with the actual risk related to tumor histopathology including lesion size, depth of invasion, and lymph-vascular space involvement [4, 5]. Traditionally, lymph node metastases are detected by comprehensive pelvic and aortic lymphadenectomy with lymph nodes assessed by hematoxylin and eosin (H&E) stains. However, a clinically significant percentage of node-negative patients suffer from lymphatic recurrence, indicating possible deficiencies in the diagnosis and treatment of lymphatic dissemination. Furthermore, comprehensive lymphadenectomy is associated with an increased incidence of lymphedema, lymphocysts, and neuralgia. Utilizing more sensitive pathological and/or molecular procedures on all resected lymph nodes adds significant cost to treatment, especially given that most lymph nodes are normal. The sentinel lymph node (SLN) biopsy procedure more precisely detects the most likely involved lymph node and provides a limited number of lymph nodes for a more sensitive pathological analysis. The targeted biopsy of sentinel nodes results in less disruption of pelvic lymphatic drainage and less morbidity than comprehensive lymphadenectomy. SLN mapping is also potentially superior to traditional lymphadenectomy because it frequently detects unexpected drainage pathways that are not universally captured by traditional pelvic lymphadenectomy, such as presacral, parametrial, and internal iliac lymph node basins [6].

History

The first description of a sentinel lymph node biopsy was given by Gould in 1960 when he described the location of the most likely involved LN in parotid cancer in proximity to the tumor during en bloc dissection. Two decades later, Cabana described SLN mapping in penis by cannulating the dorsal lymphatics of the penis and performing lymphangiography [7]. Blue dye mapping was introduced by Mortan et al. [8] in cutaneous melanoma in 1992. Pathological ultrastaging of sentinel nodes that uses multiple sections of paraffin-embedded tissue and sensitive cytokeratin stains was first reported in breast cancer by Giuliano and colleagues in 1994 [9].

Lymphatic mapping in gynecologic cancer was first investigated by Levenback et al. in vulvar cancer [10]. Subsequently, Burke pioneered sentinel node detection in endometrial cancer using peri-tumoral injection of the blue dye [11], and Echt et al. [12] performed the first SLN biopsy procedures in cervical cancer. The advantages of sentinel node biopsy are evident in outcomes of many different types of cancers. The NSABP 32 trial in breast distinctly illustrated that the 8-year overall disease survival, disease-free, regional control rates are statistically equivalent in the SLN group and the axillary dissection group in breast cancer. Another randomized multicenter trial in breast also concluded that upper extremity morbidity including swelling, sensory loss, mobility loss, and quality-of-life (QOL) scores after sentinel node biopsy are better with SLN biopsy. Similarly, Phase III study by GOG 173 concluded that SLN biopsy is a reasonable alternative to inguinal-femoral

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lymphadenectomy in selected women with squamous cell cancer (SCC) of vulva (T1–T2 lesions, <4 cm) [13].

Type of Procedures: Open, Laparoscopic, Robotic

Sentinel node mapping is feasible with laparoscopic, robotic-assisted laparoscopy, and open abdominal (laparotomy) approaches. Higher detection rates are observed in minimally invasive laparoscopic-assisted surgeries as compared to open surgery (Tables 12.1 and 12.2). A meta-analysis of 17 studies on SLN biopsy of cervix cancer revealed that the pooled detection rate and sensitivity were superior in the laparoscopy group (96.1% and 89.8% vs. 90.2% and 86.3%, respectively) [14]. A meta-regression analysis of 26 studies on the utilization of SLN biopsy in EC reported no association of sensitivity to approach of procedure [15].

Table 12.1 Characteristics of significant sentinel lymph node mapping studies for patients with endometrial cancer [87–141]

Study author(s)	Year	*N*	Surgical approach	Injection site	Detection technique	Overall detection rate	Bilateral detection rate	Pathological assessments
Burke et al.	1996	15	Open	SM	Blue dye only	67	N/A	H&E
Gargiulo et al.	2003	11	Scopic	C	Tc + blue dye	100	55	H&E/IHC
Pelosi et al.	2003	16	Scopic	C	Tc + blue dye	93	60	H&E/IHC
Fersis et al.	2004	10	Open	HS	Tc	70	20	H&E
Houlb et al.	2004	25	Scopic	SM/C	Blue dye only	84	81	H&E
Lelievre et al.	2004	12	Both	C	Tc + blue dye	92	27	H&E/IHC
Niikura et al.	2004	28	Open	HS	Tc	82	N/A	H&E/IHC
Gien et al.	2005	16	Open	HS	Blue dye only	44	N/A	H&E
Maccauro et al.	2005	26	Open	HS	Tc + dye	100	N/A	H&E/IHC
Altgassen et al.	2007	23	Open	SM	Blue dye only	90	N/A	H&E/IHC
Dealoye et al.	2007	60	Both	HS	Tc + blue dye	82	37	H&E/IHC
Frumovitz et al.	2007	18	Open	SM	Tc + blue dye	45	12	H&E
Li et al.	2007	20	Open	SM	Blue dye only	75	73	H&E
Lopes et al.	2007	40	Open	SM	Blue dye only	78	N/A	H&E/IHC
Ballester et al.	2008	46	Both	C	Tc + blue dye	87	62	H&E/IHC
Bats et al.	2008	43	Both	C	Tc + blue dye	69	53	H&E/IHC
Robova et al.	2009	91	Open	SM/HS	Tc + blue dye	73	N/A	H&E
Vidal-Sicart et al.	2009	35	N/A	N/A	Tc only	62	N/A	N/A
Zenzola et al.	2009	14	Open	C	Tc + blue dye	71	N/A	N/A
Feranec et al.	2010	21	Open	HS	Tc + blue dye	81	N/A	N/A
Mais et al.	2010	34	Both	C	Blue dye only	62	N/A	H&E/IHC
Ballester et al.	2011	125	Both	C	Tc + blue dye	89	69	H&E/IHC
Khoury-Collado et al.	2011	266	Both	C, C/SM	Blue dye only	84	67	H&E/IHC
How et al.	2012	100	Scopic	C	Tc + blue dye	92	72	H&E/IHC
Barlin et al.	2012	498	Both	C	Blue dye only	81	73	H&E/IHC
Holloway et al.	2012	35	Scopic	C	Blue dye + ICG	100	100	H&E/IHC
Vidal et al.	2013	66	N/A	C	Blue dye only	62	56	H&E/IHC
Kim et al.	2013	635	Both	C	Blue dye only	80	62	H&E/IHC
Desai et al.	2014	120	Scopic	C	Blue dye only	86	60	H&E/IHC
Lopez et al.	2014	50	N/A	C	Blue dye only	92	100	H&E/IHC
Raimond et al.	2014	156	N/A	C	Both dye only	87	65	H&E/IHC
Sinno et al.	2014	71	Scopic	C	ICG + blue dye	83	62	H&E/IHC in Grade 3
Jewell et al.	2014	227	Scopic	C	ICG + blue dye	95	79	H&E/IHC
Touhami et al.	2015	268	Scopic	C	Tc + blue dye	94	78	H&E/IHC
How et al.	2015	100	Scopic	C	Blue dye + ICG + Tc99	92	82	H&E/IHC
Naoura et al.	2015	180	N/A	C	Tc + blue dye	88	63	H&E/IHC
Paley et al.	2016	123	Scopic	C	ICG	96	80	H&E/IHC
Holloway et al.	2016	119	Scopic	C	Blue dye + ICG	98	82	H&E/IHC
Papadia et al.	2016	75	Scopic	C	ICG	96	91	H&E/IHC

Abbreviations: *N/A* not available, *SM* subserosal myometrium, *C* cervix, *HS* hysteroscopic, *H&E* hematoxylin and eosin staining, *IHC* immunohistochemistry, *Tc* technicium-99

Table 12.2 Characteristics of sentinel lymph node mapping studies for patients with cervical cancer (selected reports with $n \geq 50$ cases) [87–141]

Study author(s)	Year	*N*	Stage	Surgical approach	Detection technique	Overall detection rate (%)	Bilateral detection rate	Histological analysis
Malur et al.	2001	50	IA1–IIB, IV	Both	Tc + blue dye	78	N/A	H&E
Dargent et al.	2003	70	IA1–IIB	N/A	Tc + blue dye	90	N/A	H&E/IHC
Plante et al.	2003	70	IA1–IIA	Scopic	Tc + blue dye	87	60%	FS/H&E/IHC
Basta et al.	2005	52	IA2–IIB	N/A	Tc + blue dye	96	N/A	IHC
Di Stefano et al.	2005	50	IA2–IIA	Open	Blue dye only	90	54%	FS/H&E/IHC
Rob et al.	2005	183	IA1–IIA	Both	Tc + blue dye	100	54%	FS/H&E/IHC
Silva et al.	2005	56	IA2–IIA	Open	Tc + blue dye	100	N/A	H&E/IHC
Frumovitz et al.	2006	50	IA2–IB1	Open	Tc only	93	38%	H&E/IHC
Marnitz et al.	2006	151	IA1–IV	Both	Tc + blue dye	94	60%	N/A
Wydra et al.	2006	100	IB1–IIA	N/A	Tc + blue dye	84	66%	FS/H&E/IHC
Altgassen et al.	2007	60	IA1–IIB	Open	Blue dye	93	N/A	FS
Coutant et al.	2007	67	IA1–IIB	Scopic	Tc + blue dye	85	39%	H&E/IHC
Daraï et al.	2007	54	IA1–IB1, IIA–IIB	Scopic	Tc + blue dye	83	N/A	H&E/IHC
Lee et al.	2007	57	IB1–IIA	N/A	Tc + blue dye	100	N/A	FS
Seong et al.	2007	89	IA2–IIB	Both	Blue dye	57	N/A	FS/H&E
Yuan et al.	2007	81	IB1–IIA	N/A	Blue dye	83	56%	H&E/IHC
Altgassen et al.	2008	590	IA1–IV	Both	Tc + blue dye	90	36%	H&E
Bats et al.	2008	71	IA2–IIB	Scopic	Tc + blue dye	91	35%	H&E/IHC
Diaz-Feijoo et al.	2008	50	IA2–IIA	Both	Tc + blue dye	100	N/A	H&E/IHC
Rob et al.	2008	40	IA1–IB1	Scopic	N/A	100	90%	FS/H&E/IHC
Strnad et al.	2008	158	IA2–IB1	Both	Tc + blue dye	99	90%	FS/H&E/IHC
Pazin et al.	2009	50	IB1–IIA	N/A	Blue dye	92	38%	N/A
Pluta et al.	2009	60	IA1–IB1	Scopic	Tc + blue dye	100	88%	FS/H&E/IHC
Van de Lande et al.	2009	58	IB1–IIA	Scopic	Tc + blue dye	97	N/A	FS/H&E/IHC
Vieira et al.	2009	56	IA1–IIA	N/A	Tc + blue dye	84	54%	FS/H&E
Yamashita et al.	2009	58	IA1–IIIB	Both	Tc + blue dye	86	N/A	FS/H&E
Darlin et al.	2010	105	IA1–IIA	Both	Tc only	90	59%	FS/H&E/IHC
Ogawa et al.	2010	82	IA1–IIB	N/A	Tc only	88	66%	H&E/IHC
Cormier et al.	2011	122	IA1–IIA	Both	Tc + blue dye	93	75%	H&E/IHC
Diaz et al.	2011	81	IA1–IIB	N/A	Tc + blue dye	95	72%	H&E/IHC
Du et al.	2011	68	IA2–IB1	Open	Tc only	94	41%	FS/H&E/IHC
Kato et al.	2011	50	IA2–IB1	N/A	Tc only	94	72%	FS/H&E/IHC
Roy et al.	2011	211	IA1–IIA	Scopic	Tc + blue dye	99	86%	FS/H&E/IHC
Lecuru et al.	2011	139	IA1–IB1	Scopic	Tc + blue dye	98	75%	H&E/IHC
Devaja et al.	2012	86	IA1–IB1, IIA	Both	Tc + blue dye	98	N/A	H&E/IHC
Klat et al.	2012	204	IA2–IB2	N/A	Tc + blue dye	94	N/A	IHC
Hoogendam et al.	2013	62	IA1–IIA	Scopic	Tc + blue dye	94	87%	N/A
Klapdor et al.	2014	51	IA1–IV	Both	Tc + blue dye	94	80%	FS/H&E
De Frietas et al.	2015	57	IA2–IIA	Open	Tc + blue dye	84.2	58.3%	H&E/IHC

Abbreviations: *N/A* not available, *H&E* hematoxylin and eosin staining, *IHC* immunohistochemistry, *FS* frozen section, *Tc* technicium-99

Injection Sites

The cervix is a midline uterine structure that has bilateral pelvic lymphatic drainage in the pelvis. Lymphatic flow of the uterine corpus is more complex and drains bilateral and bidirectional to both, pelvic nodes through the cervical lymphatics and para-aortic basins through the infundibulopelvic lymphatics. The cervix is now the most commonly injected site for both cervical and endometrial cancers. Injection of dye in the cervix is more easily accessible and gives more reproducible results than other methods such as fundal and hysteroscopic tumor injections. Aortic lymph nodes have been identified as sentinel in approximately 5% of patients; however, the sensitivity for detection of aortic metastasis has not been fully described. The National Comprehensive Cancer Network (NCCN) guidelines recommend cervical injection of the dye or radioactive tracer at either two cardinal points or four cardinal points in the cervix (i.e., 3, 9 o'clock position, or 2, 4, 8, 10, or 3, 6, 9, 12 o'clock positions) for cervix and endometrial cancers [16, 17]. Deeper injections in cervix are considered efficacious for uterine cancer [17]. It was earlier debated that cervical injection might miss some

sentinel node pathways from the uterine cornua to the aortic basin. This appears less concerning as the risk of isolated para-aortic metastases is approximately 1–2% in pelvic node-negative patients. Moreover, corpus injection using transvaginal sonography (TVS) or hysteroscopy has the con of less reproducibility and more variability [18]. Adequacy of injection of the dye or radiotracer in cervix to map the uterus has been confirmed by multiple retrospective studies (Table 12.1). A meta-analysis of 26 studies incorporating 1101 endometrial cancers reported that the use of peri-cervical injection was associated with higher SLN detection rate than other injection sites (coeff 0.15, $p = 0.031$) [15].

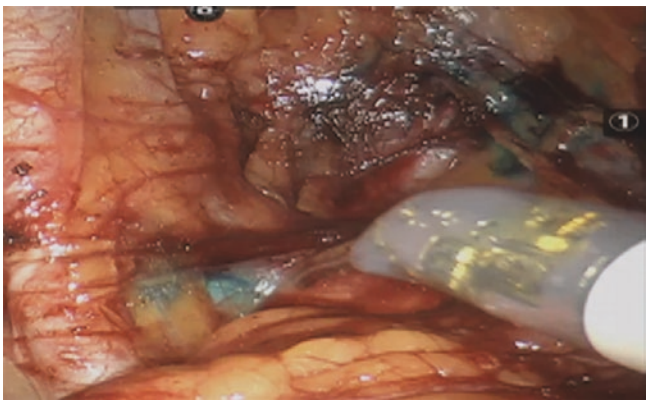

Fig. 12.1 Colorimetric detection of isosulfan blue (ISB) in left parametrial lymphatics leading to left external iliac lymph node

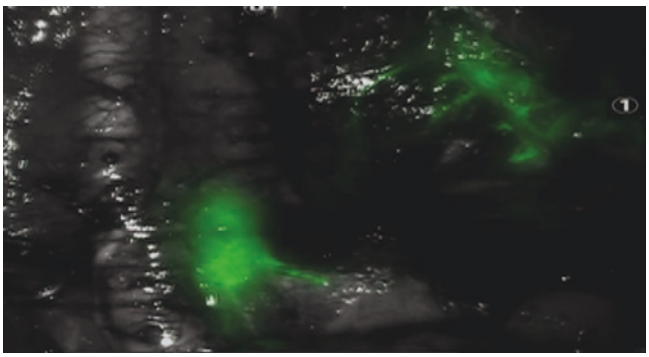

Fig. 12.2 Near-infrared (NIR) imaging of indocyanine green (ICG) in the same patient (as in Fig. 12.3) showing parametrial lymphatics and left external iliac lymph node

Colored Dyes, Radioactive Tracers, Fluorescent Dyes

Traditionally, colored or radiotracer dyes have been used to detect SLN in several different cancers. Methylene blue and isosulfan blue (ISB) dyes are the least expensive techniques because they are visualized in white light and do not require the expense of imaging systems (Fig. 12.1). These dyes are conveniently injected intraoperatively 10–15 min before the SLN dissection. However, blue dyes migrate quickly and should be visualized within 30 min in order to avoid missing the sentinel node. ISB) can cause anaphylactic reactions (1/1000 injections), and methylene blue can cause paradoxical methemoglobinemia leading to a falsely low serum O_2 saturation. Methylene blue is not FDA approved for lymphatic mapping and has been associated with skin necrosis in extremity mapping. The overall detection rate of SLN by blue dye alone in cervical and endometrial cancers is 44–93%, with bilateral detection ranging from 38 to 81% (Tables 12.1 and 12.2).

Tc99 is a radiocolloid that percolates in lymphatics and requires a gamma camera or single-photon emission computerized tomography (SPECT) scan for detection. The SLN detection rate for Tc99 in early-stage cervical cancer is 69–100% [19–22] and as high as 82% in endometrial cancer [23]. Short protocol (day of surgery) uses 0.2–1 mCi of Tc99 and long protocol (24 h before surgery) and uses 2–4 mCi of colloid. A preoperative lymphoscintigram/SPECT scan is taken 30 min after the injection for short protocol that delivers images to the surgeon to locate the nodes. Gamma laparoscopic or handheld cameras are required to help dissect the nodes. In more recent times, Tc 99 has commonly been used with blue dye to improve SLN detection (Tables 12.1 and 12.2).

ICG is a tricarbocyanine dye that fluoresces in the near-infrared (NIR) spectrum when illuminated with 806 nm near infrared light. The fluorescent light is then captured using a special video camera (Fig. 12.2). ICG can cause hypersensitivity in women sensitive to iodine. It was initially used in vascular surgeries; however, now it has been used in a variety of different procedures. It can be used for SLN detection in the setting of open, laparoscopic, or robotic-assisted surgery. ICG was first utilized in breast cancer in 2005 by Kitai et al. [24] and then in melanoma by Fujiwara et al. in 2009 [25]. The combination of blue dye and ICG was described in endometrial cancer with high detection rates by Rossi et al. (88%) and Holloway et al. (100%) in 2012 [26, 27]. Retrospective case series suggest that ICG alone has comparable sensitivity to combination of colorimetric and radiotracer dyes (Tables 12.1 and 12.2). A recent prospective randomized trial showed that ICG plus ISB had an overall and bilateral detection rate of (96 and 84% compared to ISB only 76 and 40%, respectively) [28]. Rocha and colleagues performed a systematic review of ten studies including 422 patients of endometrial and cervical cancers using ICG. The pooled detection rate from cervical injection of ICG ranged from 78 to 100% [29]. Fluorescent dyes are considered superior in detecting SLN in obese women [30]. Manufacturers are now developing advanced molecules of fluorescent dyes and videoscopes to improve the precision in finding the sentinel nodes. Activatable fluorescent probes (smart probes)

are being tested to delineate cancer cells in vivo. Future prospects include detection of tumor margin in cervix and vulva, detection of a metastatic nodes in vivo and precise imaging of metastatic disease [31].

Pathologic Assessment of Sentinel Lymph Nodes

Ultrastaging was first reported by Giuliano and colleagues in 1995, when they described the upstaging potential of enhanced histopathological analysis of SLN in breast cancer using multilevel sectioning and cytokeratin stains [32]. Ultrastaging is a more meticulous histologic examination of the SLNs involving multilevel H&E assessment and use of immunohistochemistry stains. The number of step sections, the depth of micro-sectioning the tissue block, the interval between sections, and the number of slides used for IHC are all variables that can influence the sensitivity of determining ITC/micro-metastases (Fig. 12.3).

As per the 7th edition American Joint Committee on Cancer (AJCC) and the 7th edition Union for International Cancer Control (UICC) guidelines, macro-metastases is defined as groups of malignant cells >2 mm, and micro-metastases is defined as <0.2 mm and/or 200 cells but greater than 2 mm. Isolated tumor cells (ITC) are single tumor cells or small clusters of cells not more than 0.2 mm that can be detected by routine H&E stains or IHC [33]. An additional criterion for ITC) is fewer than 200 cells in a single histological cross section. ITC do not typically show evidence of metastatic activity (e.g., proliferation of stromal reaction) or penetration of vascular or lymphatic sinus wall, and so cases with ITC)in LN or at distant sites are classified as N0 or M0, respectively. All sentinel nodes are recommended to be serially sectioned at 2 mm intervals perpendicular to the long axis and entirely submitted for routine processing and H&E staining.

A randomized controlled study by Weaver et al. [34] in 5611 clinically negative node patients with breast cancer concluded that the clinical benefit of additional evaluation, including IHC analysis of initially H&E-negative sentinel

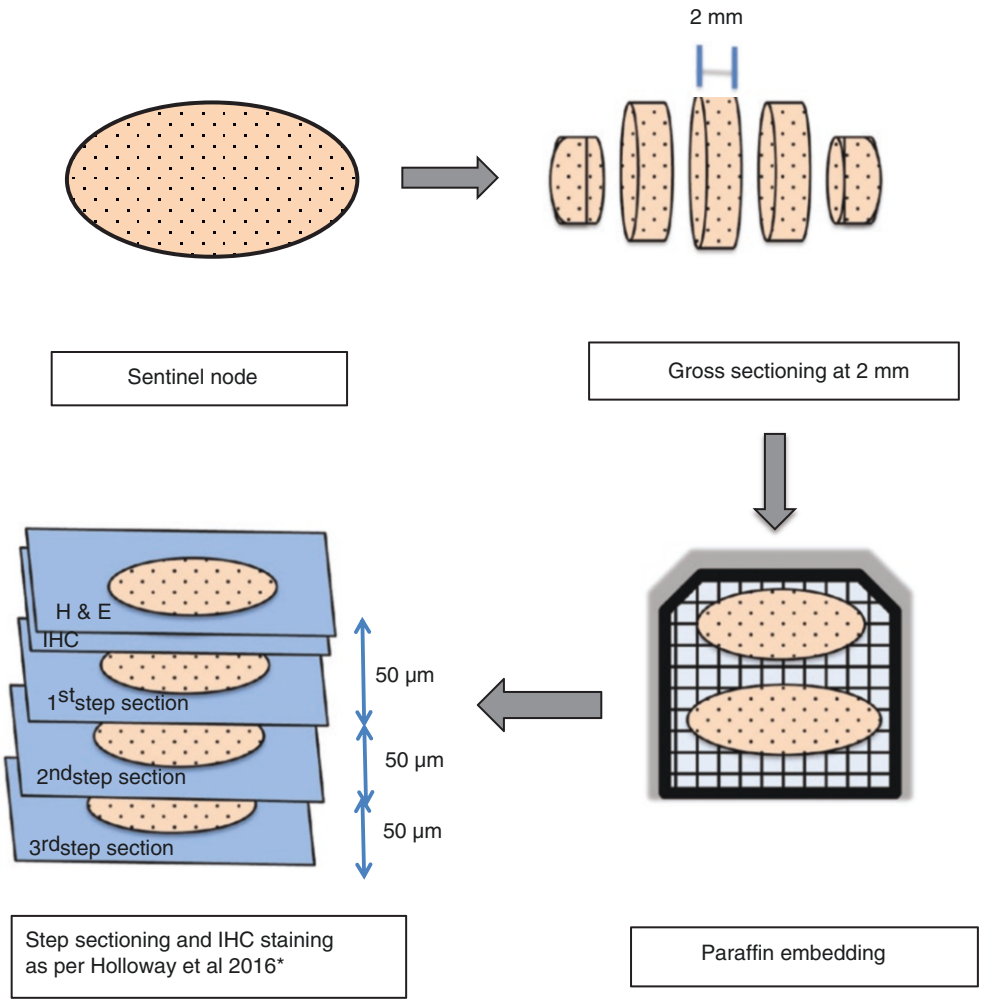

Fig. 12.3 Diagrammatic representation of ultrastaging [39]. The number of sections per block varies in publications from three to six step sections, 40–200 µm apart along with varying number IHC slides [26, 38, 40–43]

nodes in patients with breast cancer is minimal [34]. Thus, the current breast guidelines by the AJCC, the College of American Pathologists (CAP), and the NCCN does not recommend the routine use of step-level sections beyond 2 mm and cytokeratin (CK)-IHC in the evaluation of SLNs [33, 35]. The clinical significance of limited number of micro-metastases or any number of ITC is less valuable in breast cancer patients who receive systemic therapy (hormonal therapy and/or chemotherapy) and whole breast irradiation based on clinical and pathologic features irrespective of occult metastases. In contrast, the impact of more sensitive lymph node assessment to tailor adjuvant therapy in endometrial and cervix cancer cannot be underestimated. Indiscriminant radiation to all early-stage cancer patients undergoing sentinel node biopsy would potentially be as toxic as traditional lymphadenectomy.

There are no standard micro-sectioning/IHC recommendations, either for endometrial or for cervical cancers. The Memorial Sloan Kettering Cancer Center (MSKCC) ultrastaging protocol executes sectioning the H&E-negative blocks into two sections 50 μm apart and examining two slides for H&E and two slides for anti-pan cytokeratin antibody (AE1/AE3) with an additional H&E slide [36, 37]. The number of sections per block varies in published literature, from three to six step sections, 40–200 μm apart. The number IHC stained slides also vary from one to four [26, 38–43]. Another ultra-sectioning approach described is serial sectioning the complete node at regular intervals of ≤250 μm [44–47].

The optimal ultrastaging proposal for endometrial and cervical cancers is unclear. Theoretically, serial sectioning at every 2 mm should ideally detect all macro-metastases in that node, and serial micro-sectioning at every 200 μm should detect all micro-metastases. The lower dimension of ITC is zero, and therefore, no healthcare system can afford the cost of looking all the ITC by micro-sectioning. Detection of ITC by) IHC can result in clinically false-positive results because IHC might identify benign glandular inclusions with no mitotic potential. Thus, defining the size range of the metastases by prognostic significance instead of arbitrary numbers is the first step to define optimal ultrastaging protocol in the near future. Like any other diagnostic test, ultrastaging should be validated in terms of cost-effectiveness of additional numbers of microscopic slides inspected and IHC stained to prevent one recurrence.

Significance of Low-Volume Metastases

The term low-volume metastasis refers to micro-metastasis and ITC. Several studies have highlighted the significance of low-volume metastases in SLN and the relationship to non-SLN involvement. Touhami and colleagues studied a cohort of 268 endometrial cancer patients and reported that patients with SLN micro-metastases have a 5% risk of having another positive non-SLN [43]. In a prospective study, Holloway et al. [39] studied the association of non-SLN metastases with the size of SLN metastases in a study cohort of 119 endometrial cancer patients mapped with SLN biopsy. The authors observed that non-SLN metastases was detected in 33% of the cases with sentinel node ITC, 60% of the cases with sentinel node micro-metastases, and 50% cases with sentinel node macro-metastases ($p > 0.05$). SLNs may not reflect the largest volume of metastatic disease, because approximately 5% of patients with micro-metastatic volume in the SLNs have been reported to be associated with macro-metastatic disease in non-SLNs [48].

Few studies have outlined the oncological value of low-volume metastases in cervix and endometrial cancer. In a large study group of 894 stage IB–IIB cervical cancer patients, Horn et al. concluded that 5-year RFS and OS were significantly lower in patients with micro-metastases compared to node-negative patients [49]. Cibula et al. [44, 45] evaluated 645 stage IA–IIB cervical cancer patients who underwent sentinel lymph node biopsy followed by pelvic lymphadenectomy. Sentinel lymph nodes that were negative for metastasis on the initial H&E screen were further subjected to the pathologic ultrastaging protocol at eight different centers. The authors reported that the presence of micro-metastasis in SLN was associated with significant reduction of overall survival, which was equivalent to patients with macro-metastasis. No prognostic significance of ITC was observed [44, 45].

In endometrial cancer, Erkanli et al. [50] evaluated 47 patients who were considered node-negative by H&E screening. The investigators detected seven additional micro-metastases using IHC; 87.5% of women with micro-metastases had high-risk uterine histology. The 3-year recurrence-free survival was 100% in patients without micro-metastases and 71% in patients with micro-metastases ($p = 0.0004$). In a similar study, Todo et al. [51] retrospectively reviewed paraffin-embedded blocks of 61 H&E node-negative patients with intermediate-risk uterine histology. The authors observed that the presence of ITC and micro-metastases was an independent risk factor for extra-pelvic recurrence (hazard ratio, 17.9; 95% confidence interval [CI], 1.4–232.2). The 8-year OS and RFS were 71 and 55.6% in ITC/MM group compared to 92 and 84% in the node-negative group, respectively ($p > 0.05$). Additionally, recurrence of disease was higher in the patients with ITC or micro-metastases who did not receive adjuvant chemotherapy (100% vs. 28.6%, respectively, $p = 0.17$). However, given the small sample size, these results were not statistically significant. Of note, ITC/micro-metastases status is highly associated with high-risk uterine factors in endometrial cancer [36, 37, 50, 51]. The independent clinical significance of ITC and micro-metastases in women with high-risk

factors is still unknown. At this time, there are no treatment guidelines with respect to isolated tumor cells or micrometastases, and decisions about adjuvant therapy should be made in concert with known histopathologic risk factors. The independent prognostic significance of ITC and micrometastasis should be further evaluated in prospective registration trials.

Surgical Algorithm

The goal of using sentinel node mapping in uterine cancer is to detect lymph node metastases with amplified sensitivity and negative predictive value (NPV) yet avoid the morbidities of comprehensive staging lymphadenectomy procedures. Retrospective studies have documented that unilateral pelvic SLN status on one side of the pelvis does not predict the presence or absence of metastasis on the contralateral side. Sometimes, unusual topography of cervical drainage might also deliver false-negative results. Parametrial lymph nodes are reported to be sentinel nodes in 3–15% of cervical cancer patients [6, 52]. Isolating these parametrial sentinel nodes can be challenging because of the diffuse staining and/or gamma ray noise of the parametrium with the colored dye or the radiotracer dye through cervical injection. False-negative SLN mapping in patients with positive parametrial node associated with cervical cancer can be averted by en bloc parametrectomy during radical hysterectomy [45, 53].

A surgical algorithm for cervix cancer was developed by Cormier et al. [52] and retrospectively applied to 122 cervical cancer patients (FIGO stages IA1 to IIA) patients who underwent SLN procedure followed by a complete bilateral pelvic lymphadenectomy. The algorithm incorporates complete side-specific lymphadenectomy including inter-iliac or subaortic nodes on the unmapped side of hemipelvis as well as removal of any suspicious nodes and en bloc parametrectomy with the resection of the cervix (Fig. 12.4). It was suggested that the algorithm would improve sensitivity and NPV while lowering the false-negative rate (FNR) [52]. The best reported bilateral detection rate of cervical cancer in literature is approximately 80% and hence 20% women with early-stage cervical cancer would undergo at least side-specific lymphadenectomy following Cormier's surgical algorithm. Most recently, Fagotti et al. [54] proposed a modification of the surgical algorithm after studying 333 patients with early-stage cervical cancer. The authors described a group of patient with very low risk for nodal metastases characterized by squamous and adenosquamous histology, tumor diameter of <2 cm, and negative nodes on MRI, none of the patient within this group had lymph node involvement. This group can omit side-specific lymphadenectomy even when the SLN is not detected on that hemipelvis [54].

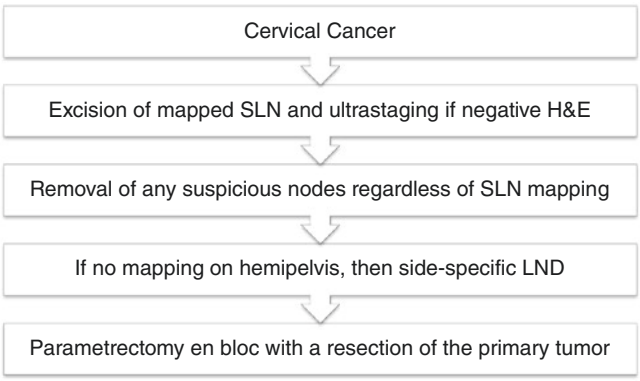

Fig. 12.4 Cervical cancer surgical SLN mapping algorithm. Modified from Cormier et al. [52]. *Abbreviations*: *SLN* sentinel lymph node, *H&E* hematoxylin and eosin, *LND* lymphadenectomy

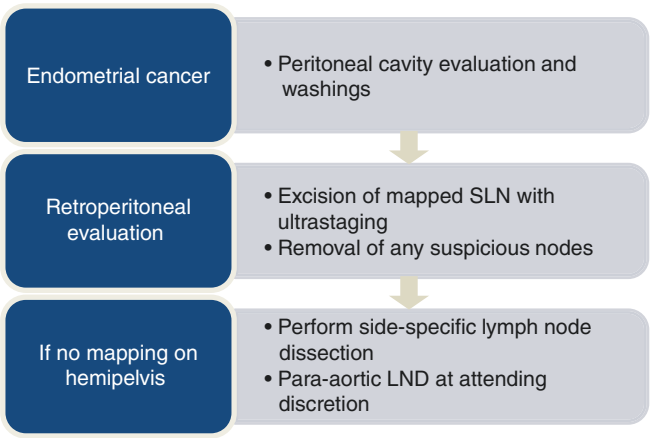

Fig. 12.5 Endometrial cancer surgical staging algorithm. Modified from Barlin et al. [55]. *Abbreviations*: *SLN* sentinel lymph node, *H&E* hematoxylin and eosin, *LND* lymphadenectomy

Correspondingly, Barlin et al. [55] retrospectively applied a similar surgical algorithm that incorporates side-specific lymphadenectomy, as well as removal of any suspicious nodes and peritoneal lesions in a study cohort of 498 endometrial cancer patients undergoing SLN mapping. The proposed endometrial surgical algorithm was estimated to reduce the FNR from 14.9 to 1.9%. The NCCN guidelines recommend utilization of this surgical algorithm for successful utilization of SLN mapping [17, 55] (Fig. 12.5). Cormier and colleagues subsequently analyzed the efficacy of the NCCN surgical algorithm in endometrial cancer on 1385 patients from a historical database [56]. They observed that 37 out of 190 node-positive patients had false-negative SLN. Retrospectively applying the [55] surgical algorithm dropped the FNR from 19 to 5% [56]. Sinno et al. [57] have proposed a hypothetical algorithm called the restricted frozen section algorithm that would apparently reduce lymphadenectomy rates as compared to the NCCN surgical algorithm. Retrospective application of their algorithm to

114 patients with apparent uterine-confined, grade 1/2 endometrial cancer and complex atypical hyperplasia reduced the pelvic lymphadenectomy rates to 9.2% in the restricted frozen section algorithm as compared to 36.8% in the standard surgical algorithm. In this proposed algorithm, ipsilateral pelvic and para-aortic lymphadenectomy is performed only if high-risk uterine features are identified in women who have unilateral or bilateral failed mapping.

Sentinel Lymph Node Mapping in Cervix Cancer

Use of SLN mapping algorithm in select stage I patients with tumor <4 cm is a NCCN category 2A recommendation since 2014. Bilateral pelvic lymphadenectomy could be avoided in approximately 75% of early cervix cancer patients by following the proposed surgical algorithm for cervix cancer [52]. A recent meta-analysis of diagnostic accuracy of SLN (18 studies; 1275 patients) reported that patients who have FIGO IA2, IB1, and IIA primary tumor size <4 cm, with clinically non-suspicious lymph nodes, have a minimal risk of 0.08% (1/1257) of undiagnosed pelvic metastases after sentinel node mapping. Thus, suggesting that these patients can be safely managed by SLN biopsies alone [58].

Various trials report high detection rates and sensitivity for detection of metastases in cervical cancer. The multi-institution trial from the Arbeitsgemeinschaft Gyn€ökologische Onkologie (AGO) Study Group evaluated 507 women with cervical cancer of all stages and reported an overall sensitivity of 77.4% [59]. The reason for such a low overall sensitivity in this trial was the lack of ultrastaging and >20% women with bulky cervix tumors. Ultrastaging is considered an essential part of SLN mapping because micrometastases is associated with non-sentinel node metastases and restricting ultrastaging might increase the FNR [60, 61]. The multi-institutional SENTICOL (Ganglion Sentinelle dans le Cancerdu Col) study performed SLN biopsy followed by completion pelvic lymphadenectomy and reported a 97.8% detection rate, 92% sensitivity for metastases, and 2.8% false-negative rate that lowered to 1.3% with successful bilateral mapping. These observations have led to the current surgical algorithm by Cormier [62]. In another sub-study of the same cohort, the authors found that 38.2% of 139 cervical cancer patients had at least one SLN in an unexpected area and 5.1% had SLNs only in unexpected areas [6]. These unexpected lymph node basins are in anatomical locations not typically dissected using traditional lymphadenectomy protocols.

Large tumor size and lymph-vascular space invasion (LVSI) have been reported to negatively affect SLN mapping success in cervical cancer [63, 64]. The NCCN guideline states that the technique can be used in tumor diameters up to 4 cm but gives best detection rates and mapping results in tumor size ≤2 cm. Conization is not considered a contraindication for SLN mapping. The feasibility of SLN mapping after conization was reported by Kato et al. [65] who compared 18 stage IB1 cases with prior conization to 32 stage IB1 cases without conization. No significant differences were observed with the SLN detection rate, negative predictive value, and the distribution of sentinel nodes between the conization and non-conization groups [65, 66]. Previously, a few small retrospective subset studies reported poor detection rates post-conization [19, 21, 67]. However, in a recent meta-analysis of 67 SLN mapping studies in cervical cancer, pooled detection rate of 91% in post-conization patients was reported [68].

In many centers, radical surgery and lymphadenectomy are performed following neoadjuvant chemotherapy (NAC) for locally advanced cervical cancer. No negative impact of NAC has been observed on the detection of SLN biopsy in cervical cancer. Slama et al. [69] studied 82 patients with locally advanced cervical cancers (FIGO IB1 >3cm, IB2, IIA2, and selected IIB), out of which 51 patients had SLN biopsy prior to NAC and 31 patients underwent radical surgical procedure including SLN biopsy after three courses of "dose density" NAC. There was insignificant difference in the detection rate per patient when comparing SLN group and NAC-SLN group (88.2% vs. 87.1%) and in the bilateral detection rate (62.7% vs. 58.1%) [69]. Similarly, high overall detection rate of 92.3% and bilateral detection rate of 91.7% was demonstrated in another cohort of 26 patients with stage IB2 tumors after the NAC [70]. The SLN biopsy is also being applied in early-stage cervical cancer women undergoing fertility sparing simple or radical trachelectomy [71].

The learning curve effect is an important factor in the success of SLN mapping in both cervical and endometrial cancers. Plante et al. [72] and Seong et al. [66] have demonstrated that the detection rate improves significantly with experience. A similar study in endometrial cancer suggested that more than 30 cases are needed to significantly improve the detection rates from 77 to 94% [73].

The sensitivity of intraoperative frozen section on sentinel nodes varies greatly from 33 to 100% in different cervix cancer studies [69]. Bats et al. [74] analyzed SENTICOL cohorts and observed a poor diagnostic value of frozen section on sentinel lymph nodes with a sensitivity of 20.7% only. The OSNA (one-step nucleic assay amplification) assay detecting CK19 mRNA is a rapid intraoperative assay that has provided results equivalent to those with the 2 mm interval H&E pathology in preliminary reports [75]. Hopefully, intraoperative molecular detection techniques might improve the diagnostic accuracy of frozen section in the near future. Quantitative reverse transcriptase-polymerase chain reaction (qRT-PCR) methods are new advances in the SLN ultrastaging. They are highly sensitive, require

relatively less time to perform, and are cost-effective as compared to extensive ultrastaging processes. Durst et al. [76] described the prognostic significance of using HPV mRNA as a molecular marker for sentinel node involvement and revealed that in the cox regression analysis the hazard ratio (95% CI) for disease recurrence was 3.8 (1.5–9.3, p = 0.004) for HPV-mRNA-positive compared to HPV-mRNA-negative patients [76].

Sentinel Lymph Node Mapping in Endometrial Cancer

Sentinel lymph node mapping is a category 3 recommendation for apparent uterus-confined endometrial cancer and has been described in the NCCN guideline since 2014. The SLN algorithm clearly is appropriate for patients with low-risk histology and has been shown to increase the detection of low-volume metastasis, significantly altering therapy [39]. Morbidity including lower extremity lymphedema can be avoided in low-risk populations who stand little to benefit from comprehensive lymphadenectomy (Fig. 12.6). The guidelines still caution that the safety and efficacy of SLN biopsy procedure on high-risk histology populations has not been as thoroughly evaluated as low-risk histology, and careful attention to peritoneal findings and removal of any suspicious lymph nodes is mandatory. A completion lymphadenectomy should be considered even in cases with successful mapping until more trial data with long-term outcomes are available. The SLN biopsy is also not recommended for uterine sarcoma in the guidelines [17].

Diagnostic and prognostic roles of lymph node involvement in the management of endometrial cancer are not uniformly accepted. Proponents of lymphadenectomy condemn the results of two randomized clinical trials that refuted the survival advantages of systematic lymphadenectomy [77, 78]. There are multiple shortcomings of these studies, and several retrospective studies have suggested a therapeutic benefit associated with lymphadenectomy in intermediate- and high-risk uterus-confined endometrial cancer [79]. Nevertheless, it seems logical and consistent with decades of surgical and oncologic experience to remove macrometastatic lymph node disease from the pelvic and paraaortic basins in order to improve the efficacy of adjuvant treatment in high-risk endometrial cancer [80]. At a minimum, the SLN technique allows gathering pathologic staging information that will alter adjuvant therapy and minimize the risk for morbidity compared to traditional lymphadenectomy.

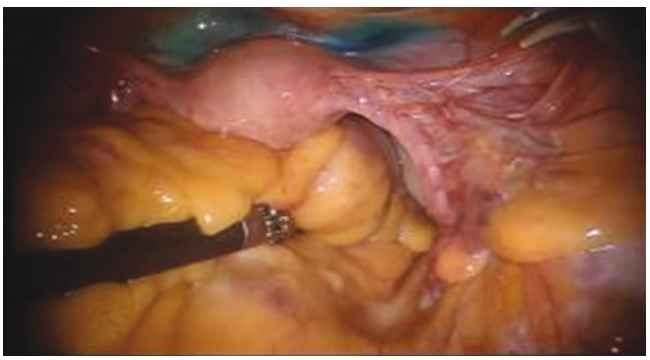

Fig. 12.6 Video demonstration of sentinel lymph node mapping in endometrial cancer. To view, please click on the link: https://www.youtube.com/watch?v=tURBei-qPeA&feature=em-share_video_user

Some investigators have reported lower SLN detection rates and high false-negative rate with high-risk histology cohorts. However, the overall detection rate and a bilateral detection rate in a high-risk case series of 36 patients with grade 3 endometrioid, clear cell, serous, or carcinosarcoma was 83 and 56%, respectively, not dissimilar to other series in the literature with low-risk or mixed populations [81]. In a study of 156 low/intermediate European Society of Medical Oncology (ESMO) and 24 high-risk patients, [82] demonstrated that the SLN detection rate and bilateral detection were comparable in both the low/intermediate and high-risk groups. However, the FNR for patients with high-risk endometrial cancer was greater than low/intermediate group (6% vs. 20%, p = 0.0008). Notably, the FNR in high-risk group decreased from 20 to 9% when the surgical algorithm was applied [82]. Ballester et al. [83] also reported a higher FNR of 18% in patients with type II histology compared to none in type I histology. This is possibly a result of probability, given the higher number of events (metastases) present in patients with high-risk histologies and underpowered studies for comparison. However, these results have called into question the reliability of the SLN procedure in high-risk histology patients, and completion lymphadenectomies should be considered for patients with high-risk histologies until more data with clinical outcomes accrue. Hopefully, prospective trials will further clarify the role of SLN mapping in high-risk histology.

Other than histology of tumor, factors influencing the rate of successful SLN mapping can be the type and number of dyes used, site of injection, operator experience, type of abdominal access, time after the injection of dye, patients' BMI, site of tumor, LVSI of tumor, and the use of radiation in the field. Tanner et al. [84] evaluated 20 factors for an association with the successful bilateral SLN mapping including the patient factors, inflammatory/lymphatic factors, tumor factors, and surgeon factors. The study concluded that the blue dye, high BMI >30, and clinically enlarged lymph nodes are adverse factors influencing success of SLN mapping [84]. In a similar study, Eriksson et al. [30] reported that the success of LN mapping decreased with obesity, irrespective of the dye used. However, SLN

mapping was significantly improved with the use of ICG and NIR fluorescence imaging compared with the blue dye irrespective of BMI.

Attention to details included in the NCCN SLN algorithm [17] cannot be emphasized enough in order to assure accurate surgical staging. It is recommended that surgeon perform standard lymphadenectomy with at least the initial 20 SLN biopsy procedures to demonstrate satisfactory SLN detection rate. The false-negative rate should be continuously assessed, recognizing that in low-risk populations with few metastases, many more cases than the initial 20 will be required for assurance of a low false-negative rate <5%. Complete evaluation of the peritoneal cavity is recommended to perform SLN biopsy procedures only in patients with uterus-confined endometrial cancer. The mapped lymphatic pathways that emanate from the parametria should be identified, followed by the excision of the most proximal lymph nodes in the pathway. Many secondary and tertiary lymph nodes beyond the sentinel will take up dye, and they should not be considered "sentinel." As suggested by Barlin et al. [55], SLN algorithm, removal of suspicious lymph nodes, and side-specific lymphadenectomy for unmapped hemipelvis are of utmost importance to reduce the false-negative rate.

There is paucity of literature on the recurrence and survival data of women who are staged by SLN protocol. Most SLN studies are retrospective and compare clinic-pathologic outcomes from patients who underwent comprehensive lymphadenectomy to those who underwent the SLN protocol followed by "add-on" pelvic lymphadenectomy. Randomized controlled trials are desirable to accurately quantify the recurrence and survival statistics between the SLN biopsy protocols and standard lymphadenectomy groups, however, unlikely to be accomplished. Raimond et al. [85] studied the effect of SLN biopsy protocol with pelvic lymphadenectomy on the adjuvant therapy and compared the oncological outcomes with women who underwent comprehensive lymphadenectomy only. The SLN procedure significantly changed the type of adjuvant therapy administered compared with the women who had lymphadenectomy or no staging ($p < 0.001$). However, the addition of SLN procedure did not improve the RFS (HR = 0.89, 95% CI 0.42–1.90; $p = 0.77$) [85]. Eriksson et al. [30] performed a multi-institutional study to demonstrate the impact of SLN protocol on the survival rates in women with superficial myo-invasion. They compared survival rate, overall survival, and disease-specific survival rate by SLN approach ($n = 642$) with selective lymphadenectomy approach and intraoperative histology by frozen section. Overall survival and 3-year overall survival was not significantly different between the two cohorts [30]. Also, Schiavone et al. [86] compared the oncological outcomes of 136 patients with carcinosarcoma undergoing SLN mapping ($n = 48$) versus routine lymphadenectomy ($n = 88$). The authors counted all the macro-metastases/micro-metastases and ITC (H&E or IHC) as positive; however, the rate of lymph node metastases in the SLN group and lymphadenectomy group were similar. Consequently, there was insignificant difference in the type of adjuvant therapy received and PFS between the two groups [86]. Because of the frequent use of adjuvant therapies in patients with high-risk histologies, the value of the SLN algorithm may be in the avoidance of morbidity rather than improvements in survival from identifying more low-volume metastases. Future evidence for the benefits of SLN mapping in patients with low- and high-risk histology will likely come from prospective multi-institutional registry data with follow-up for recurrence and survival data.

Conclusions/Personal Views

Sentinel node biopsy is a feasible and reliable strategy to determine lymph node status in apparent early-stage endometrial and cervical cancers. This technique opens the door to an improved surgical standard of care that is more precise and less morbid than traditional comprehensive pelvic and aortic lymphadenectomy. Evidence suggests that the best candidates for SLN biopsy includes patients with stage IA1 with LVSI (-) IB1 (≤2 cm) cervical cancer and apparent uterus confined endometrial cancer. Patient selection, surgeon experience, and following details of the surgical algorithm all appear to be key to achieve optimal results with high sensitivity for detection of the disease and a low false-negative rate. Although initial studies report non-inferior recurrence and survival rates with sentinel lymph node biopsy, further quality studies are desirable to better access the impact of SLN biopsy on the long-term survival, quality of life, and cost-effectiveness of SLN procedure in cervical and endometrial cancers.

References

1. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2016. CA Cancer J Clin. 2016;66:7–30.
2. Creasman WT, Morrow CP, Bundy BN, Homesley HD, Graham JE, Heller PB. Surgical pathologic spread patterns of endometrial cancer. A gynecologic oncology group study. Cancer. 1987;60(8 Suppl):2035–41.
3. Fuller AF Jr, Elliott N, Kosloff C, Hoskins WJ, Lewis JL Jr. Determinants of increased risk for recurrence in patients undergoing radical hysterectomy for stage IB and IIA carcinoma of the cervix. Gynecol Oncol. 1989;33:34–9.
4. Creasman WT, Zaino RJ, Major FJ, DiSaia PJ, Hatch KD, Homesley HD. Early invasive carcinoma of the cervix (3 to 5 mm invasion): risk factors and prognosis—a gynecologic oncology group study. Am J Obstet Gynecol. 1998;178:62–5.
5. Delgado G, Bundy BN, Fowler WC Jr, Stehman FB, Sevin B, Creasman WT, et al. A prospective surgical pathological study of

stage I squamous carcinoma of the cervix: a gynecologic oncology group study. Gynecol Oncol. 1989;35:314–20.
6. Bats AS, Mathevet P, Buenerd A, Orliaguet I, Mery E, Zerdoud S, et al. The sentinel node technique detects unexpected drainage pathways and allows nodal ultrastaging in early cervical cancer: insights from the multicenter prospective SENTICOL study. Ann Surg Oncol. 2013;20:413–22.
7. Cabanas RM. An approach for the treatment of penile carcinoma. Cancer. 1977;39:456–66.
8. Morton DL, Wen DR, Wong JH, Economou JS, Cagle LA, Storm FK, et al. Technical details of intraoperative lymphatic mapping for early stage melanoma. Arch Surg. 1992;127:392–9.
9. Giuliano AE, Kirgan DM, Guenther JM, Morton DL. Lymphatic mapping and sentinel lymphadenectomy for breast cancer. Ann Surg. 1994;220:391–8.
10. Levenback C, Burke TW, Gershenson DM, Morris M, Malpica A, Ross MI. Intraoperative lymphatic mapping for vulvar cancer. Obstet Gynecol. 1994;84:163–7.
11. Burke TW, Levenback C, Tornos C, Morris M, Wharton JT, Gershenson DM. Intraabdominal lymphatic mapping to direct selective pelvic and paraaortic lymphadenectomy in women with high-risk endometrial cancer: results of a pilot study. Gynecol Oncol. 1996;62:169–73.
12. Echt ML, Finan MA, Hoffman MS, Kline RC, Roberts WS, Fiorica JV. Detection of sentinel lymph nodes with lymphazurin in cervical, uterine, and vulvar malignancies. South Med J. 1999;92:204–8.
13. Levenback CF, Ali S, Coleman RL, Gold MA, Fowler JM, Judson PL, et al. Lymphatic mapping and sentinel lymph node biopsy in women with squamous cell carcinoma of the vulva: a gynecologic oncology group study. J Clin Oncol. 2012;30:3786–91.
14. Wu Y, Li Z, Wu H, Yu J. Sentinel lymph node biopsy in cervical cancer: a meta-analysis. Mol Clin Oncol. 2013;1:1025–30.
15. Kang S, Yoo HJ, Hwang JH, Lim MC, Seo SS, Park SY. Sentinel lymph node biopsy in endometrial cancer: meta-analysis of 26 studies. Gynecol Oncol. 2011;123:522–7.
16. Koh WJ, Greer BE, Abu-Rustum NR, Apte SM, Campos SM, Cho KR, et al. Cervical cancer, version 2.2015. J Natl Compr Cancer Netw. 2015;13:395–404.
17. Koh WJ, Greer BE, Abu-Rustum NR, Apte SM, Campos SM, Cho KR, et al. Uterine sarcoma, version 1.2016: featured updates to the NCCN guidelines. J Natl Compr Cancer Netw. 2015;13:1321–31.
18. Niikura H, Kaiho-Sakuma M, Tokunaga H, Toyoshima M, Utsunomiya H, Nagase S, et al. Tracer injection sites and combinations for sentinel lymph node detection in patients with endometrial cancer. Gynecol Oncol. 2013;131:299–303.
19. Dargent D, Martin X, Mathevet P. Laparoscopic assessment of the sentinel lymph node in early stage cervical cancer. Gynecol Oncol. 2000;79:411–5.
20. Silva LB, Silva-Filho AL, Traiman P, Triginelli SA, de Lima CF, Siqueira CF, et al. Sentinel node detection in cervical cancer with (99m)Tc-phytate. Gynecol Oncol. 2005;97:588–95.
21. van Dam PA, Hauspy J, Vanderheyden T, Sonnemans H, Spaepen A, Eggenstein G, et al. Intraoperative sentinel node identification with Technetium-99m-labeled nanocolloid in patients with cancer of the uterine cervix: a feasibility study. Int J Gynecol Cancer. 2003;13:182–6.
22. van de Lande J, Torrenga B, Raijmakers PG, Hoekstra OS, van Baal MW, Brölmann HA, et al. Sentinel lymph node detection in early stage uterine cervix carcinoma: a systematic review. Gynecol Oncol. 2007;106:604–13.
23. Niikura H, Okamura C, Utsunomiya H, Yoshinaga K, Akahira J, Ito K, Yaegashi N. Sentinel lymph node detection in patients with endometrial cancer. Gynecol Oncol. 2004;92:669–74.
24. Kitai T, Inomoto T, Miwa M, Shikayama T. Florescence navigation with indocyanine green for detecting sentinel lymph nodes in breast cancer. Breast Cancer. 2005;12:211–5.
25. Fujiwara M, Mizukami T, Suzuki A, Fukamizu H. Sentinel lymph node detection in skin cancer patients using real time fluorescence navigation with indocyanine green: preliminary experience. J Plast Reconstr Aesthet Surg. 2009;62:e373–8.
26. Holloway RW, Bravo RA, Rakowski JA, James JA, Jeppson CN, Ingersoll SB, Ahmad S. Detection of sentinel lymph nodes in patients with endometrial cancer undergoing robotic-assisted staging: a comparison of colorimetric and fluorescence imaging. Gynecol Oncol. 2012;126:25–9.
27. Rossi E, Ivanova A, Boggess J. Robotically assisted fluorescence guided lymph node mapping with ICG for gynecologic malignancies: a feasibility study. Gynecol Oncol. 2012;124:78–82.
28. Holloway RW, Ahmad S, Kendrick JE, Bigsby GE, Brudie LA, Ghurani GB, et al. A prospective randomized trial comparing colorimetric and fluorescent imaging for pelvic sentinel lymph node mapping in endometrial cancer. Gynecol Oncol. 2016;141(Suppl. 1):LBA-2.
29. Rocha A, Domínguez AM, Lécuru F, Bourdel N. Indocyanine green and infrared fluorescence in detection of sentinel lymph nodes in endometrial and cervical cancer staging: a systematic review. Eur J Obstet Gynecol Reprod Biol. 2016;206:213–9.
30. Eriksson AG, Montovano M, Beavis A, Soslow RA, Zhou Q, Abu-Rustum NR, et al. Impact of obesity on sentinel lymph node mapping in patients with newly diagnosed uterine cancer undergoing robotic surgery. Ann Surg Oncol. 2016;23:2522–8.
31. Yoo JS, Lee SC, Jow ZY, et al. A macrophage-specific fluorescent probe for intraoperative lymph node staging. Cancer Res. 2014;74:44–55.
32. Giuliano AE, Dale PS, Turner RR, Morton DL, Evans SW, Krasne DL. Improved axillary staging of breast cancer with sentinel lymphadenectomy. Ann Surg. 1995;222:394–9. Discussion 399–401.
33. AJCC. Cancer staging manual. 7th ed. New York: Springer; 2010. p. 347–76.
34. Weaver DL, Ashikaga T, Krag DN, Skelly JM, Anderson SJ, Harlow SP, et al. Effect of occult metastases on survival in node-negative breast cancer. N Engl J Med. 2011;364:412–21.
35. Gradishar WJ, Anderson BO, Balassanian R, Blair SL, Burstein HJ, Cyr A, et al. Breast cancer version 2.2015. J Natl Compr Cancer Netw. 2015;13:448–75.
36. Kim CH, Khoury-Collado F, Barber EL, Soslow RA, Makker V, Leitao MM Jr, et al. Sentinel lymph node mapping with pathologic ultrastaging: a valuable tool for assessing nodal metastasis in low-grade endometrial cancer with superficial myoinvasion. Gynecol Oncol. 2013;131:714–9.
37. Kim CH, Soslow RA, Park KJ, Barber EL, Khoury-Collado F, Barlin JN, et al. Pathologic ultrastaging improves micrometastasis detection in sentinel lymph nodes during endometrial cancer staging. Int J Gynecol Cancer. 2013;23:964–70.
38. Euscher ED, Malpica A, Atkinson EN, Levenback CF, Frumovitz M, Deavers MT. Ultrastaging improves detection of metastases in sentinel lymph nodes of uterine cervix squamous cell carcinoma. Am J Surg Pathol. 2008;32:1336–43.
39. Holloway RW, Gupta S, Stavitzski NM, Zhu X, Takimoto EL, Gubbi A, et al. Sentinel lymph node mapping with staging lymphadenectomy for patients with endometrial cancer increases the detection of metastasis. Gynecol Oncol. 2016;141:206–10.
40. How J, Lau S, Press J, Ferenczy A, Pelmus M, Stern J, et al. Accuracy of sentinel lymph node detection following intraoperative cervical injection for endometrial cancer: a prospective study. Gynecol Oncol. 2012;127:332–7.
41. Martínez A, Mery E, Filleron T, Boileau L, Ferron G, Querleu D. Accuracy of intraoperative pathological examination of SLN in cervical cancer. Gynecol Oncol. 2013;130:525–9.
42. Papadia A, Imboden S, Siegenthaler F, Gasparri ML, Mohr S, Lanz S, et al. Laparoscopic indocyanine green sentinel lymph node mapping in endometrial cancer. Ann Surg Oncol. 2016;23:2206–11.

43. Touhami O, Trinh XB, Gregoire J, Sebastianelli A, Renaud MC, Grondin K, Plante M. Predictors of non-sentinel lymph node (non-SLN) metastasis in patients with sentinel lymph node (SLN) metastasis in endometrial cancer. Gynecol Oncol. 2015;138:41–5.
44. Cibula D, Abu-Rustum NR, Dusek L, Zikán M, Zaal A, Sevcik L, et al. Prognostic significance of low volume sentinel lymph node disease in early-stage cervical cancer. Gynecol Oncol. 2012;124:496–501.
45. Cibula D, Abu-Rustum NR, Dusek L, Slama J, Zikán M, Zaal A, et al. Bilateral ultrastaging of sentinel lymph node in cervical cancer: lowering the false-negative rate and improving the detection of micrometastasis. Gynecol Oncol. 2012;127:462–6.
46. Beavis AL, Salazar-Marioni S, Sinno AK, Stone RL, Fader AN, Santillan-Gomez A, et al. Sentinel lymph node detection rates using indocyanine green in women with early-stage cervical cancer. Gynecol Oncol. 2016;143:302–6.
47. How J, Gotlieb WH, Press JZ, Abitbol J, Pelmus M, Ferenczy A, et al. Comparing indocyanine green, technetium, and blue dye for sentinel lymph node mapping in endometrial cancer. Gynecol Oncol. 2015;137:436–42.
48. Hinshaw HD, Boggess JF, Kowalski LD, Scalici JM, Cantrell LA, Schuler KM, et al. The relationship between endometrial cancer sentinel lymph node micro and macro metastases and uterine pathology features. Gynecol Oncol. 2016;141(Suppl. 1):A-69. DOI 10.2016/j.ygyno.2016.04.101.
49. Horn LC, Hentschel B, Fischer U, Peter D, Bilek K. Detection of micrometastases in pelvic lymph nodes in patients with carcinoma of the cervix uteri using step sectioning: frequency, topographic distribution and prognostic impact. Gynecol Oncol. 2008;111:276–81.
50. Erkanli S, Bolat F, Seydaoglu G. Detection and importance of micrometastases in histologically negative lymph nodes in endometrial carcinoma. Eur J Gynaecol Oncol. 2011;32:619–25.
51. Todo Y, Kato H, Okamoto K, Minobe S, Yamashiro K, Sakuragi N. Isolated tumor cells and micrometastases in regional lymph nodes in stage I to II endometrial cancer. J Gynecol Oncol. 2016;27:e1. DOI 10.3802/jgo.2016.27.e1. Epub 2015 Nov 23.
52. Cormier B, Diaz JP, Shih K, Sampson RM, Sonoda Y, Park KJ, et al. Establishing a sentinel lymph node mapping algorithm for the treatment of early cervical cancer. Gynecol Oncol. 2011;122:275–80.
53. de Freitas RR, Baiocchi G, Hatschbach SB, Linhares JC, Guerreiro JA, Minari CL, et al. Can a sentinel node mapping algorithm detect all positive lymph nodes in cervical cancer? Ann Surg Oncol. 2015;22:1564–9.
54. Fagotti A, Pedone Anchora L, Conte C, Chiantera V, Vizza E, Tortorella L, et al. Beyond sentinel node algorithm: toward a more tailored surgery for cervical cancer patients. Cancer Med. 2016;5:1725–30.
55. Barlin JN, Khoury-Collado F, Kim CH, Leitao MM Jr, Chi DS, Sonoda Y, et al. The importance of applying a sentinel lymph node mapping algorithm in endometrial cancer staging: beyond removal of blue nodes. Gynecol Oncol. 2012;125:531–5.
56. Cormier B, Rozenholc AT, Gotlieb W, Plante M, Giede C, Communities of Practice (CoP) Group of Society of Gynecologic Oncology of Canada (GOC). Sentinel lymph node procedure in endometrial cancer: a systematic review and proposal for standardization of future research. Gynecol Oncol. 2015;138:478–85.
57. Sinno AK, Peijnenburg E, Fader AN, Temkin SM, Stone R, Levinson K, et al. Reducing overtreatment: a comparison of lymph node assessment strategies for endometrial cancer. Gynecol Oncol. 2016;143:281–6.
58. Tax C, Rovers MM, de Graaf C, Zusterzeel PL, Bekkers RL. The sentinel node procedure in early stage cervical cancer, taking the next step; a diagnostic review. Gynecol Oncol. 2015;139:559–67.
59. Altgassen C, Hertel H, Brandstädt A, Köhler C, Dürst M, Schneider A, AGO Study Group. Multicenter validation study of the sentinel lymph node concept in cervical cancer: AGO Study Group. J Clin Oncol. 2008;26:2943–51.
60. Cibula D, Zikan M, Slama J, Fischerova D, Kocian R, Germanova A, et al. Risk of micrometastases in non-sentinel pelvic lymph nodes in cervical cancer. Gynecol Oncol. 2016;143:83–6.
61. Popa I, Plante M, Renaud MC, Roy M, Têtu B. Negative sentinel lymph node accurately predicts negative status of pelvic lymph nodes in uterine cervix carcinoma. Gynecol Oncol. 2006;103:649–53.
62. Lécuru F, Mathevet P, Querleu D, Leblanc E, Morice P, Daraï E, et al. Bilateral negative sentinel nodes accurately predict absence of lymph node metastasis in early cervical cancer: results of the SENTICOL study. J Clin Oncol. 2011;29:1686–91.
63. Barranger E, Coutant C, Flahault A, Delpech Y, Darai E, Uzan S. An axilla scoring system to predict non-sentinel lymph node status in breast cancer patients with sentinel lymph node involvement. Breast Cancer Res Treat. 2005;91:113–9.
64. Zarganis P, Kondi-Pafiti A, Arapantoni-Dadioti P, Trivizaki E, Velentzas K, Vorgias G, et al. The sentinel node in cervical cancer patients: role of tumor size and invasion of lymphatic vascular space. In Vivo. 2009;23:469–73.
65. Kato H, Todo Y, Minobe S, Suzuki Y, Nakatani M, Ohba Y, et al. Previous conization on patient eligibility of sentinel lymph node detection for early invasive cervical cancer. Int J Gynecol Cancer. 2011;21:1491–4.
66. Seong SJ, Park H, Yang KM, Kim TJ, Lim KT, Shim JU, et al. Detection of sentinel lymph nodes in patients with early stage cervical cancer. J Korean Med Sci. 2007;22:105–9.
67. Levenback C, Coleman RL, Burke TW, Lin WM, Erdman W, Deavers M, et al. Lymphatic mapping and sentinel node identification in patient with cervix cancer undergoing radical hysterectomy and pelvic lymphadenectomy. J Clin Oncol. 2002;20:688–93.
68. Kadkhodayan S, Hasanzadeh M, Treglia G, Azad A, Yousefi Z, Zarifmahmoudi L, et al. Sentinel node biopsy for lymph nodal staging of uterine cervix cancer: a systematic review and meta-analysis of the pertinent literature. Eur J Surg Oncol. 2015;41:1–20.
69. Slama J, Dundr P, Dusek L, Fischerova D, Pinkavova I, Zikan M, et al. Sentinel lymph node status in patients with locally advanced cervical cancers and impact of neoadjuvant chemotherapy. Gynecol Oncol. 2012;125:303–6.
70. Rob L, Strnad P, Robova H, Charvat M, Pluta M, Schlegerova D, et al. Study of lymphatic mapping and sentinel node identification in early stage cervical cancer. Gynecol Oncol. 2005;98:281–8.
71. Plante M, Gregoire J, Renaud MC, et al. Simple vaginal trachelectomy in early-stage low-risk cervical cancer: a pilot study of 16 cases and review of the literature. Int J Gynecol Cancer. 2013;23:916–22.
72. Plante M, Renaud MC, Têtu B, Harel F, Roy M. Laparoscopic sentinel node mapping in early-stage cervical cancer. Gynecol Oncol. 2003;91:494–503.
73. Khoury-Collado F, Glaser GE, Zivanovic O, Sonoda Y, Levine DA, Chi DS, et al. Improving sentinel lymph node detection rates in endometrial cancer: how many cases are needed? Gynecol Oncol. 2009;115:453–5.
74. Bats AS, Buénerd A, Querleu D, Leblanc E, Daraï E, Morice P, et al. SENTICOL collaborative group: diagnostic value of intraoperative examination of sentinel lymph node in early cervical cancer. A prospective, multicenter study. Gynecol Oncol. 2011;123:230–5.
75. Okamoto S, Niikura H, Nakabayashi K, Hiyama K, Matoda M, Takeshima N, et al. Detection of sentinel lymph node metastases in cervical cancer: assessment of KRT19 mRNA in the one-step nucleic acid amplification (OSNA) method. Gynecol Oncol. 2013;130:530–6.
76. Dürst M, Hoyer H, Altgassen C, Greinke C, et al. Prognostic value of HPV-mRNA in sentinel lymph nodes of cervical cancer patients with pN0-status. Oncotarget. 2015;6:23015–25.

77. ASTEC Study Group, Kitchener H, Swart AM, et al. Efficacy of systematic pelvic lymphadenectomy in endometrial cancer (MRC ASTEC trial): a randomized study. Lancet. 2009;373:125–36.
78. Benedetti-Panici P, Basile S, Maneschi F, et al. Systematic pelvic lymphadenectomy vs. no lymphadenectomy in early-stage endometrial carcinoma: randomized clinical trial. J Natl Cancer Inst. 2008;100:1707–16.
79. Cragun JM, Havrilesky LJ, Calingaert B, et al. Retrospective analysis of selective lymphadenectomy in apparent early-stage endometrial cancer. J Clin Oncol. 2005;23:3668–75.
80. Miller DS. Patients with endometrial cancer at risk for lymphatic metastasis should undergo pelvic and periaortic lymphadenectomy as part of their initial surgery. Cancer. 2017;123(2):192–6. DOI 10.1002/cncr.30418.
81. Ehrisman J, Secord AA, Berchuck A, Lee PS, Di Santo N, Lopez-Acevedo M, et al. Performance of sentinel lymph node biopsy in high-risk endometrial cancer. Gynecol Oncol Rep. 2016;17:69–71.
82. Naoura I, Canlorbe G, Bendifallah S, Ballester M, Daraï E. Relevance of sentinel lymph node procedure for patients with high-risk endometrial cancer. Gynecol Oncol. 2015;136:60–4.
83. Ballester M, Dubernard G, Lécuru F, Heitz D, Mathevet P, Marret H, et al. Detection rate and diagnostic accuracy of sentinel-node biopsy in early stage endometrial cancer: a prospective multicentre study (SENTIENDO). Lancet Oncol. 2011;12:469–76.
84. Tanner EJ, Sinno AK, Stone RL, Levinson KL, Long KC, Fader AN. Factors associated with successful bilateral sentinel lymph node mapping in endometrial cancer. Gynecol Oncol. 2015;138:542–7.
85. Raimond E, Ballester M, Hudry D, Bendifallah S, Daraï E, Graesslin O, et al. Impact of sentinel lymph node biopsy on the therapeutic management of early-stage endometrial cancer: results of a retrospective multicenter study. Gynecol Oncol. 2014;133:506–11.
86. Schiavone MB, Zivanovic O, Zhou Q, Leitao MM Jr, Levine DA, Soslow RA, et al. Survival of patients with uterine carcinosarcoma undergoing sentinel lymph node mapping. Ann Surg Oncol. 2016;23:196–202.
87. Altgassen C, Paseka A, Urbanczyk H, Dimpfl T, Diedrich K, Dahmen G, et al. Dilution of dye improves parametrial SLN detection in patients with cervical cancer. Gynecol Oncol. 2007;105:329–34.
88. Ballester M, Dubernard G, Rouzier R, Barranger E, Darai E. Use of the sentinel node procedure to stage endometrial cancer. Ann Surg Oncol. 2008;15:1523–9.
89. Basta A, Pitynski K, Basta P, Hubalewska-Hola A, OplawskI M, Przesziakowski D. Sentinel node in gynaecological oncology. Rep Pract Oncol Radiother. 2005;10:1–4.
90. Bats AS, Clement D, Larousserie F, Le Frere-Belda MA, Pierquet-Ghazzar N, Hignette C, et al. Does sentinel node biopsy improve the management of endometrial cancer? Data from 43 patients. J Surg Oncol. 2008;97:141–5.
91. Bats AS, Lavoué V, Rouzier R, Coutant C, Kerrou K, Daraï E. Limits of day-before lymphoscintigraphy to localize sentinel nodes in women with cervical cancer. Ann Surg Oncol. 2008;15:2173–9.
92. Coutant C, Morel O, Delpech Y, Uzan S, Daraï E, Barranger E. Laparoscopic sentinel node biopsy in cervical cancer using a combined detection: 5-years experience. Ann Surg Oncol. 2007;14:2392–9.
93. Daraï E, Lavoué V, Rouzier R, Coutant C, Barranger E, Bats AS. Contribution of the sentinel node procedure to tailoring the radicality of hysterectomy for cervical cancer. Gynecol Oncol. 2007;106:251–6.
94. Dargent D, Enria R. Laparoscopic assessment of the sentinel lymph nodes in early cervical cancer. Technique: preliminary results and future developments. Crit Rev Oncol Hematol. 2003;48:305–10.
95. Darlin L, Persson J, Bossmar T, Lindahl B, Kannisto P, Måsbäck A, Borgfeldt C. The sentinel node concept in early cervical cancer performs well in tumors smaller than 2 cm. Gynecol Oncol. 2010;117:266–9.
96. Delaloye JF, Pampallona S, Chardonnens E, Fiche M, Lehr HA, De Grandi P, et al. Intraoperative lymphatic mapping and sentinel node biopsy using hysteroscopy in patients with endometrial cancer. Gynecol Oncol. 2007;106:89–93.
97. Desai PH, Hughes P, Tobias DH, Tchabo N, Heller PB, Dise C, et al. Accuracy of robotic sentinel lymph node detection (RSLND) for patients with endometrial cancer (EC). Gynecol Oncol. 2014;135:196–200.
98. Devaja O, Mehra G, Coutts M, Montalto SA, Donaldson J, Kodampur M, Papadopoulos AJ. A prospective single-center study of sentinel lymph node detection in cervical carcinoma: is there a place in clinical practice? Int J Gynecol Cancer. 2012;22:1044–9.
99. Diaz JP, Gemignani ML, Pandit-Taskar N, Park KJ, Murray MP, Chi DS, et al. Sentinel lymph node biopsy in the management of early-stage cervical carcinoma. Gynecol Oncol. 2011;120:347–52.
100. Díaz-Feijoo B, Gil-Moreno A, Pérez-Benavente MA, Morchón S, Martínez-Palones JM, Xercavins J. Sentinel lymph node identification and radical hysterectomy with lymphadenectomy in early stage cervical cancer: laparoscopy versus laparotomy. J Minim Invasive Gynecol. 2008;15:531–7.
101. Di Stefano AB, Acquaviva G, Garozzo G, Barbic M, Cvjeticanin B, Meglic L, et al. Lymph node mapping and sentinel node detection in patients with cervical carcinoma: a 2-year experience. Gynecol Oncol. 2005;99:671–9.
102. Du XL, Sheng XG, Jiang T, Li QS, Yu H, Pan CX, et al. Sentinel lymph node biopsy as guidance for radical trachelectomy in young patients with early stage cervical cancer. BMC Cancer. 2011;11:157.
103. Feranec R, Moukova L, Stanicek J, Stefanikova L, Chovanec J. Sentinel lymph node identification using hysteroscopy in patients with endometrial cancer. Klin Onkol. 2010;23:92–8.
104. Fersis N, Gruber I, Relakis K, Friedrich M, Becker S, Wallwiener D, et al. Sentinel node identification and intraoperative lymphatic mapping: first results of a pilot s patients with endometrial cancer. Eur J Gynaecol Oncol. 2004;25:339–42.
105. Frumovitz M, Coleman RL, Gayed IW, Ramirez PT, Wolf JK, Gershenson DM, et al. Usefulness of preoperative lymphoscintigraphy in patients who undergo radical hysterectomy and pelvic lymphadenectomy for cervical cancer. Am J Obstet Gynecol. 2006;194:1186–93.
106. Frumovitz M, Bodurka DC, Broaddus RR, Coleman RL, Sood AK, Gershenson DM, et al. Lymphatic mapping and sentinel node biopsy in women with high-risk endometrial cancer. Gynecol Oncol. 2007;104:100–3.
107. Gargiulo T, Giusti M, Bottero A, Leo L, Brokaj L, Armellino F, et al. Sentinel lymph node (SLN) laparoscopic assessment early stage in endometrial cancer. Minerva Ginecol. 2003;55:259–62.
108. Gien LT, Kwon JS, Carey MS. Sentinel node mapping with isosulfan blue dye in endometrial cancer. J Obstet Gynaecol Can. 2005;27:1107–12.
109. Holub Z, Jabor A, Lukac J, Kliment L. Laparoscopic detection of sentinel lymph nodes using blue dye in women with cervical and endometrial cancer. Med Sci Monit. 2004;10:CR587–91.
110. Hoogendam JP, Hobbelink MG, Veldhuis WB, Verheijen RH, et al. Preoperative sentinel node mapping with (99m)Tc-nanocolloid SPECT-CT significantly reduces the intraoperative sentinel node retrieval time in robot assisted laparoscopic cervical cancer surgery. Gynecol Oncol. 2013;129:389–94.
111. Jewell EL, Huang JJ, Abu-Rustum NR, Gardner GJ, Brown CL, Sonoda Y, et al. Detection of sentinel lymph nodes in minimally invasive surgery using indocyanine green and near-infrared fluorescence imaging for uterine and cervical malignancies. Gynecol Oncol. 2014;133:274–7.

112. Khoury-Collado F, Murray MP, Hensley ML, Sonoda Y, Alektiar KM, Levine DA, et al. Sentinel lymph node mapping for endometrial cancer improves the detection of metastatic disease to regional lymph nodes. Gynecol Oncol. 2011;122:251–4.
113. Klapdor R, Mücke J, Schneider M, et al. Value and advantages of preoperative sentinel lymph node imaging with SPECT/CT in cervical cancer. Int J Gynecol Cancer. 2014;24:295–302.
114. Klat J, Sevcik L, Simetka O, et al. What is the risk for parametrial involvement in women with early-stage cervical cancer with tumour b20 mm and with negative sentinel lymph nodes? Aust N Z J Obstet Gynaecol. 2012;52:540–4.
115. Lee YS, Rhim CC, Lee HN, Lee KH, Park JS, Namkoong SE. HPV status in sentinel nodes might be a prognostic factor in cervical cancer. Gynecol Oncol. 2007;105:351–7.
116. Lelievre L, Camatte S, Le Frere-belda MA, Kerrou K, Froissart M, Taurelle R, et al. Sentinel lymph node biopsy in cervix and corpus uteri cancers. Int J Gynecol Cancer. 2004;14:271–8.
117. Li B, Li XG, Wu LY, Zhang WH, Li SM, Min C, Gao JZ. A pilot study of sentinel lymph nodes identification in patients with endometrial cancer. Bull Cancer. 2007;94:E1–4.
118. Lopes LA, Nicolau SM, Baracat FF, Baracat EC, Goncalves WJ, Santos HV, et al. Sentinel lymph node in endometrial cancer. Int J Gynecol Cancer. 2007;17:1113–7.
119. López-De la Manzanara Cano C, Cordero García JM, Martín-Francisco C, Pascual-Ramírez J, Parra CP, Céspedes Casas C. Sentinel lymph node detection using 99mTc combined with methylene blue cervical injection for endometrial cancer surgical management: a prospective study. Int J Gynecol Cancer. 2014;24:1048–53.
120. Maccauro M, Lucignani G, Aliberti G, Villano C, Castellani MR, Solima E, et al. Sentinel lymph node detection following the hysteroscopic peritumoural injection of 99mTc-labelled albumin nanocolloid in endometrial cancer. Eur J Nucl Med Mol Imaging. 2005;32:569–74.
121. Mais V, Peiretti M, Gargiulo T, Parodo G, Cirronis MG, Melis GB. Intraoperative sentinel lymph node detection by vital dye through laparoscopy or laparotomy in early endometrial cancer. J Surg Oncol. 2010;101:408–12.
122. Malur S, Krause N, Köhler C, Schneider A. Sentinel lymph node detection in patients with cervical cancer. Gynecol Oncol. 2001;80:254–7.
123. Marnitz S, Köhler C, Bongardt S, Braig U, Hertel H, Schneider A, German Association of Gynecologic Oncologists (AGO). Topographic distribution of sentinel lymph nodes in patients with cervical cancer. Gynecol Oncol. 2006;103:35–44.
124. Ogawa S, Kobayashi H, Amada S, Yahata H, Sonoda K, Abe K, et al. Sentinel node detection with (99m)Tc phytate alone is satisfactory for cervical cancer patients undergoing radical hysterectomy and pelvic lymphadenectomy. Int J Clin Oncol. 2010;15:52–8.
125. Paley PJ, Veljovich DS, Press JZ, Isacson C, Pizer E, Shah C. A prospective investigation of fluorescence imaging to detect sentinel lymph nodes at robotic-assisted endometrial cancer staging. Am J Obstet Gynecol. 2016;215:117.e1–7.
126. Pazin V, Dragojević S, Miković Z, Dukić M, Rakić S, Marinković J, et al. The value of sentinel lymphadenectomy in radical operative treatment of cervical cancer. Vojnosanit Pregl. 2009;66:539–43.
127. Pelosi E, Arena V, Baudino B, Bello M, Giusti M, Gargiulo T, et al. Pre-operative lymphatic mapping and intra-operative sentinel lymph node detection in early stage endometrial cancer. Nucl Med Commun. 2003;24:971–5.
128. Pluta M, Rob L, Charvat M, Chmel R, Halaska M Jr, Skapa P, Robova H. Less radical surgery than radical hysterectomy in early stage cervical cancer: a pilot study. Gynecol Oncol. 2009;113:181–4.
129. Rob L, Pluta M, Strnad P, Hrehorcak M, Chmel R, Skapa P, Robova H. A less radical treatment option to the fertility-sparing radical trachelectomy in patients with stage I cervical cancer. Gynecol Oncol. 2008;111(2 Suppl):S116–20.
130. Robova H, Charvat M, Strnad P, Hrehorcak M, Taborska K, Skapa P, et al. Lymphatic mapping in endometrial cancer: comparison of hysteroscopic and subserosal injection and the distribution of sentinel lymph nodes. Int J Gynecol Cancer. 2009;19:391–4.
131. Roy M, Bouchard-Fortier G, Popa I, Grégoire J, Renaud MC, Têtu B, Plante M. Value of sentinel node mapping in cancer of the cervix. Gynecol Oncol. 2011;122:269–74.
132. Sinno AK, Fader AN, Roche KL, Giuntoli RL II, Tanner EJ. A comparison of colorimetric versus fluorometric sentinel lymph node mapping during robotic surgery for endometrial cancer. Gynecol Oncol. 2014;134:281–6.
133. Strnad P, Robova H, Skapa P, Pluta M, Hrehorcak M, Halaska M, Rob L. A prospective study of sentinel lymph node status and parametrial involvement in patients with small tumour volume cervical cancer. Gynecol Oncol. 2008;109:280–4.
134. van de Lande J, Davelaar EM, von Mensdorff-Pouilly S, Water TJ, Berkhof J, van Baal WM, et al. SCC-Ag, lymph node metastases and sentinel node procedure in early stage squamous cell cervical cancer. Gynecol Oncol. 2009;112:119–25.
135. Vidal F, Leguevaque P, Motton S, Delotte J, Ferron G, Querleu D, et al. Evaluation of the sentinel lymph node algorithm with blue dye labeling for early-stage endometrial cancer in a multicentric setting. Int J Gynecol Cancer. 2013;23:1237–43.
136. Vidal-Sicart S, Domenech B, Lujan B, Pahisa J, Torne A, Martinez-Roman S, et al. Sentinel node in gynaecological cancers: our experience. Rev Esp Med Nucl. 2009;28:221–8.
137. Vieira SC, Sousa RB, Tavares MB, Silva JB, Abreu BA, Santos LG, et al. Preoperative pelvic lymphoscintigraphy is of limited usefulness for sentinel lymph node detection in cervical cancer. Eur J Obstet Gynecol Reprod Biol. 2009;145:96–9.
138. Wydra D, Sawicki S, Wojtylak S, Bandurski T, Emerich J. Sentinel node identification in cervical cancer patients undergoing transperitoneal radical hysterectomy: a study of 100 cases. Int J Gynecol Cancer. 2006;16:649–54.
139. Yamashita T, Katayama H, Kato Y, Nishiwaki K, Hayashi H, Miyokawa N, Sengoku K. Management of pelvic lymph nodes by sentinel node navigation surgery in the treatment of invasive cervical cancer. Int J Gynecol Cancer. 2009;19:1113–8.
140. Yuan SH, Xiong Y, Wei M, Yan XJ, Zhang HZ, Zeng YX, et al. Sentinel lymph node detection using methylene blue in patients with early stage cervical cancer. Gynecol Oncol. 2007;106:147–52.
141. Zenzola V, Gonzalez C, Lander JS, Contreras I, Medina F, Castillo J, et al. Use of sentinel lymph node biopsy with patent blue labeling and radiocolloid in patients with endometrial cancer. Rev Venez Oncol. 2009;21:3–10.

Robotic Radical Hysterectomy for Early-Stage Cervical Cancer

13

Alaa El-Ghobashy, San Soo Hoo, and Javier Magrina

Introduction

Cervical cancers represent 3.5% of all gynaecological malignancies with a 55% overall 5-year survival. In the United Kingdom, around 3500 cases are diagnosed every year (~9.5–10.5/100,000). This disease results in 1000 deaths annually. The incidence and mortality dropped dramatically in the 1990s due to the impact of the introduction of cervical screening programme. Radical hysterectomy remained the preferred method of treatment for patients with early-stage disease. The operation compromises two components: central resection of the cervix and its surroundings as well as complete removal of the draining regional lymph nodes. In 2006, Sert and Abeler described the first reported robotic-assisted radical hysterectomy (Piver Type III) and bilateral pelvic lymph node dissection for Stage IB1 cervical carcinoma. The operation lasted 7 h and 20 min with an estimated blood loss of 200 mL [1]. The patient was discharged home 4 days later without major complications. Several reports/statements were published in literature supporting the robotic technique and demonstrating its oncological safety [2]. The surgical technique of the robotic radical hysterectomy described in this chapter follows the principles of those originally reported by Okabayashi in 1921 [3], which were designed to minimise the transection of the pelvic autonomic nerves.

Classifications of Robotic Radical Hysterectomy

Several classifications of the type hysterectomy had been reported in literature. The Piver-Rutledge classification (Fig. 13.1), reported in 1974, included Type I, extrafascial hysterectomy; Type II, modified Wertheim's hysterectomy; Type III, Wertheim-Meigs' hysterectomy; Type IV, extended radical hysterectomy; and Type V, exenteration [4].

A revised classification by Querleu-Morrow published in 2008 [5] standardised the reporting of hysterectomy to Type A, extrafascial hysterectomy; Type B, modified radical hysterectomy; Type C1, nerve-sparing radical hysterectomy; Type C2, Type III radical hysterectomy; and Type D, laterally extended parametrectomy (Fig. 13.2).

The extent of paracervical resection described with the robotic technique is referred to as Type III radical hysterectomy which is similar to the type C2 of the newly revised classification.

Indications of Radical Hysterectomy

The robotic radical hysterectomy is indicated in patients with cervical cancer Stage IA2 up to Stage IIA when the preoperative workup suggests high likelihood of curative intent with surgery alone. The extent of radical pelvic resection depends on size of the tumour and the lymphovascular involvement. However, the vaginal resection is dependent on the location of the tumour margins. In patients with a margin near or involving the vaginal fornix, a longer segment of vagina will be necessary. This technique can also be applicable to patients with endometrial cancer with cervical stromal invasion.

Patient's Positioning and Setup

The patient is positioned in low dorsal lithotomy (modified Lloyd-Davies) position. The head should be protected with a foam pad and aligned in axis of the trunk. The eyes should

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be lubricated and closed. The legs are placed in padded holders (Allen Stirrups, Allen Medical, Acton, MA) and should be symmetrically placed and relaxed in a mid-flexion position with pneumatic cuffs (Flowtrons) wrapped around them. The arms are also foam padded and loosely tucked at sides after securing all IV lines. The patient is placed with a naked back directly on an anti-skid foam material (Tyco/Kendall, Mansfield, MA) [6]. Some centres use Autogrippantes straps which are crossed across the shoulders and chest walls to secure the patient to the table. A heating blanket/cover is placed over the patient to maintain the temperature throughout the surgery. A Trendelenburg test (25°–30°) is done to test the secure position of the patient and to allow the anaesthetist to ascertain any changes in patient's ventilation. The patient is subsequently returned to the supine position and then prepped and draped. It is the routine practice in our centre to use the V Care® uterine manipulator to manoeuvre the uterus during surgery. The cervical cup of the manipulator is fixed in situ to the cervix using Vicryl sutures at 6 and 12 o'clock sites to prevent tumour dissemination/contamination of the surgical field. Other centres use McCartney tubes, vaginal probes or Rumi manipulators with/without colpo-occluders (Cooper Medical, Trumbull, CT). The bladder is emptied by inserting a Foley's urethral catheter.

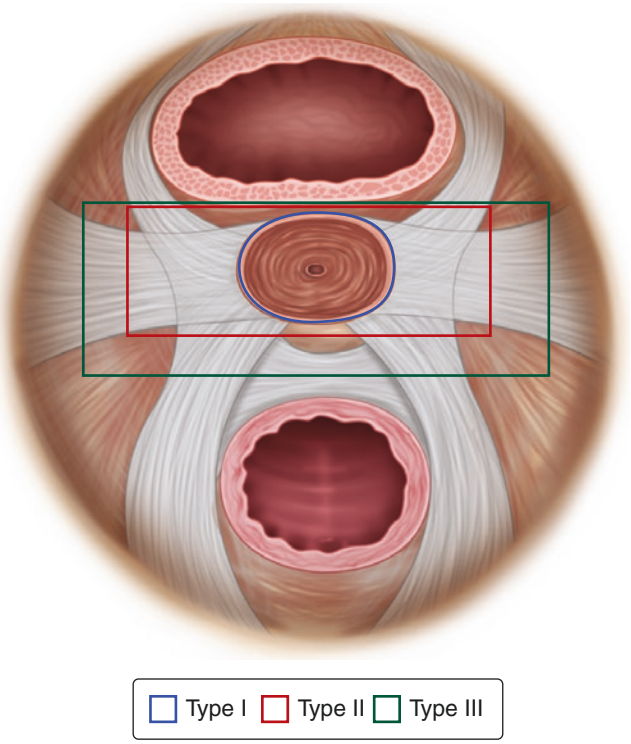

Fig. 13.1 Piver Rutledge hysterectomy classification

Surgical Steps

Entry Technique and Trocars' Placements

A standard entry method is usually practised using a Veress needle inserted at the umbilicus to create pneumoperitoneum (20–25 mmHg). In cases with previous abdominal surgeries, either a Palmer's point entry or open access using Hasson's technique can be considered. A long 12 mm trocar (Endopath

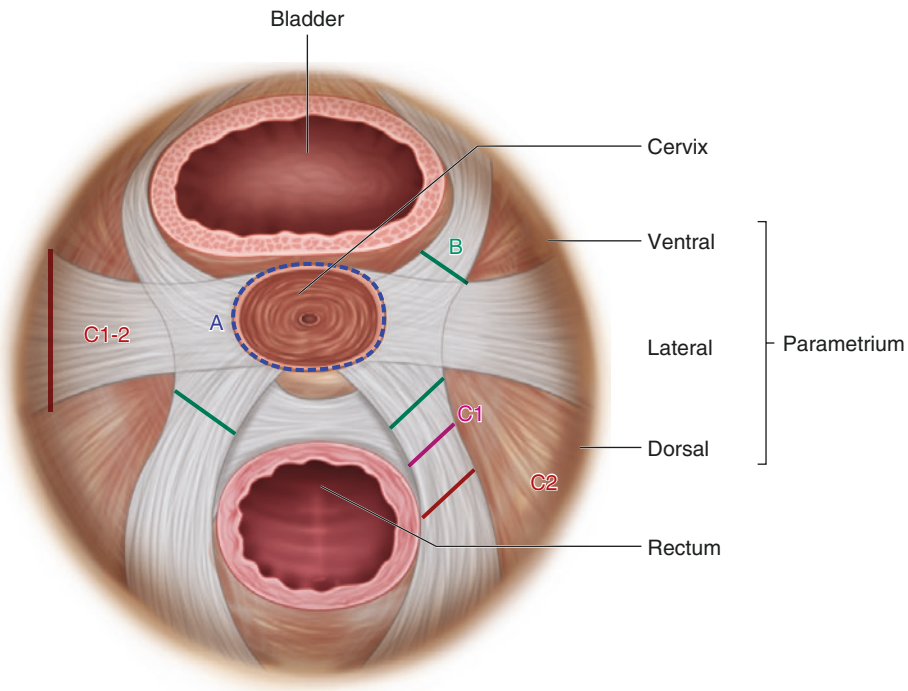

Fig. 13.2 Querleu Morrow hysterectomy classification

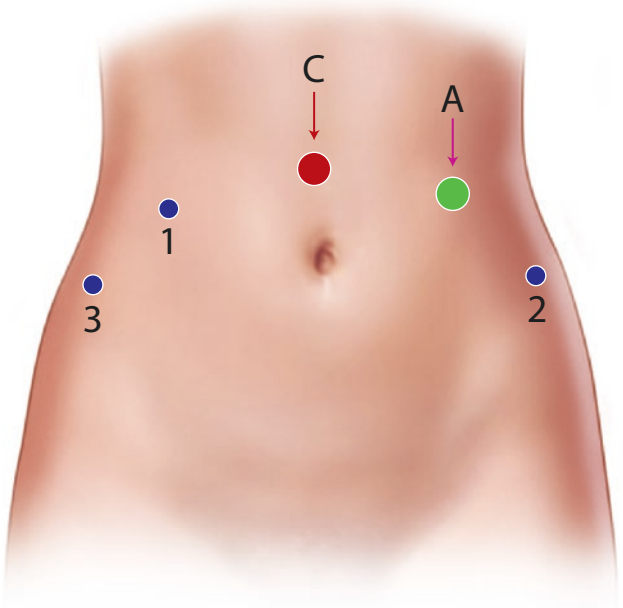

Fig. 13.3 Ports placement for Robotic radical hysterectomy. C = Camera port (12 mm), A = assistant's port (12 mm), 1/2/3 = Robotic arms' ports (8 mm)

XCEL Bladeless, Ethicon) is inserted above the umbilicus after a 10 mm transverse incision is made. Camera is inserted for 360 views to rule out internal organ injuries and assess the operability. All other trocars should be inserted under direct vision. This includes three intuitive (8 mm) metal trocars for arms 1–3 and an assistant trocar (10–12 mm XCEL port). The configuration of the trocars is like a letter C (Fig. 13.3). Some surgeons prefer an M configuration with the camera trocar inserted in the umbilicus. Care should be taken to place the trocars at least 8 cm apart in order to avoid clashes of mechanical robotic arms during surgery. The upper abdomen is explored in the supine position. The patient is then placed in the Trendelenburg position to a degree enough to displace the sigmoid and small bowel out of the pelvis and allow a safe pelvic operation.

Patient's Cart Docking and Instruments' Insertion

The standard da Vinci, da Vinci Si or da Vinci Xi robotic systems (Intuitive Surgical; Sunnyvale, CA) are adequate for the operation. The robotic column is side docked lateral to the patient's right knee. The robotic arms are fastened to the robotic trocars once these are inserted. Surgical instruments (Intuitive Inc., Sunnyvale, CA) are inserted as follows: EndoWrist fenestrated bipolar forceps or PK grasper in the left robotic arm, EndoWrist monopolar diathermy scissors/spatula in the right robotic arm and EndoWrist Prograsper forceps in the right lateral robotic arm to assist with retraction. The instruments are connected to the diathermy machine (Forced Triad Machine, Covidien). The power settings are adjusted to 30–40 W blend for cutting/spray for coagulation and 30–40 medium for the bipolar mode.

An EndoWrist needle holder is used to replace the monopolar scissors/spatula to suture the vaginal cuff. The assistant stands to the left of the patient and performs the functions of sealing and dividing of vascular pedicles (with a vessel sealer device when required), suction and irrigation, peritoneal cytology, removal of small specimens, tissue retraction and insertion and removal of sutures for closure of the vaginal cuff.

Development of Lateral Retroperitoneal Spaces

A lateral peritoneal incision is made transecting the round ligament and anterior broad ligament peritoneum to above the pelvic brim. The paravesical and pararectal spaces are developed at the start to identify the parametria, (also known as cardinal ligament, parametrial web, paracervical tissues and lateral parametrium). The ureters are identified on the pelvic peritoneum and traced to the crossing with the uterine arteries.

Management of the Adnexae

In case of adnexal removal, a peritoneal window is made between the ureter and the infundibulopelvic ligament, which is then divided with a vessel sealer at the level of the pelvic brim. This window prevents ureteral injury at this level. If the adnexa are preserved, the ovarian pedicles are divided medially, as well as their peritoneal attachments and placed laterally above the pelvic brim. It is our routine practice to remove the fallopian tubes (bilateral salpingectomy) with the hysterectomy specimen when ovarian conservation is required in order to minimise the future risk of fallopian tubes cancer.

Pelvic and Para-aortic Lymphadenectomy

The external iliac nodes, from the bifurcation of the common iliac vessels to the inguinal ligament, the obturator nodes above and below the obturator nerve, the ventral and lateral nodes of the hypogastric artery and the ventral and lateral common iliac nodes, from the bifurcation of the common iliacs to the bifurcation of the aorta, are removed bilaterally. When clinically/radiologically indicated, frozen section of the removed lymph nodes is performed intraoperatively.

In the presence of positive pelvic nodes, a bilateral aortic lymphadenectomy is carried out to the renal vessels. Using the same trocar placement and instruments, the inframesenteric nodes can be safely removed. For the infrarenal nodes, the robotic system arms are undocked and the operating table rotated 180°, resulting in the robotic column being now located at the patient's head or lateral to the right shoulder. Three trocars are placed suprapubically, two for the assistant and one for the endoscopic camera. The robotic arms redocked, and using the same robotic instruments, the aortic lymphadenectomy is extended to the infrarenal group of nodes, up to the level of the renal vessels. The benefit of removing positive aortic nodes has been addressed in the recent literature [7, 8]. The technique of infrarenal aortic lymphadenectomy and rotation of the operating table has been described elsewhere [9]. The new da Vinci Xi system allows rotation of the robotic arms after undocking them from the pelvic position without the need to rotate the operating table. Once the arms are rotated 180°, they are docked again. However, it still requires the placement of additional trocars suprapubically for the optical trocar and assistant.

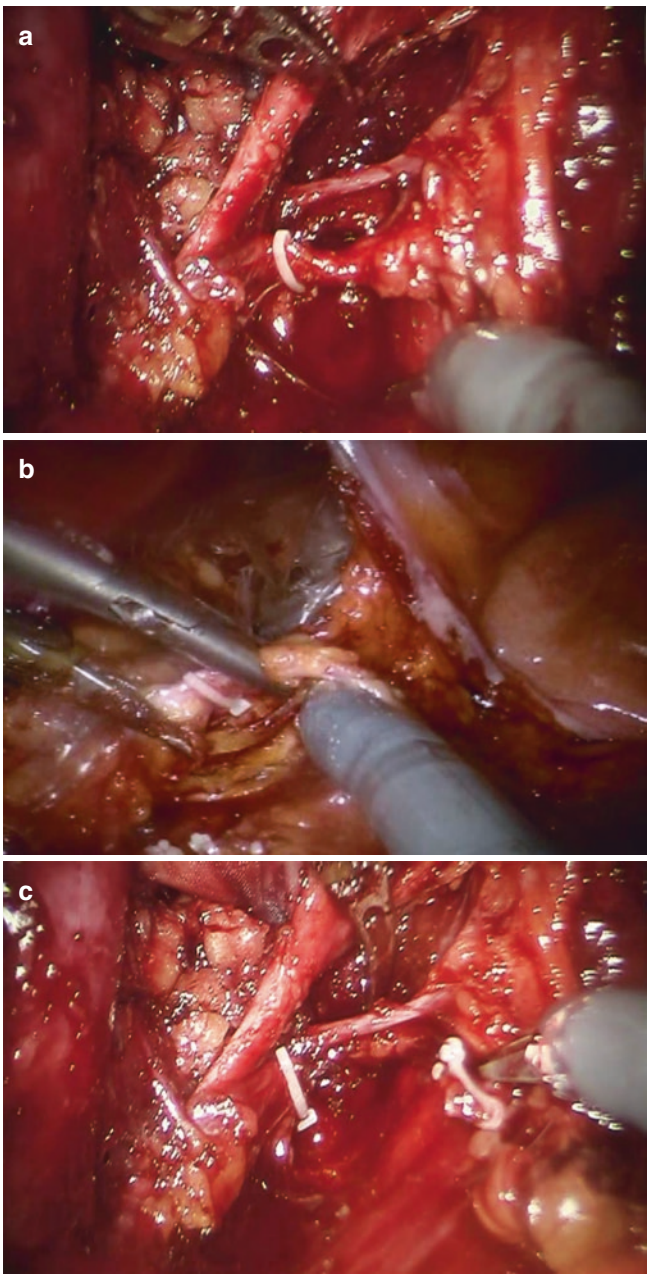

Fig. 13.4 (**a**) Dissection of the left uterine vessels with the application of Hem-o-lok® clips. (**b**) Dissection of the left uterine vessels with the application of Haem-lock. (**c**) Dissection of the left superficial uterine vessels with the exposure of deep vessels

Parametrial Division

With the paravesical and pararectal spaces dissected, the vascular portion of the lateral parametrium is transected at the origin of its vessels from the internal iliac artery and vein with successive applications of a vessel sealer/clips (Hem-o-lok®) and continuing dorsally to the level of the deep uterine vein (Fig. 13.4a–c). This level of transection separates the ligamentous portion from the neural portion of the lateral parametrium and serves to preserve the dorsal neural portion which contains the parasympathetic pelvic splanchnic nerves arising from S2, S3 and S4.

Uterosacral Ligament Division

The ureters are first separated from their pelvic peritoneal attachments, from the pelvic brim to the uterine arteries. The peritoneum of the cul-de-sac is divided horizontally with the monopolar scissors/spatula to the level of the ureters laterally. The rectovaginal space is developed caudally to the upper vaginal half. With the rectovaginal space developed and the ureters freed from their peritoneal attachments, the uterosacral ligaments are identified and transected at the level of the anterior rectal wall. The transection is directed towards the upper

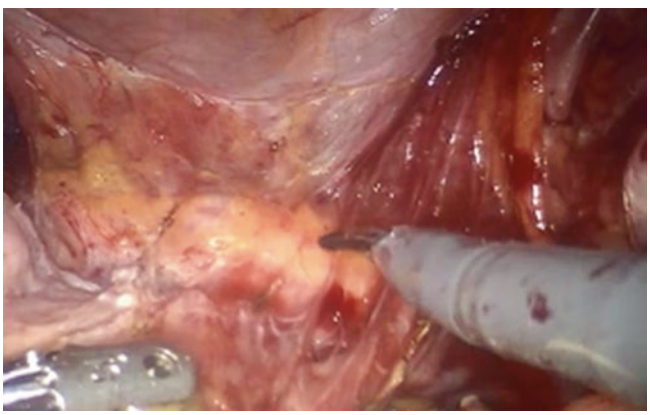

Fig. 13.5 Bladder dissection over the V-Care uterine manipulator

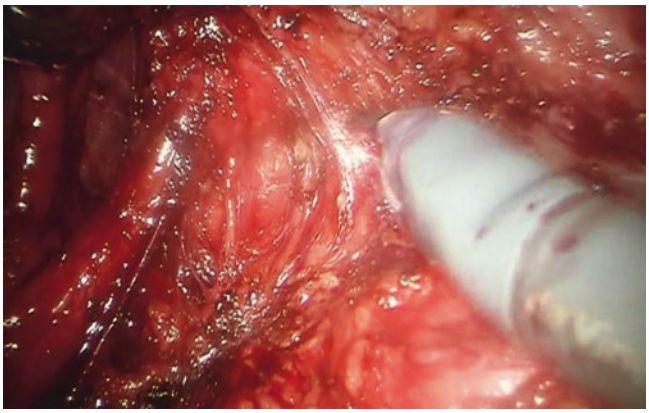

Fig. 13.6 Dissection of the left ureter and the bladder pillar

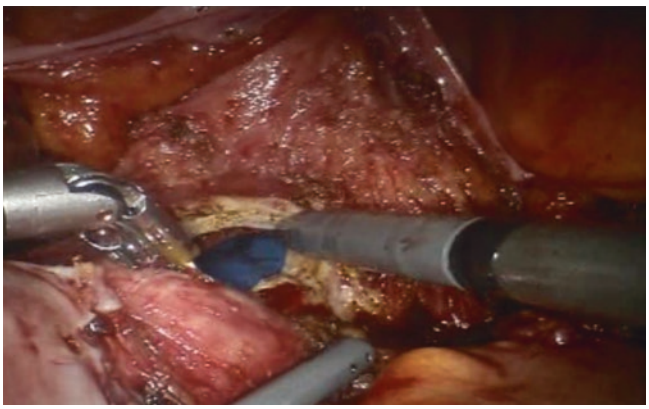

Fig. 13.8 Anterior vaginal entry using monopolar diathermy scissors

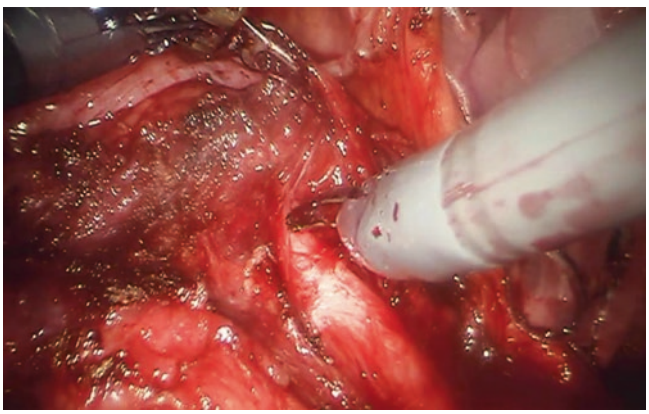

Fig. 13.7 Dissection of the right ureter and the bladder pillar

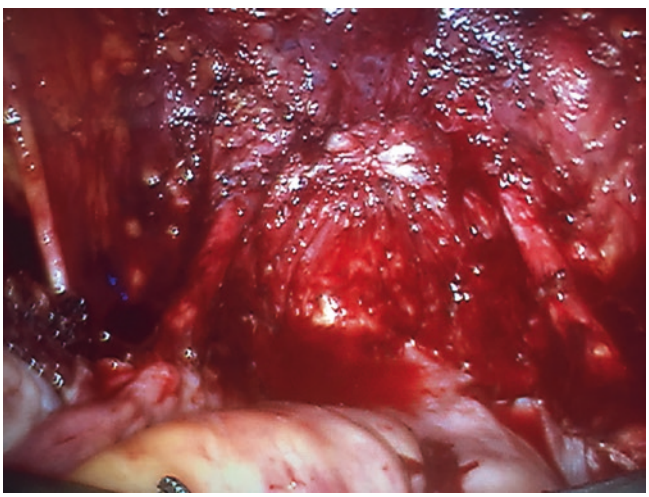

Fig. 13.9 The pelvic view at the end of surgery after the vaginal closure. Note the clear visualisation of both ureters

posterior vaginal third (and not to the sacrum) in order to preserve the caudal portion of the sympathetic nerves, which are a continuation of the superior hypogastric plexus. They can be isolated on the lateral aspect of the uterosacral ligaments.

Bladder and Ureteral Dissection

The uterovesical peritoneum is divided horizontally. The assistant at the vaginal end advances the V Care manipulator cephalically to facilitate the separation of the bladder from the cervix and vagina (Fig. 13.5). The dissection is carried out caudally to the upper half of the vagina. The ureters should be dissected and freed completely from the pelvic brim till its entrance into the parametrial/ureteric tunnel. The ventral part of the vesicouterine ligament is then transected with diathermy to unroof the ureter. It is then mobilised laterally by dividing with the monopolar scissors/spatula its loose attachments to the dorsal aspect of the vesicouterine ligament, until the latter is exposed and identified. Further dissection of this section of the ligament will render the ureter totally free from its attachments and can be elevated ventrally (Figs. 13.6 and 13.7).

Vaginal Resection

The assistant advances the V Care manipulator further to identify the junction of the vagina and exocervix. The length of the vaginal margin to excise is then determined using the diameter of the instruments as a measuring tool. It is important to consider that margins obtained with a stretched vagina will be shorter once the tension is removed. The vagina is entered at the 12 o'clock position and divided with the monopolar scissors/spatula (using cutting current) (Fig. 13.8). The V care uterine manipulator together with the attached surgical specimen is pulled out of the vagina.

Vaginal Cuff Closure

The vaginal edges are approximated with a purse string no. 1 Vicryl suture. This is performed vaginally by the assistant after the extraction of the specimen. We found this technique easy, quick, cheap and less likely to result in vault

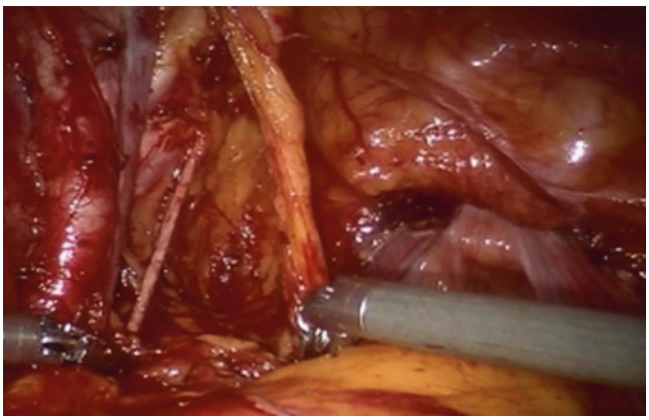

Fig. 13.10 The pelvic view at the end of surgery after the vaginal closure. Note the exposure of the left lateral pelvic side wall

dehiscence/rupture. It is important to incorporate a minimum of 5 mm of vagina with each bite and 5 mm of separation in between sutures. Some surgeons close the cuff with a continuous 2-0 V-loc (Ethicon Endo Surgery, Cincinnati, OH) (Fig. 13.9). The pelvis is thoroughly irrigated with saline. To check for adequate haemostasis, it is important to normalise the blood pressure and to lower the CO_2 insufflation pressure before finishing the procedure. It is our routine practice to leave a drain (Robinson's drain size 20) in the pelvis for the first 24 h. The lateral pelvic peritoneum is left open (Fig. 13.10).

The robotic patient's cart is undocked and all trocars are removed under direct vision. The sheath is closed at the camera and the assistant trocars' sites to avoid hernia. The skin is approximated with monocryl 2-0 (Fig. 13.10).

Postoperative Care

The patient is usually transferred to the recovery ward to be observed for 1–2 h before returning to the gynaecology ward. She will be allowed oral intake of liquids, food and medications on the same day of the operation. Ambulation with physiotherapy is commenced on day 1 of surgery. The drain should be removed on the morning of surgery if there is no significant drainage. Prophylactic anticoagulation with low molecular weight heparin will start after 6 h of surgery and will continue daily for the following 28 days (NICE guidance). The urinary bladder will be freely drained through Foley's catheter for the first 24 h of surgery. On discharge (day 1 or 2), a flip flow valve will be attached to Foley's catheter, and the patient will be instructed to empty her bladder every 2–3 h and before going to bed. The catheter will be removed after 5–7 days. A routine bladder scan for residual urine is usually recommended after the catheter removal. A postoperative visit is performed at 2 weeks from surgery to check on the patient's recovery, assess robotic port sites and update her about the final histopathology results.

References

1. Sert BM, Abeler VM. Robotic-assisted laparoscopic radical hysterectomy (Piver type III) with pelvic node dissection–case report. Eur J Gynaecol Oncol. 2006;27:531–3.
2. Magrina JF, Kho RM, Weaver AL, Montero RP, Magtibay PM. Robotic radical hysterectomy: comparison with laparoscopy and laparotomy. Gynecol Oncol. 2008;109:86–91.
3. Okabayashi H. Radical abdominal hysterectomy for cancer of the cervix uteri, modification of the Takayama operation. Surg Gynecol Obstet. 1921;33:335–41.
4. Symmonds RE. Some surgical aspects of gynecologic cancer. Cancer. 1975;36(2):649–60.
5. Querleu D, Morrow CP. Classification of radical hysterectomy. Lancet Oncol. 2008;9:297–303.
6. Magrina JF, Long JB, Kho RM, Giles DL, Montero RP, Magtibay PM. Robotic transperitoneal infrarenal aortic lymphadenectomy: technique and results. Int J Gynecol Cancer. 2010;20(1):184–7.
7. Leblanc E, Narducci F, Frumovitz M, Lesoin A, Castelain B, Baranzelli MC, Taieb S, Fournier C, Querleu D. Therapeutic value of pretherapeutic extraperitoneal laparoscopic staging of locally advanced cervical carcinoma. Gynecol Oncol. 2007;105:304–11.
8. Gold MA, Tian C, Whitney CW, Rose PG, Lanciano R. Surgical versus radiographic determination of para-aortic lymph node metastases before chemoradiation for locally advanced cervical carcinoma. A Gynecologic Oncology Group study. Cancer. 2008;112:1954–63.
9. Klauschie J, Wechter ME, Jacob K, Zanagnolo V, Montero R, Magrina J, Kho R. Use of anti-skid material and patient-positioning to prevent patient shifting during robotic-assisted gynecologic procedures. J Minim Invasive Gynecol. 2010;17(4):504–7.

14 Compartmental Theory in Uterine Cancer, Anatomical Considerations and Principles of Compartmental Cervical Cancer Surgery Step by Step

Rainer Kimmig

Introduction

The concept of compartmental surgery in uterine cancer is founded on basic findings with respect to embryologically defined organ compartments and loco-regional tumour spread. It has been summarised by M. Höckel as follows [1]:

> "The ontogenetic theory of loco-regional cancer spread regards cancer as a clinical manifestation of the pathological reactivation and maintenance of the sequential developmental programmes that previously controlled the stepwise embryological morphogenesis of the tissue from which the cancer originated. In the state of morphostasis that characterises adult organisms, these programmes are silenced. During malignant progression, these programmes run in retrograde sequence, which leads to cancer infiltration of ever larger tissue areas. However, because the reactivated morphogenetic programmes need topologically defined tissue domains—morphogenetic fields—to provide positional information for their interpretation, local tumour propagation is confined to permissive compartments (topographically defined tissue domains where malignant cells can survive, migrate, and proliferate), which are determined by the state of malignant progression. The tissue at risk of local tumour spread, the cancer field, is the mature tissue derived from the corresponding morphogenetic field in the embryo, which is labelled with the respective positional information. The theory can be tested morphologically and clinically for all tumours. Verification of this theory would offer substantial potential to improve prognostic assessment and surgical treatment. Identification of the complementary positional information for tumour cells in different ontogenetic stages, and their associated cancer fields, could be a molecular research strategy to further test the theory".

Background

Tested for cancer of the female lower genital tract [1]:

> "The ontogenetic theory of tumour spread is consistent with the pattern analysis of cancers of the lower female genital tract that have been reported over the past 15 years [2–7]. The theory offers an explanation for the inconsistencies found in current concepts regarding the monitoring and treatment of cancer, such as the divergence from the spheroid growth pattern of many primary tumours, the absence of robustness for the prognostic significance of the margin width after wide tumour excision, and the failure to locally control tumours despite adequate surgical procedures [8, 9]. The clinical results noted by our group in the treatment of patients with cervical cancer who underwent total mesometrial resection represent another indication that the theory is correct [2–4] as ontogenetic tumour staging proved to be a better predictor of overall survival than pathological T staging [4]".

These findings will lead consequently to a different understanding of surgical needs for loco-regional cancer control. Wide margins in all directions depending on tumour size will be replaced by complete resection of the embryologically defined organ compartment completely including its border lamella preserving adjacent neighbouring compartmental structures irrespective of the tumour size.

Using this approach it has been shown that loco-regional recurrence rate is extremely low in compartment-confined cervical cancers even without any additional radiotherapy and a concomitantly low incidence of postoperative sequelae [4]. This seems also true for endometrial cancer [10]. However, in contrast to compartmental TME of rectal cancer [11], which is well accepted as standard due to randomised controlled studies, these are still lacking for gynaecological cancers.

With respect to uterine cancer surgery, the lymphatic network of the compartment or even the subcompartment of tumour growth may be used as guide for targeted resection of the entire compartment [12]. The embryonic origin of lymphatic vessels in mammals [13] is regarded as a stepwise process starting from the embryonic veins, where lymphatic endothelial cells (LEC) are initially specified [14]. Although the lymphatic system develops by budding from cardinal veins and paralleling them, no open connections remain except for the jugular lymph sacs which drain to the subclavian veins. The very first draining lymphatic capillaries may also arise from scattered local mesenchymal cells expressing lympho-endothelial markers [13]. Clinically very important is the presence of valves within the lymphatic vessels responsible for a directed "downstream flow" [14]. Thus the lymphatic network marks the organ compartment of origin and

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the lymphatic downstream compartments at risk and thus may be used as guide for resection. In addition, no functional active connections across compartment borders to the bladder or rectum could be detected [12]. The accuracy of identifying the so-called sentinel nodes by ICG (and other agents) has already been shown convincingly for uterine and especially also endometrial cancer [15–19]. As previously shown [20], the compartmental order of pelvic organ systems and their compartmental vascular and lymphatic supply can also be demonstrated in perioperative imaging.

These findings enable to develop a surgical strategy to remove the compartmental tissue at risk, completely, and to preserve adjacent structures, e.g. nerves and neighbouring compartments reducing surgical sequelae to a minimum. The high accuracy of sentinel node technique additionally gives way to surgical strategies reducing overall radicalness by omitting radical lymphadenectomy in regions where no tumour metastases can be expected. This may dramatically reduce morbidity due to lymphadenectomy, theoretically without compromising loco-regional tumour control.

Although this surgical concept was built primarily on basic scientific findings, the hypothesis successfully tested in rectal, cervical and vulvar cancer [4, 6, 11, 15, 20, 21] and even first promising results in endometrial cancer [10].

In this chapter, the technique of total mesometrial resection (TMMR) [22] and the therapeutic lymphadenectomy (tLNE) [23] which were adapted from the Höckel's open procedure to robotic surgery will be described in detail, with special focus on compartmental anatomy, whereas peritoneal mesometrial resection (PMMR) for endometrial cancer will be shown in Chap. 15 [24]. Visualisation of lymphatic network and nodes for intraoperative navigation will also be included [12, 25, 26].

Surgical Technique

In ontogenetically defined compartmental surgery in principle, not only the tumour but also the tumour-bearing organ (sub)compartment is resected completely. For better understanding the embryonic anatomy of development of Müllerian compartment and adjacent bowel and bladder compartments is shown in Fig. 14.1.

Together with the entire compartment, also the connecting structures to the lymphatic compartments at risk are resected; the compartments—also the lymphatics—are separated from the surrounding tissue by the border lamella, which serve as barrier for malignant tumour growth. Thus, resecting the tissue covered by the bordering lamella provides a high degree of loco-regional tumour control by resecting the soil for recurrence even without additional radiotherapy. The resection of the Müllerian compartment together with the lymph compartments at risk in cervical

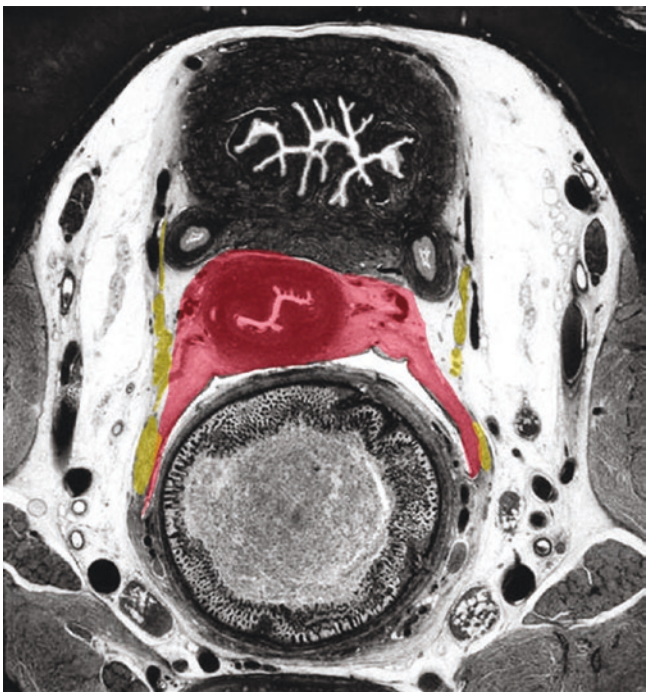


Fig. 14.1 Embryonal defined Müllerian compartment (*red*) with neighbouring compartments of the bladder, rectum and hypogastric nerves (according to [3])

cancer is adequate for tumours of ontogenetical stage oT1 and oT2 (compare [4]). For higher stages extended mesometrial resection (EMMR) or (laterally) extended endopelvic resection ((L)EER) [27] could be adequate, but will not be subject of this chapter. Peritoneal mesometrial resection with therapeutic pelvic and para-aortic lymphadenectomy for endometrial cancer [23, 24] will be described in detail in Chapter. 15.

The difference of TMMR and PMMR is based on the different lymphatic drainage of the cervical and corporal subcompartment. In cervical cancer, therefore, resection of the ligamentous mesometrium dorsally and the deep prespinal and preischiasciatic nodes is necessary, which is not the case for endometrial cancer; on the other hand, the infundibulopelvic ligament has to be completely resected together with the para-aortic nodes due to the lymphatic drainage along the mesonephric ovarian pathway in endometrial cancer, which is not necessary in cervical cancer. In order to remove the entire utero-ovarian vessel network and to guarantee the complete resection of the peritoneum covering the Müllerian compartment in endometrial cancer, this has to be removed, too—giving the procedure its prefix "peritoneal". In Table 14.1 the differences of TMMR and PMMR, as well as in regions of therapeutic lymph node resection, are shown.

For systematic overview of surgical steps and corresponding surgical anatomy, the steps will be worked out in the order of Table 14.1. The technique has originally been described in

Table 14.1 Common and different steps in compartmental hysterectomy and therapeutic lymphadenectomy in cervical and endometrial cancer due to different subcompartments of tumour origin

	Cervical cancer	Endometrial cancer
Uterus, vascular mesometrium	+	+
Uterus, ligamentous mesometrium	+	–
Fallopian tubes	+	+
Ovaries, IP ligaments	–	+
External iliac and paravisceral nodes	+	+
Preischiasciatic and prespinal nodes	+	–
Common iliac nodes	+	+
Inframesenteric para-aortic nodes	+/–	+
Infrarenal para-aortic nodes	+/–	+

[12, 22–26]; furthermore, the technique—although continuously optimised—has been already included in several surgical textbooks or atlases [28–32]. Thus, parts of already published sequences and figures will be implemented.

Uterus, Vascular Mesometrium

First of all, lymphatic drainage along the lymphatic networks of vascular and ligamentous mesometria will be demonstrated: A typical aspect of local lymphatic distribution of ICG following cervical application is shown in Fig. 14.2. The vascular drainage along the uterine vessels to the pelvic iliac region is demonstrated in Fig. 14.3, whereas the posterior pathway along the ligamentous mesometrium to the deep internal iliac and presciatic nodes is shown in Fig. 14.4.

The preparation of the vascular mesometrium starts with identification of the umbilical artery, which has to be prepared to its branching from the internal iliac artery and will be shown on the left. Consecutively, the uterine artery and the superior vesical artery/arteries (variable) can be identified (Fig. 14.5). The bladder will be prepared and pushed down to the level where the ureters enter the bladder exact in the midline along the vaginal wall. Now, the border of the bladder and Müllerian compartment can easily be identified, and these may be separated from each other. The border is avascular except for the vesicouterine anastomoses forming the so-called vesicovaginal ligament (Fig. 14.6). Secondly, the posterior surface of the vascular mesometrium has to be prepared; this is done starting by opening the space between the ureter medially, which should be left in its attachment with the mesureter and the hypogastric nerve plexus, and the anterior branch of the iliac artery, laterally, which should be followed to the branching of the uterine artery (Fig. 14.7). The vascular mesometrium, containing the uterine blood and lymphatic vessels, should be now

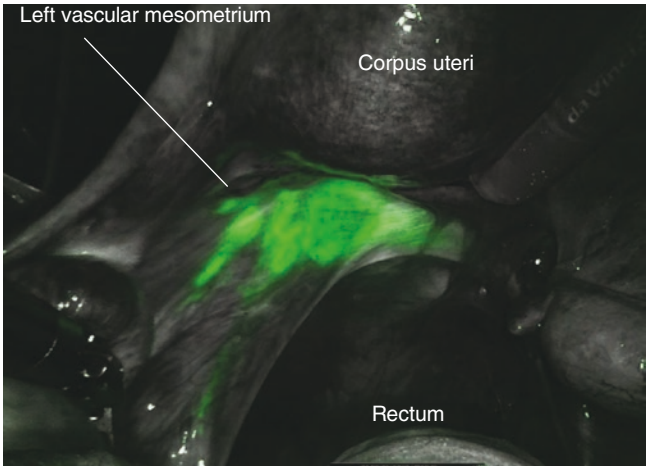


Fig. 14.2 Left vascular mesometrium with lymphatic drainage (ICG)

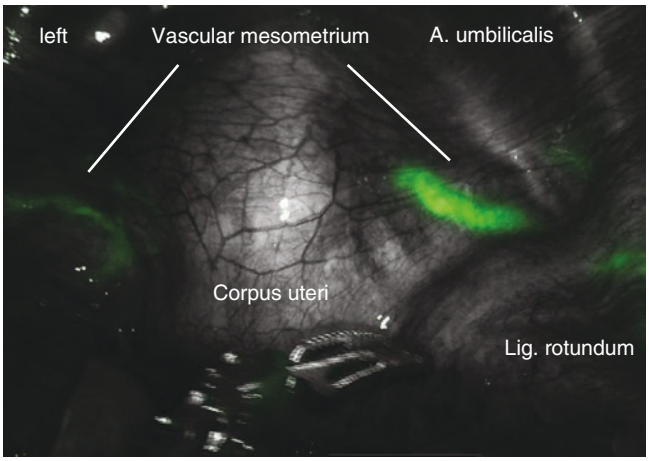


Fig. 14.3 Lymphatic drainage along uterine vessels to pelvic side wall (ICG)

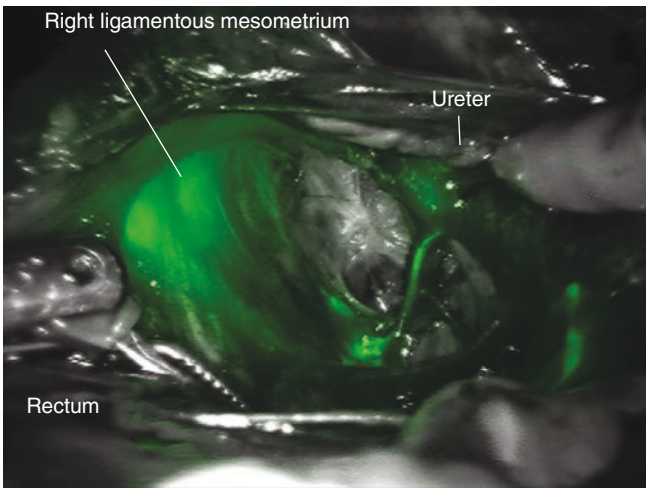


Fig. 14.4 Right ligamentous mesometrium with lymphatic drainage [24]

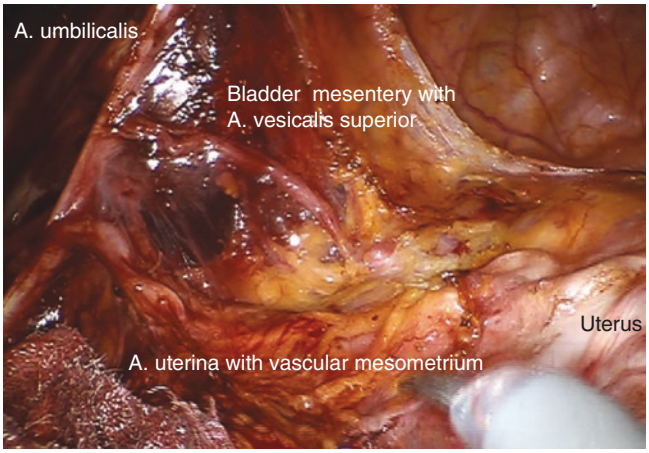


Fig. 14.5 Preparation of the umbilical artery and identification of uterine and superior vesical artery (*left*) [24]

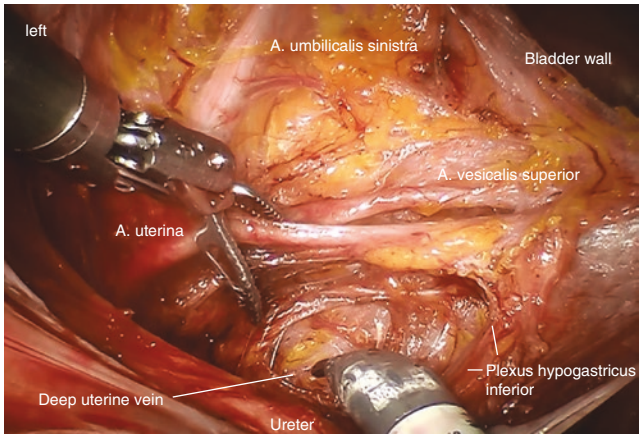


Fig. 14.8 Resection of left vascular mesometrium at the internal iliac branching [22]

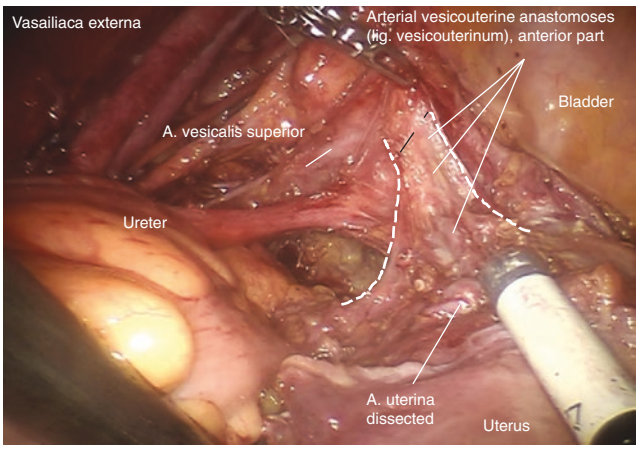


Fig. 14.6 Preparation of the anterior part of the left vascular mesometrium corresponding to vesicouterine ligament [22]

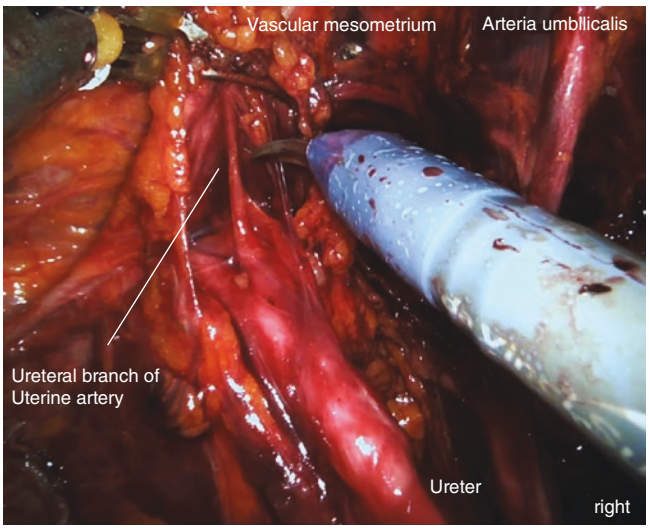


Fig. 14.9 Uterine ureteral supplying artery on the right prior to dissection

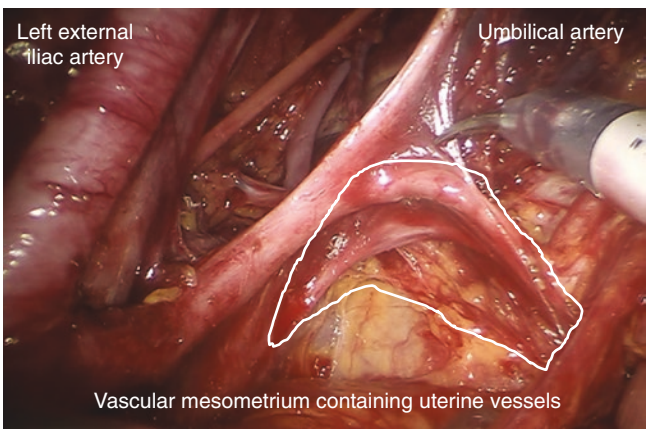


Fig. 14.7 Preparation of the lateral part of the left vascular mesometrium [22]

coagulated and cut entirely at its branching off from their superordinated pelvic vessels (Fig. 14.8). In cervical cancer, the deep uterine vein should be resected, whereas this is not necessary in endometrial cancer. Below the deep uterine vein, there is no more vascular connection to the pelvic vessels, so that the vascular mesometrium may be lifted up to expose the ureter and the uterine ureteral supplying vessels. These have to be cut before the vesicouterine anastomoses and the ureteral tunnel can be exposed (shown on the right, Fig. 14.9). Following dissection of these vessels ventrally to the ureter, the ureter can be pushed laterally and caudally to preserve the mesureter and the laterally and caudally running bladder branches of the lower hypogastric nerve. The uterine branches have to be cut to mobilise the bladder branches (Fig. 14.10]. Finally, in cervical cancer the venous anastomoses dorsally of

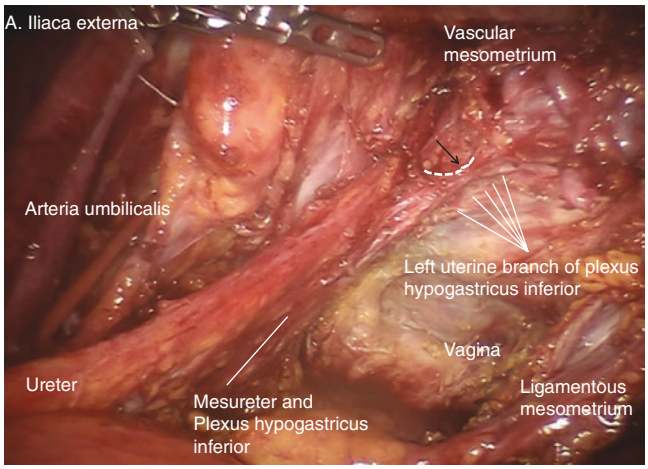


Fig. 14.10 Dissection of left uterine branching nerves to lateralise inferior hypogastric nerve [22]

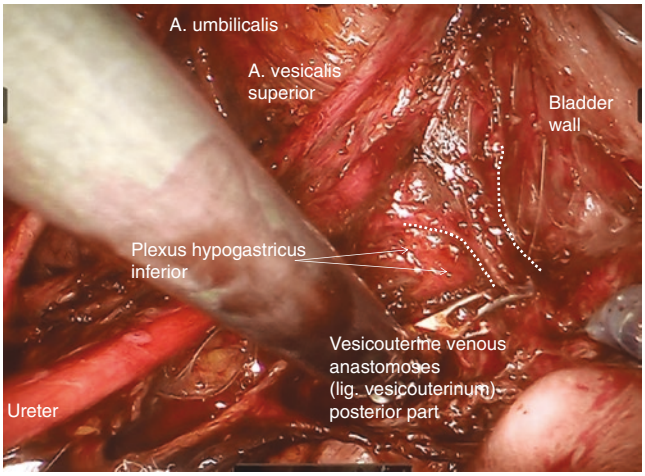


Fig. 14.11 Dissection of venous vesicouterine anastomoses on the left [30]

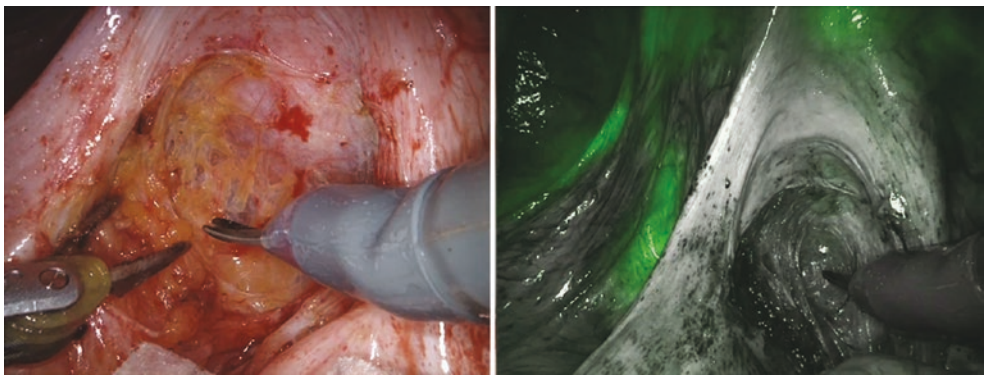


Fig. 14.12 Preparation of rectovaginal space and exposition of ligamentous mesometrium

the ureter have to be cut to reach the mesocolpium (Fig. 14.11). This completes the mobilisation of the vascular mesometrium. The same procedure will be repeated on the right side.

Uterus, Ligamentous Mesometrium

The ligamentous mesometrium is a three-dimensional structure consisting of a rectouterine/rectovaginal part with attachment to the anterior lateral mesorectum and a sacrouterine part surrounding the mesorectum attached to the pelvic fascia and the mesorectum dorsolaterally. The lymphatic network draining the posterior cervix is running at the lateral surface of the sacrouterine part and is draining to the deep internal iliac, mainly presciatic lymph nodes (Fig. 14.4). Caudally ventrally, this lymphatic network is connected to the deep venous lymph network of the vascular mesometrium. At least the drainage of ICG via this posterior pathway does not show regularly connections to the mesorectum, implying that usually the lymph drains predominantly to the pelvic side wall. To prepare the ligamentous mesometrium, first the peritoneum has to be incised to open the rectovaginal space. The rectal fat will be dissected from the vaginal wall and the rectovaginal and rectouterine ligaments on both sides (Fig. 14.12). Secondly, the lateral border of the ligamentous mesometrium is prepared by dissecting the ureter, the mesureter and the inferior hypogastric plexus from the peritoneum before detaching the nerve plexus from the ligamentous mesometrium (Fig. 14.13). Using ICG lymphatic staining, the lymphatic drainage along the ligament may serve as intraoperative guide (Fig. 14.14). Finally, the ligamentous mesometrium will be dissected along its attachments to the mesorectum medially and along the pelvic fascia laterally and mobilised towards the cervix (Fig. 14.15). Close to the cervix, lymphatic vessels connect to the deep (venous) part of vascular mesometrium, all draining posteriorly to the hypogastric plexus to the deep paravisceral internal iliac nodes. This completes the mesometrial resection of the uterus, and the extent of vaginal resection has to be defined. In case of vaginal infiltration, the mesocolpium has to be resected in the same way. The total mesometrial resection is published as video (Video 1 [33]), as it is with the ICG-labelled resection of ligamentous mesometrium (Video 2 [34]).

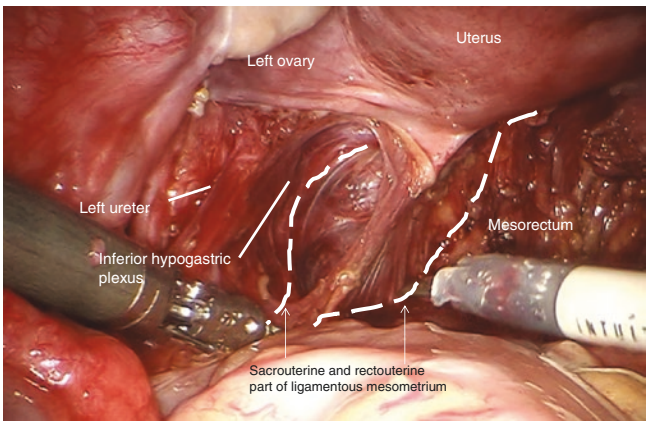


Fig. 14.13 Resection lines of the left ligamentous mesometrium in cervical cancer

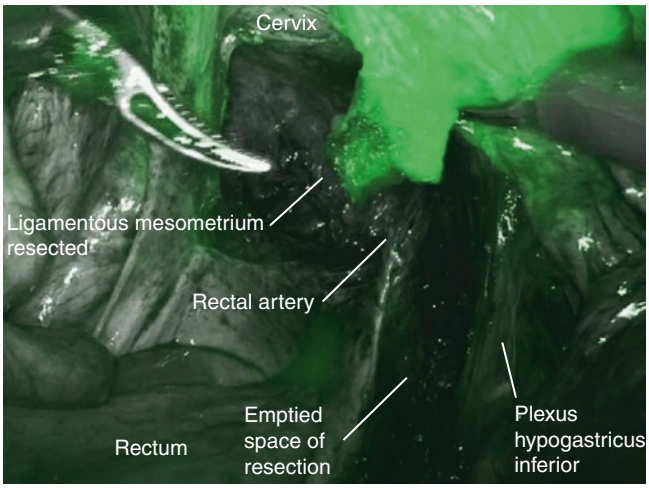
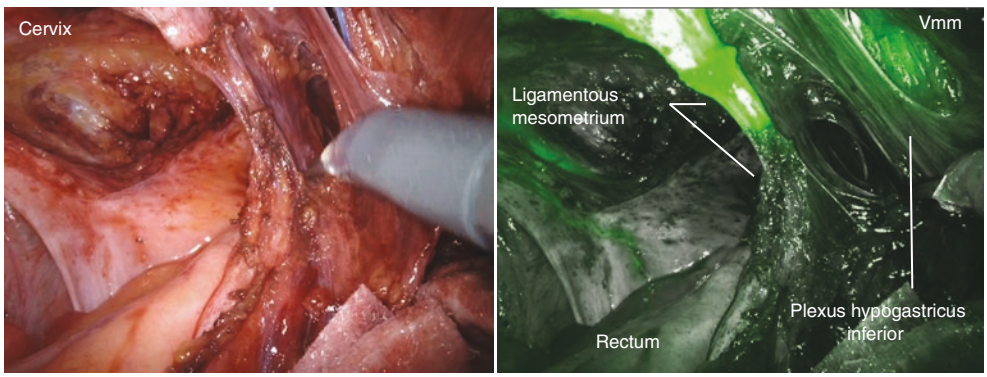


Fig. 14.15 Resected right ligamentous mesometrium labelled by intracervical ICG

Fig. 14.14 ICG labelling of the ligamentous mesometrium and vascular mesometrium (Vmm) on the right



Colpotomy

The extent of vaginal resection has to be determined preoperatively. Since this is the only intracompartmental resection of the whole procedure to maintain vaginal function, at least 1 cm of clear margins has to be achieved. This should be confirmed best intraoperatively by frozen section.

Fallopian Tubes

Embryologically the fallopian tubes are of Müllerian origin in their main part and should therefore be removed in complete compartmental surgery dissecting along the mesosalpinx.

Ovaries, IP Ligaments

In squamous cell cervical cancer, there is no need for ovarian resection, whereas in adenocarcinoma it may be indicated. However, in endometrial cancer ovaries and the infundibulopelvic ligaments are part of the primary draining compartment and should be resected completely.

First Order of Draining Lymph Compartments in Cervical Cancer

In cervical cancer, the cervical compartment is drained to the paravisceral and external iliac nodes along the vascular mesometrium and additionally to the prespinal and presciatic nodes along the ligamentous mesometrium.

At present, state of the art is to resect the first- and second-order lymph compartments, i.e. external iliac, paravisceral and common iliac, including subaortic lymph basin if lymphadenectomy is indicated (Fig. 14.16). Since downstream nodal involvement is extremely rare if the first-order lymph nodes are not involved, accurate sentinel node detection and examination may reduce the extent of lymph node dissection in the future.

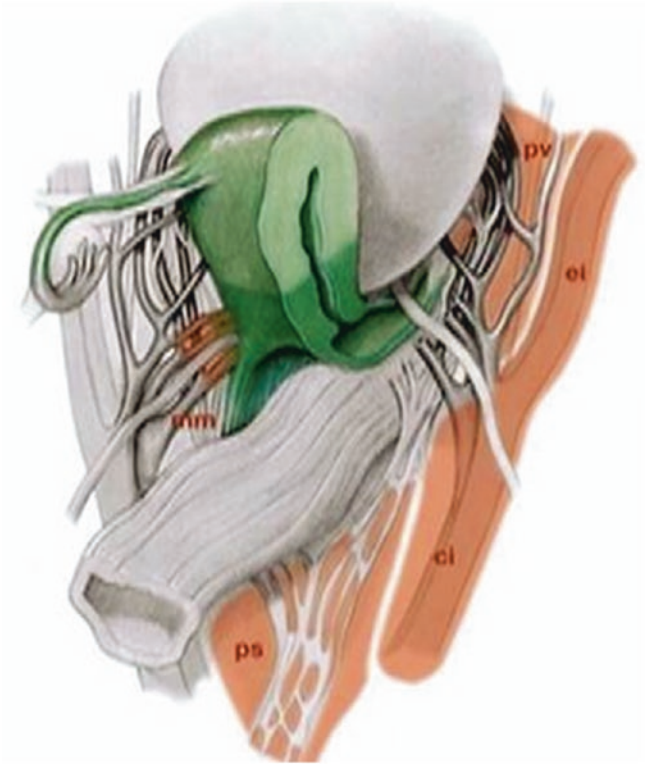


Fig. 14.16 Müllerian compartment (*green*) and connected lymph compartments (*salmon*) in the adult [3]

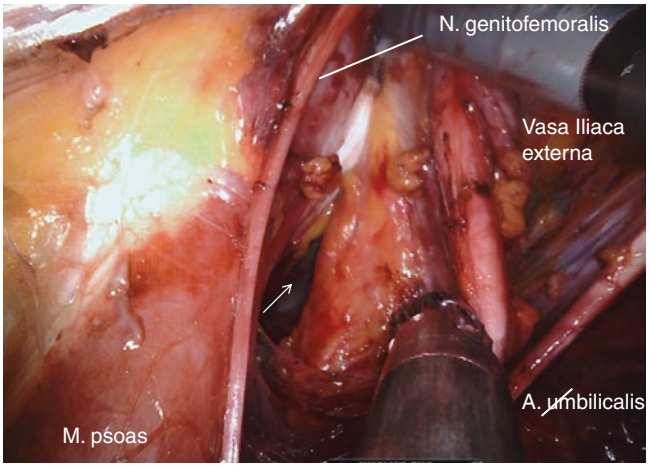


Fig. 14.17 Mobilisation of lateral iliac lymph compartment border (*left*)

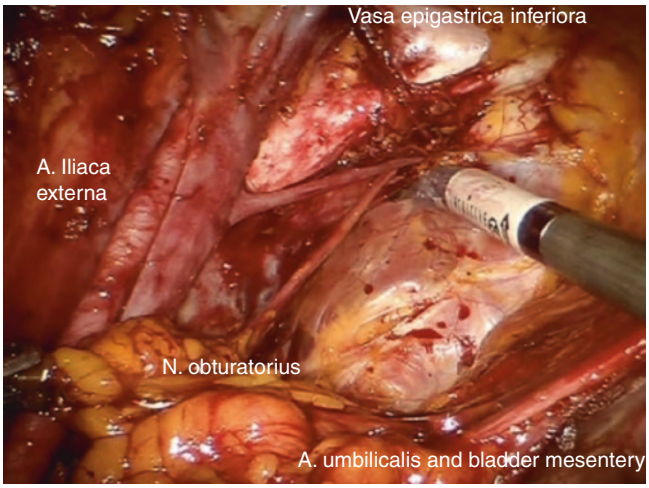


Fig. 14.18 Paravisceral and external iliac nodes—inferior part, *left*

External Iliac and Paravisceral Nodes

To prepare efficiently the external and paravisceral lymph compartment "en bloc", the dissection starts at the ventral lateral border of the compartment by separating and preserving the genitofemoral nerve and the fascia of the psoas muscle from the compartment starting at the iliac bifurcation down to the femoral channel.

Next, the fasciae of the psoas, obturator internus and levator muscles will be detached in the avascular part lateral to the compartment (Fig. 14.17).

Third, lymphatic compartment will be opened along the external iliac artery, to get a medial and a lateral part to unwrap the external iliac vessels.

The procedure continues caudally, above the level of the epigastric and circumflex vessels by cutting the peripheral lymphatic vessels entering the pelvis through the femoral channel (Fig. 14.18). In asymptomatic nodal situation, the lymphatic network caudally to the mentioned vessels should be preserved to reduce risk of lymph oedema.

Before dissecting the nodes, the bladder mesentery will be prepared by identification of the umbilical artery, which will be exposed to the anterior branch of internal iliac artery, and gives access to the lateral surface of the border lamella, separating the bladder compartment from the paravisceral lymphatic compartment. The avascular space will be opened, and the medial preparation meets the lateral at the deepest point of endopelvic fascia (Fig. 14.18).

Nodal dissection starts medially by dissecting the tissue from the artery first and from the vein secondly. The obturator nerve and vessels are identified easily about 1–2 cm below the pecten ossis pubis following a frequently present vein connecting the obturator with the external iliac vein (Fig. 14.18).

Preparing the lymphatic compartment from distally to cranially, it may be mobilised "en bloc", and due to the initial separation laterally and division of the compartment ventrally, it is possible to entirely unwrap the iliac vessels (Video 2 [34]); the deep draining lymph vessels to the presciatic nodes (Fig. 14.19) will guide to the deep posterior part of lymph compartment (Video 3 [35]).

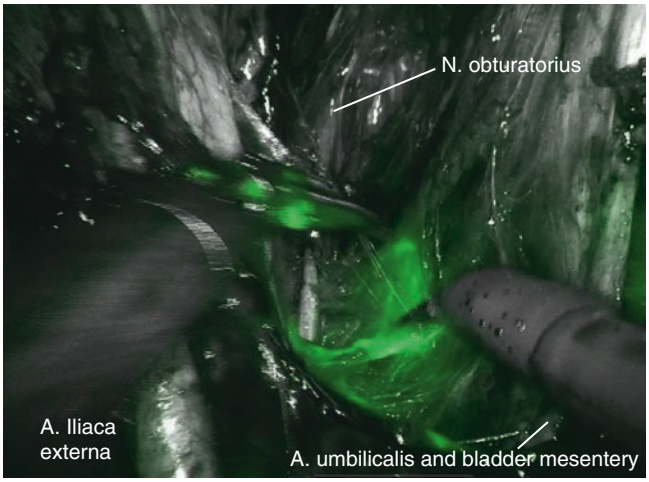


Fig. 14.19 Deep connections to the posterior paravisceral lymph compartment

Second Order of Draining Lymph Compartments in Cervical Cancer

Common Iliac Nodes (Including Subaortic Nodes)

As already mentioned, for safety reasons also the common iliac nodes are recommended to be removed in the standard procedure for cervical cancer treatment. Per definition, common iliac node compartment extends from aortic bifurcation to iliac bifurcation, which is usually marked by the crossing ureter and may also be visualised by ICG (Fig. 14.21).

The dissection starts by peritoneal incision laterally to the right common iliac artery. Being extended cranially and caudally, first the superior hypogastric plexus will be identified and lifted up together with the mesosigma (Fig. 14.22).

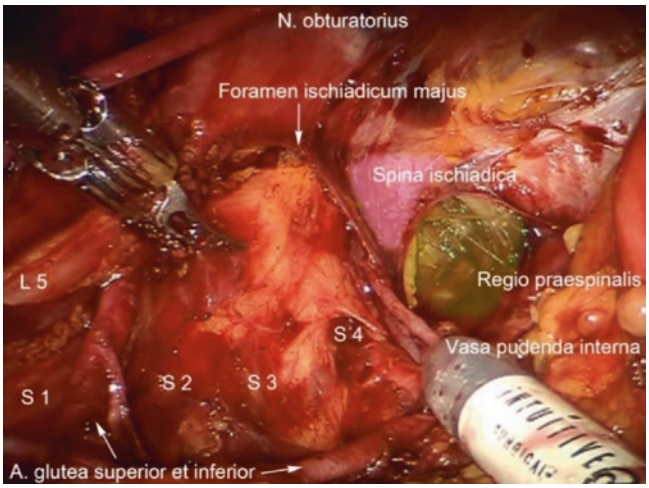


Fig. 14.20 Upper paravisceral, presciatic and prespinal node compartment left [35]

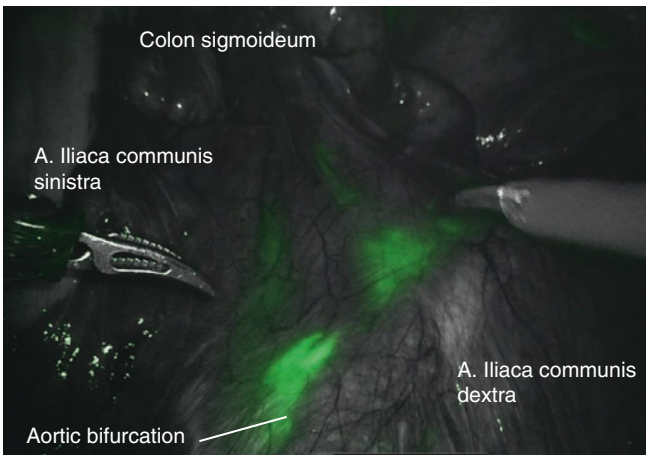


Fig. 14.21 ICG fluorescence of left common iliac and subaortic nodes (cervical injection)

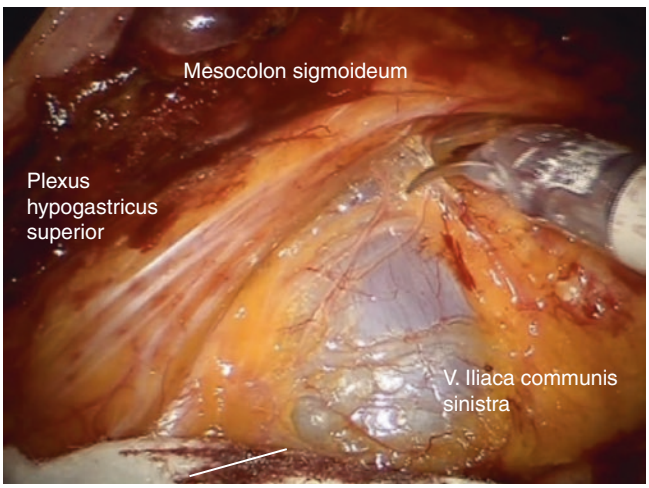


Fig. 14.22 Separation of mesosigma and superior hypogastric plexus from common iliac lymph compartment

Presciatic and Prespinal Nodes

Although the preischiadic and prespinal nodes may already be mobilised and resected together with prepared paravisceral lymph compartment, often nodes between the gluteal vessels and in the prespinal region will remain. However, these have also been removed meticulously to prevent pelvic side wall recurrence if not irradiated postoperatively. This step is not necessary in endometrial cancer, since there is no drainage to this region from uterine corpus.

As shown in Fig. 14.20, the prespinal and presciatic region should be cleaned of lymphatic tissue, and gluteal vessels and the ischiadic nerve are exposed (Video 4 [36]).

Second, the caudal aortic and common iliac lymph compartment will be exposed entirely. The dissection starts at the right side, moving from lateral to medial, first separating the right ureter and mesureter, which is located laterally and dorsally from the compartment.

The nodal compartment will now be dissected by detaching the tissue from the right iliac artery and vein, from the subaortic area exposing the median sacral artery (Fig. 14.23), the promontory and internal and common iliac vessels down to S2 on each side. Completing the dissection on the left in the same way and ending up laterally dorsally at the genitofemoral nerve, the psoas fascia, the ureter and the sympathetic chain. The ICG may again be used to support lymphadenectomy (Fig. 14.23a, b). The final pelvic aspect following first- and second-order lymphadenectomy in cervical cancer is shown in Fig. 14.24 (Video 5 [37]).

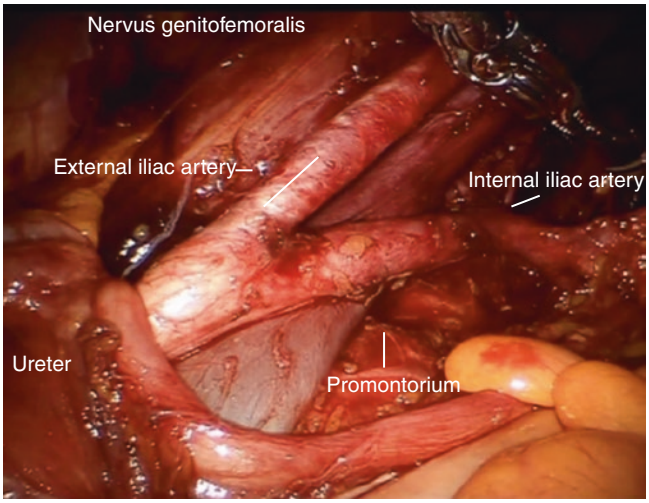


Fig. 14.24 Final result of removal of pelvic iliacal lymph compartments on the left (primary and secondary compartment of the cervix) [23]

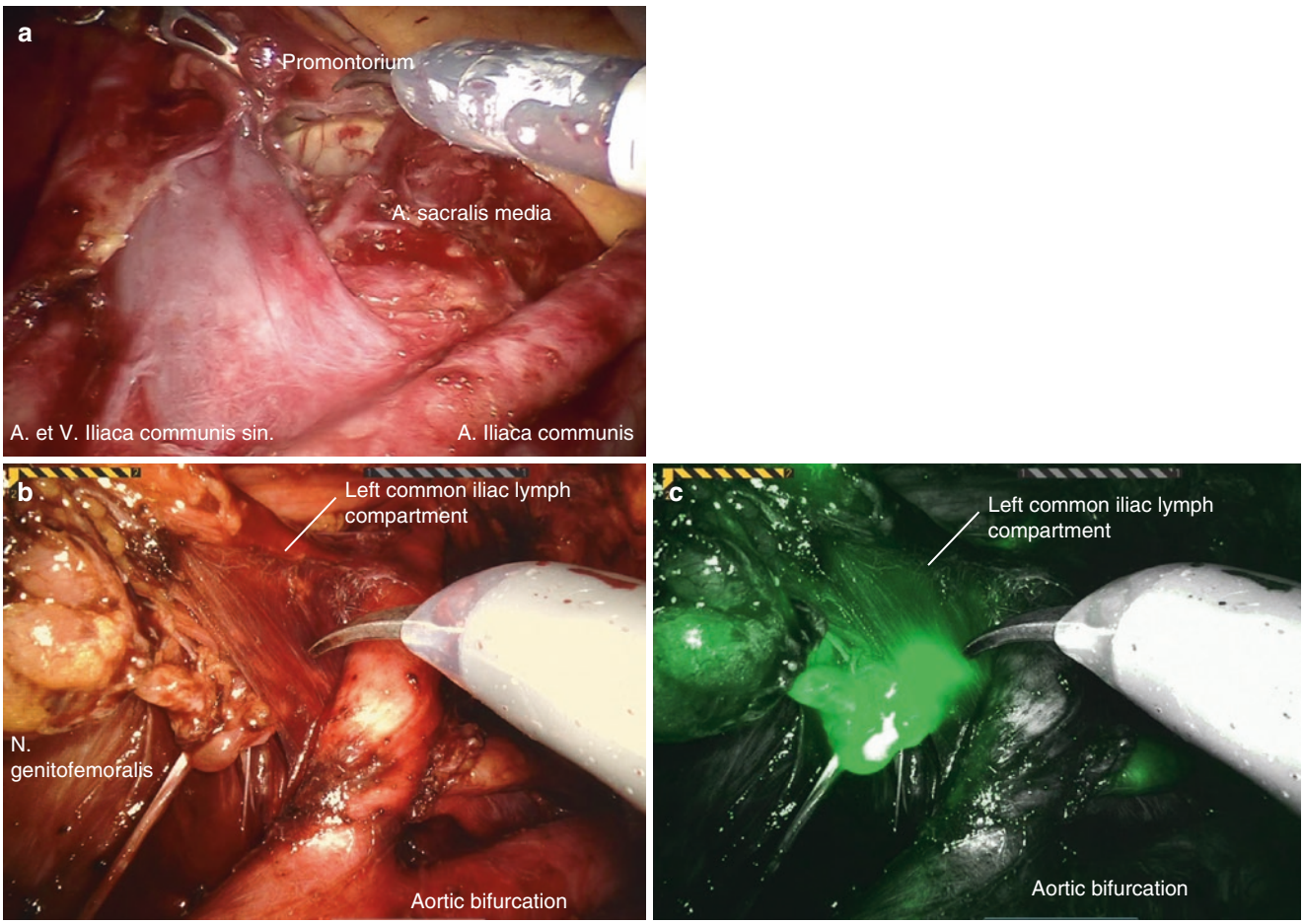


Fig. 14.23 Subaortic (common iliac) lymph compartment removed on the right. (**a**) Unwrapping of the left common iliac artery (normal light). (**b**) Unwrapping of the left common iliac artery (ICG green fluorescence)

Third Order of Draining Lymph Compartments in Cervical Cancer

Inframesenteric Para-aortic Nodes

If necessary, the dissection can be extended cranially by preparing the tissue upwards from the same access, and again ICG fluorescence may guide the dissection (Fig. 14.25a–c). Sometimes, branches of the right or left sympathetic chain to the superior hypogastric plexus have to be cut to lift the plexus up to get sufficient access (Fig. 14.26) for complete resection of the infra- and supramesenteric lymph compartment (Fig. 14.27). The dissection usually may be easily performed, keeping venous vessels in mind arising from the caval vein in this region (Videos 6 and 7 [38, 39]).

Fourth Order of Draining Lymph Compartments in Cervical Cancer

Infrarenal Para-aortic Nodes

If indicated, the procedure will be extended to the infrarenal region of para-aortic nodes. It has to be kept in mind in nodal resection that in cervical cancer the lumbar compartments are of high risk to be involved; thus also the posterior (lumbar) compartments have to be thoroughly removed in addition to the anterior (mesenteric) compartments. On the right side, the resection usually may be performed without problems to the level of the renal veins since no structures to be preserved are crossing. Since the connecting fibres of the right sympathetic chain are crossing from right to left

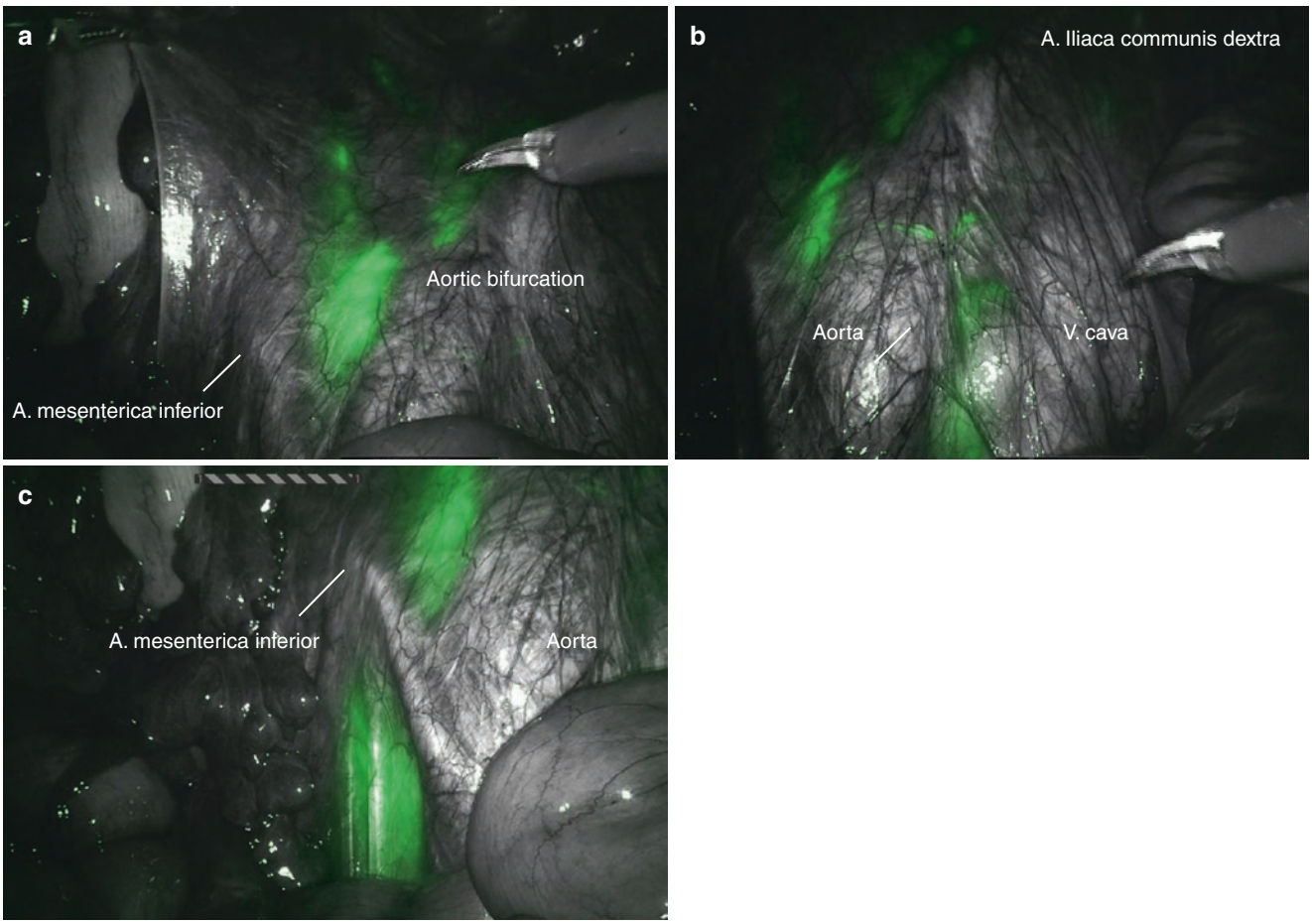


Fig. 14.25 (**a**) Left para-aortic drainage following cervical injection (ICG). (**b**) Right para-aortic drainage following cervical injection (ICG). (**c**) Left para-aortic drainage following cervical injection (ICG) [38]

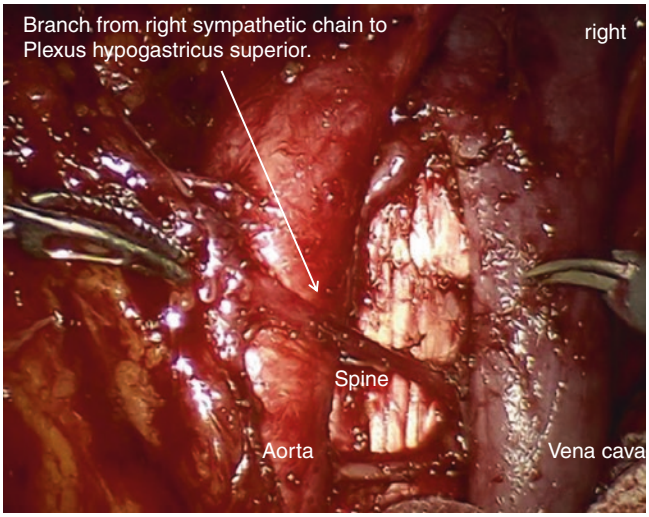


Fig. 14.26 Connecting nerve branch to the right sympathetic chain [30]

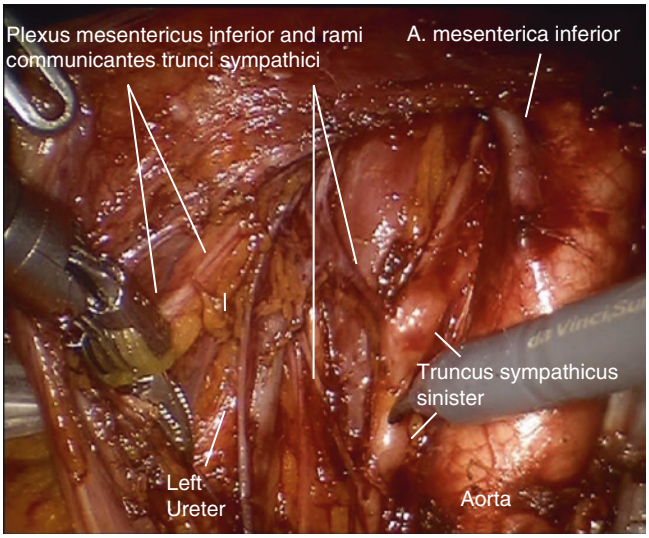


Fig. 14.28 Removal of left supramesenteric lymph compartments [30]

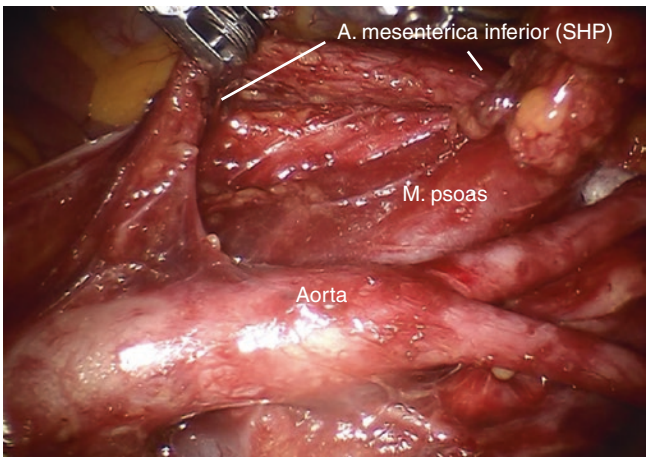


Fig. 14.27 Complete removal of inframesenteric lymph compartments [23]

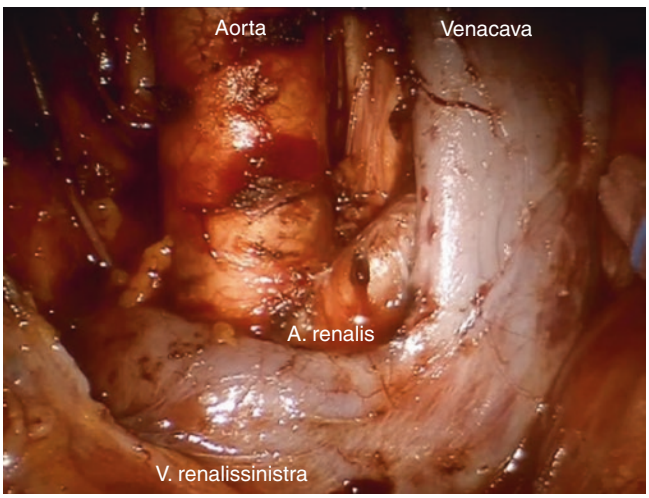


Fig. 14.29 Final result of removal of supramesenteric/infrarenal lymph compartments

between the V. cava and Aorta, the inferior mesenteric plexus and superior hypogastric plexus are fixed and can often only be elevated entirely by cutting some of the branches (Fig. 14.25). On the other hand, the left-sided part of the plexus may usually be preserved, since lymphatic compartments run medially to the fibres (Fig. 14.28).

To complete infrarenal lymphadenectomy, the visceral and lumbar compartments have to be resected up to the renal vessels, by preserving the paravertebral vessels the sympathetic chain and the vegetative nerve plexus as completely as possible. (Fig. 14.29). In ovarian and endometrial cancer, the mesonephric ovarian pathway including the ovarian vessels should entirely be dissected also, which is not mandatory in cervical cancer (Videos 8 and 9 [40, 41]).

Summary and Future Perspective

Compartmental surgery is based on the principals of embryological development of organ compartments, their interactions and consequences for tumour progression. Thus, it enables in early ontogenetic stages to exert tumour control by surgery only. However, in higher stages surgically more radical treatment may be necessary on the one hand, and in addition treatment for control of systemic disease may be necessary. This will mostly be drug based, whereas radiotherapy may be preserved for treatment of recurrent disease which in addition prevents additional toxic side effects.

There are lot of efforts to reduce the surgical radicality to spare unnecessary morbidity. Although, this is extremely important, the way it is done may not be the best one by reducing the extent of resection irrespectively of mode of tumour progression. Diagnostically, sentinel node biopsy and simple hysterectomy may be excellent to define the risk of recurrence with less radical surgery. However therapeutically, this may put patients at risk, who will have early disease between the tumour site and the sentinel region, which could be easily cured by compartmental resection. Since compartmental resection dramatically reduces side effects with respect to classical radical surgery, this should not be accepted. In situations where a spread and thus recurrence cannot be precluded, compartmental surgery could control for loco-regional recurrence by dissecting the whole organ compartment of risk including the sentinel nodes "en bloc". In case of negative nodes, the complete lymphadenectomy could be omitted, which is the responsible of the major part of morbidity today. This approach, although to be shown, would enhance tumour control and reduce morbidity at the same time.

With respect to the high loco-regional control of compartmental surgery and the high accuracy of sentinel node biopsy in predicting nodal disease downstream of the sentinel nodes, the following concept could overcome weaknesses of the current strategy:

Pelvic compartmental organ surgery with removal of the sentinel region "en bloc", i.e. TMMR with TCL (targeted compartmental lymphadenectomy) as has been already described for endometrial cancer (Video 10 [42]), could achieve both excellent loco-regional control and precluding nodal disease, thus reducing morbidity in node-negative patients.

References

1. Höckel M. Morphogenetic fields of embryonic development in locoregional cancer spread. Lancet Oncol. 2015;16:e148–51.
2. Höckel M, Horn LC, Fritsch H. Association between the mesenchymal compartment of uterovaginal organogenesis and local tumour spread in stage IB-IIB cervical carcinoma: a prospective study. Lancet Oncol. 2005;6:751–6.
3. Höckel M, Horn LC, Manthey N, et al. Resection of the embryologically defined uterovaginal (Müllerian) compartment and pelvic control in patients with cervical cancer: a prospective analysis. Lancet Oncol. 2009;10:683–92.
4. Höckel M, Hentschel B, Horn L-C. Association between developmental steps in the organogenesis of the uterine cervix and locoregional progression of cervical cancer: a prospective clinicopathological analysis. Lancet Oncol. 2014;15:445–56.
5. Höckel M, Kahn T, Einenkel J, et al. Local spread of cervical cancer revisited: a clinical and pathological pattern analysis. Gynecol Oncol. 2010;117:401–8.
6. Höckel M, Schmidt K, Bornmann K, Horn L-C, Dornhöfer N. Vulvar field resection: novel approach to the surgical treatment of vulvar cancer based on ontogenetic anatomy. Gynecol Oncol. 2010;119:106–13.
7. Höckel M, Horn L-C, Illig R, Dornhöfer N, Fritsch H. Ontogenetic anatomy of the distal vagina: relevance for local tumor spread and implications for cancer surgery. Gynecol Oncol. 2011;122:313–8.
8. Höckel M, Horn L-C. The puzzle of close surgical margins is not puzzling. Gynecol Oncol. 2013;130:224–5.
9. Höckel M, Dornhöfer N. Understanding and preventing local tumour recurrence. Lancet Oncol. 2009;10:645–6.
10. Kimmig R, Iannaccone A, Aktas B, Buderath P, Heubner M. Embryologically based radical hysterectomy as peritoneal mesometrial resection (PMMR) with pelvic and para-aortic lymphadenectomy for loco-regional tumor control in endometrial cancer: first evidence for efficacy. Arch Gynecol Obstet. 2016;294(1):153–60. https://doi.org/10.1007/s00404-015-3956-y.
11. Heald RJ, Rayan DRH. Recurrence and survival after total mesorectal excision for rectal cancer. Lancet. 1986;327:1479–82.
12. Kimmig R, Aktas B, Buderath P, Rusch P, Heubner M. Intraoperative navigation in robotically assisted compartmental surgery of uterine cancer by visualisation of embryologically derived lymphatic networks with indocyanine-green (ICG). J Surg Oncol. 2016;113(5):554–9. https://doi.org/10.1002/jso.24174.
13. Ribatti D, Crivellato E. The embryonic origins of lymphatic vessels: an historical review. Br J Haematol. 2010;149:669–74.
14. Yang Y, Oliver G. Development of the mammalian lymphatic vasculature. J Clin Invest. 2015;124:888–97.
15. Zahl Eriksson AG, Ducie J, Ali N, McGree ME, Weaver AL, Bogani G, Cliby WA, Dowdy SC, Bakkum-Gamez JN, Abu-Rustum NR, Mariani A, Leitao MM Jr. Comparison of a sentinel lymph node and a selective lymphadenectomy algorithm in patients with endometrioid endometrial carcinoma and limited myometrial invasion. Gynecol Oncol. 2016;140(3):394–9. https://doi.org/10.1016/j.ygyno.2015.12.028.
16. Darin MC, Gómez-Hidalgo NR, Westin SN, Soliman PT, Escobar PF, Frumovitz M, Ramirez PT. Role of indocyanine green in sentinel node mapping in gynecologic cancer: is fluorescence imaging the new standard? J Minim Invasive Gynecol. 2016;23(2):186–93. https://doi.org/10.1016/j.jmig.2015.10.011. Review.
17. Sinno AK, Peijnenburg E, Fader AN, Temkin SM, Stone R, Levinson K, Murdock T, Tanner EJ. Reducing overtreatment: a comparison of lymph node assessment strategies for endometrial cancer. Gynecol Oncol. 2016;143(2):281–6. https://doi.org/10.1016/j.ygyno.2016.08.323.
18. Tschernichovsky R, Diver EJ, Schorge JO, Goodman A. The role of lymphadenectomy versus sentinel lymph node biopsy in early-stage endometrial cancer: a review of the literature. Am J Clin Oncol. 2016;39(5):516–21. https://doi.org/10.1097/COC.0000000000000302.
19. Ruscito I, Gasparri ML, Braicu EI, Bellati F, Raio L, Sehouli J, Mueller MD, Panici PB, Papadia A. Sentinel node mapping in cervical and endometrial cancer: indocyanine green versus other conventional dyes-a meta-analysis. Ann Surg Oncol. 2016;23(11):3749–56. https://doi.org/10.1245/s10434-016-5236-x. Review
20. Santiago IA, Gomes AP, Heald RJ. An ontogenetic approach to gynecologic malignancies. Insights Imaging. 2016;7(3):329–39. https://doi.org/10.1007/s13244-016-0480-y. Review.
21. Höckel M, Horn LC, Tetsch E, Einenkel J. Pattern analysis of regional spread and therapeutic lymph node dissection in cervical cancer based on ontogenetic anatomy. Gynecol Oncol. 2012;125(1):168–74. https://doi.org/10.1016/j.ygyno.2011.12.419.
22. Kimmig R, Wimberger P, Buderath P, Aktas B, Iannaccone A, Heubner M. Definition of compartment-based radical surgery in uterine cancer: radical hysterectomy in cervical cancer as 'total

mesometrial resection (TMMR)' by M Höckel translated to robotic surgery (rTMMR). World J Surg Oncol. 2013;11:211. https://doi.org/10.1186/1477-7819-11-211.
23. Kimmig R, Iannaccone A, Buderath P, Aktas B, Wimberger P, Heubner M. Definition of compartment based radical surgery in uterine cancer-part I: therapeutic pelvic and periaortic lymphadenectomy by Michael Höckel translated to robotic surgery. ISRN Obstet Gynecol. 2013;2013:297921. https://doi.org/10.1155/2013/297921.
24. Kimmig R, Aktas B, Buderath P, Wimberger P, Iannaccone A, Heubner M. Definition of compartment-based radical surgery in uterine cancer: modified radical hysterectomy in intermediate/high-risk endometrial cancer using peritoneal mesometrial resection (PMMR) by M Höckel translated to robotic surgery. World J Surg Oncol. 2013;11:198. https://doi.org/10.1186/1477-7819-11-198.
25. Kimmig R, Aktas B, Buderath P, Heubner M. Robotically assisted peritoneal mesometrial resection (PMMR) in endometrial cancer supported by ICG labeling of the compartmental lymphatic system. Gynecol Oncol Rep. 2016;16:24. https://doi.org/10.1016/j.gore.2016.03.004.
26. Kimmig R, Rusch P, Buderath P, Aktas B. Left paraaortic, inframesenteric lymphadenectomy preserving the superior hypogastric plexus supported by indocyanine green (ICG) labeling of the lymphatic compartment in cervical cancer. Gynecol Oncol Rep. 2016;18:14. https://doi.org/10.1016/j.gore.2016.09.002.
27. Höckel M, Horn LC, Einenkel J. (Laterally) extended endopelvic resection: surgical treatment of locally advanced and recurrent cancer of the uterine cervix and vagina based on ontogenetic anatomy. Gynecol Oncol. 2012;127(2):297–302. https://doi.org/10.1016/j.ygyno.2012.07.120.
28. Kimmig R. Diagnostische und therapeutische Lymphonodektomie and Totale Mesometriale Resektion nach Höckel. In: Wagner U, Hoffmann R, Bartsch DK, editors. Operationsatlas Gynäkologische Onkologie. Berlin: Springer; 2013. https://doi.org/10.1007/978-3-642-35128-0. pp. 97–108 and 117–128. eBook ISBN: 978-3-642-35128-0.
29. Kimmig R, Aktas B, Heubner M. Compartment-based radical surgery: the TMMR, FMMR and PMMR family in uterine cancer. In: Kilic SG, Ertan K, Kose MF, editors. Robotic surgery. Practical examples in gynecology. Berlin: De Gruyter; 2013. p. 287–318. ISBN: 978-3-11-030657-6. Chapter 23.
30. Kimmig R. Chapter 69: Robotic-assisted radical hysterectomy as compartmental resection according to rTMMR and rPMMR and Chapter 70: Robotically assisted therapeutic pelvic and paraaortic lymphadenectomy in uterine cancer. In: Alkatout I, Mettler L, editors. Hysterectomy, a comprehensive surgical approach. Switzerland: Springer; 2017. ISBN: 978-3-319-22496-1. (in press).
31. Höckel M, Kimmig R. Chapter 50: Compartment resection in gynaecologic oncology: TMMR and LEER. In: Ayhan A, Reed N, Gultekin M, Dursun P, editors. Textbook of gynaecological oncology (ESGO): Günes; 2016. p. 45–454. ISBN: 978-975-277-645-6.
32. Kimmig R. Chapter 64: Compartment resection in endometrial cancer: peritoneal mesometrial resection (PMMR) and therapeutic lymphadenectomy. In: Ayhan A, Reed N, Gultekin M, Dursun P, editors. Textbook of gynaecological oncology (ESGO): Günes; 2016. p. 558–64. ISBN: 978-975-277-645-6.
33. Kimmig K. Video 1. Laparoscopic robotically assisted total mesometrial resection and therapeutic lymphadenectomy (TMMR) according to Michal Hoeckel's technique—part two. ESGO eAcademy. 2 Aug 2012; 33615. http://eacademy.esgo.org/esgo/2000/dvds/33615/k.rainer.kimmig.laparoscopic.robotically.assisted.total.medometrial.resection.html?f=p14s49121m10.
34. Kimmig K. Video 2. Robotic surgery in gynaecology—therapeutic lymphadenectomy of the pelvic nodes (TPL1)—module II: lower paravisceral and external iliac nodes. ESGO eAcademy. 3 Oct 2013; 38737. http://eacademy.esgo.org/esgo/2000/dvds/38737/k.rainer.kimmig.robotic.surgery.in.gynaecology.-.therapeutic.lymphadenectomy.html?f=s49121m10.39.
35. Kimmig R, Buderath P, Rusch P, Aktas B. Video 3. Surgical anatomy of the ligamentous mesometrium and robotically assisted ICG-guided resection in cervical cancer. Educational video. Gynecol Oncol Rep. 2016;20:4.
36. Kimmig K. Video 4. Robotic surgery in gynecology—therapeutic lymphadenectomy of the pelvic nodes (TPL1)—module III: upper paravisceral—prespinal and preischaidic nodes. ESGO eAcademy. 10 Oct 2013; 38738. http://eacademy.esgo.org/esgo/2000/dvds/38738/k.rainer.kimmig.robotic.surgery.in.gynecology.-.therapeutic.lymphadenectomy.of.html?f=l5987m10.
37. Kimmig K. Video 5. Robotic surgery in gynaecology—therapeutic lymphadenectomy of the pelvic nodes (TPL1)—module I: common iliac, subaortic and presacral nodes. ESGO eAcademy. 10 Oct 2013;38736. http://eacademy.esgo.org/esgo/2000/dvds/38736/k.rainer.kimmig.robotic.surgery.in.gynaecology.-.therapeutic.lymphadenectomy.html?f=l5987m10.
38. Kimmig K. Video 6. Robotic surgery in gynaecology—therapeutic paraaortic lymphadenectomy (TPL2)—module IV: inframesenteric periaortic nodes. ESGO eAcademy. 8 Oct 2013; 95407. http://eacademy.esgo.org/esgo/2000/dvds/95407/k.rainer.kimmig.robotic.surgery.in.gynaecology.-.therapeutic.paraaortic.html?f=l5987m10.
39. Kimmig R, Rusch P, Buderath P, Aktas B. Video 7. Left paraaortic, inframesenteric lymphadenectomy preserving the superior hypogastric plexus supported by indocyanine green (ICG) labeling of the lymphatic compartment in cervical cancer. Gynecol Oncol Rep. 2016;18:14. https://doi.org/10.1016/j.gore.2016.09.002.
40. Kimmig K. Video 8. Robotic surgery in gynaecology—therapeutic paraaortic lymphadenectomy (TPL2)—module V1: infrarenal/supramesenteric periaortic nodes. ESGO eAcademy. 6 Jun 2013; 95405. http://eacademy.esgo.org/esgo/2000/dvds/95405/k.rainer.kimmig.robotic.surgery.in.gynaecology.-.therapeutic.paraaortic.html?f=s49121m10.
41. Kimmig K. Video 9. Robotic surgery in gynecology—therapeutic paraaortic lymphadenectomy (TPL2)—module V2: infrarenal periaortic nodes with resection of 'mesonephric' compartment of ovarian vessels. ESGO eAcademy. 3 Jun 2014; 95406. http://eacademy.esgo.org/esgo/2000/dvds/95406/k.rainer.kimmig.robotic.surgery.in.gynecology.-.therapeutic.paraaortic.html?f=s49121m10.
42. Kimmig R, Buderath P, Rusch P, Aktas B. Video 10. Technique of ICG-guided targeted compartmental pelvic lymphadenectomy (TCL) combined with pelvic peritoneal mesometrial resection (PMMR) for locoregional control of endometrial cancer—a proposal. Educational video. Gynecol Oncol Rep. 2017;20:125–6.

15 Peritoneal Mesometrial Resection (PMMR) with Therapeutic Lymphadenectomy (tLNE) in Endometrial Cancer

Rainer Kimmig

Introduction

PMMR (peritoneal mesometrial resection) is the surgical equivalent to TMMR (total mesometrial resection) in endometrial cancer and has first been described in detail in 2013 [1, 2]. Background and principles of compartmental surgery and differences of the surgical approach due to the different subcompartment of tumour origin are outlined in Chapter 14. In short, with respect to the tumour bearing subcompartment of uterine corpus, there is no drainage to the ligamentous mesometrium (i.e. sacrouterine ligament) and nodes of the sacrouterine and preischiadic region [3]. Thus, neither the ligamentous mesometrium nor the preischiadic nodes have to be dissected; on the other hand, there is drainage from the fundus along the mesonephric ovarian vessel system suggesting complete resection of these structures including the para-aortic mesenteric lymph nodes being first-order regional lymph compartments on the basis of the concept of compartmental surgery.

These differences in lymphatic drainage may be demonstrated functionally with injection of indocyanine green (ICG) into the uterine corpus prior to surgery. In Fig. 15.1 it is shown that there is no drainage along the ligamentous mesometrium, whereas the vascular mesometrium fully drains. The drainage along the fundus (Fig. 15.2) may be followed along the ovarian vessels (Fig. 15.3) up to the para-aortic nodes ventrally of the aorta and between aorta and caval vein (Fig. 15.4). The data with respect to local uterine drainage have been already summarized together with the results following cervical injection in [3].

Electronic supplementary material The online version of this chapter (doi:10.1007/978-3-319-63429-6_15) contains supplementary material, which is available to authorized users.

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Technique of PMMR

Following inspection and coagulation of fallopian tubes in endometrial cancer, the peritoneum is incised lateral to the right infundibulopelvic ligament, and if not primarily resected completely—which should always be done in complete PMMR—the ovarian vessels are coagulated and cut well above the adnexa. The peritoneum is divided to the right round ligament.

Step 1: The peritoneum is incised as shown in Fig. 15.3a that still covers the utero-ovarian vessel network which contains also the lymphatics (Fig. 15.3b) to be resected, first, following dissection of the round ligament ventrally along the border between Müllerian and bladder peritoneum to the cervicovesical fold. The bladder is pushed down to expose the vagina down at the level where it is planned to be resected.

Step 2: Second, the peritoneal incision is done similarly at the posterior peritoneal surface to open the rectovaginal space in the same way (Fig. 15.3c, d). This integral part of PMMR will be done for two reasons: first, to resect the embryologically "uterine peritoneum" completely and, second, not to dissociate the supplying and draining vascular and lymph vessel system of the Müllerian and mesonephric compartments.

Step 3: The umbilical artery will be prepared to its origin from the internal iliac artery and the branching of the uterine and the superior vesical artery will be identified.

Step 4: The vascular mesometrium will be exposed ventrally by detaching it from the bladder mesentery opening the avascular space between the uterine and superior vesical artery (Fig. 15.4a, b) and posteriorly by opening the avascular space between the ureter, the uterine artery and the internal iliac artery. In case of ICG labelling the lymphatic draining vessels will cross the umbilical artery at the origin of the uterine artery connecting to the iliac sentinel nodes (Fig. 15.5).

Step 5: The vascular mesometrium containing the uterine artery and vein will be coagulated and cut at the origin from

A. El-Ghobashy et al. (eds.), *Textbook of Gynecologic Robotic Surgery*, https://doi.org/10.1007/978-3-319-63429-6_15

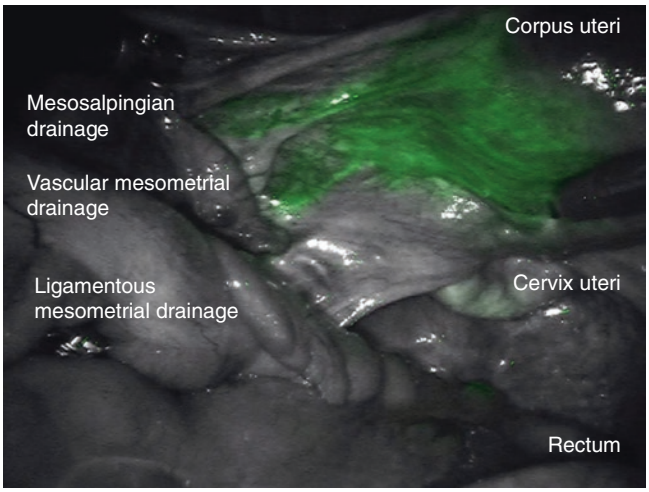

Fig. 15.1 Lymphatic corporal network in endometrial cancer (corporal injection of ICG)

the iliac vessels (Fig. 15.6) and lifted up together ventrally and medially to identify the ureter and its supplying vessels (Fig. 15.7).

Step 6: Connecting vessels from the vascular mesometrium to the ureter will be coagulated and cut.

Step 7: The uterovesical anastomosing vessels anteriorly to the ureter will be identified and cut (Fig. 15.8, so-called vesicouterine ligament). Now the ureter can be mobilized and pushed laterally caudally.

Step 8: The cervical venous drainage and the ligamentous mesometrium are now coagulated and cut paracervically to expose the vaginal wall.

Steps 1–8 will be repeated on the left side.

Step 9: Colpotomy and removal of the PMMR specimen along the vagina.

The fluorescence persists throughout the surgery as can be seen in Fig. 15.9.

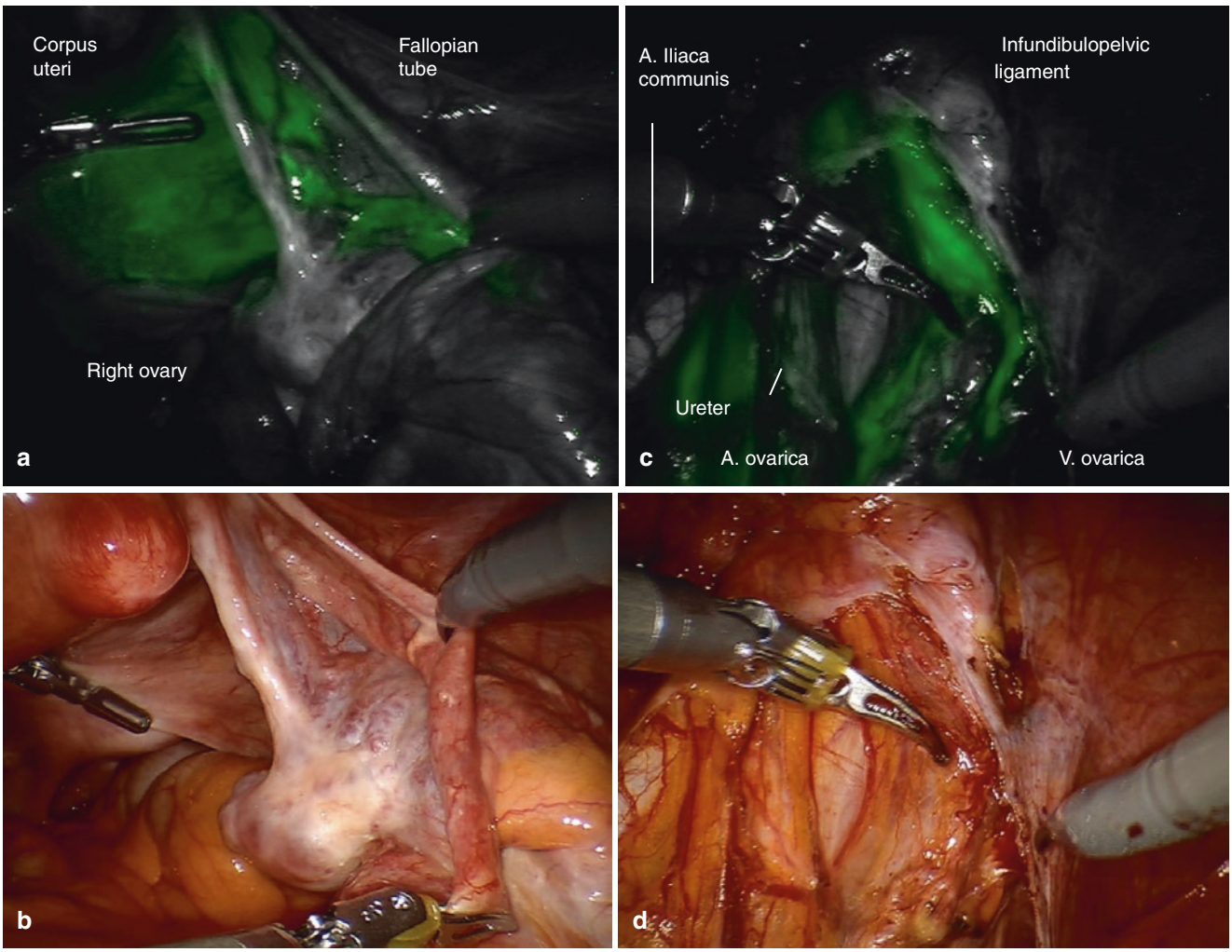

Fig. 15.2 Lymph drainage right infundibulopelvic ligament (ICG and real light comparison) [1]

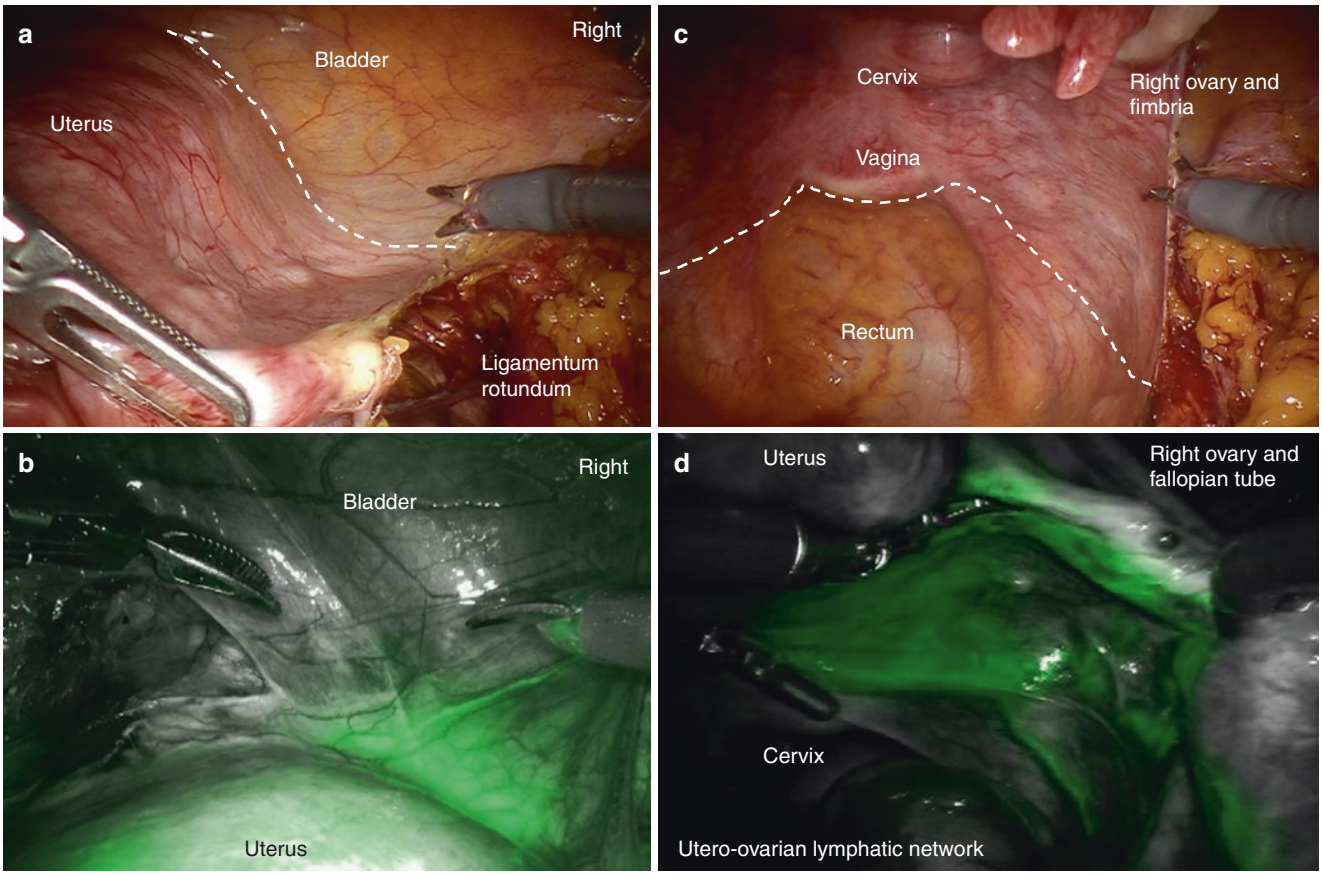

Fig. 15.3 Ventral (**a**, **b**) and dorsal (**c**, **d**) peritoneal incision in PMMR covering the utero-ovarian vessel network with (**b**, **d**) and without (**a**, **c**) intracorporal ICG application [1, 2]

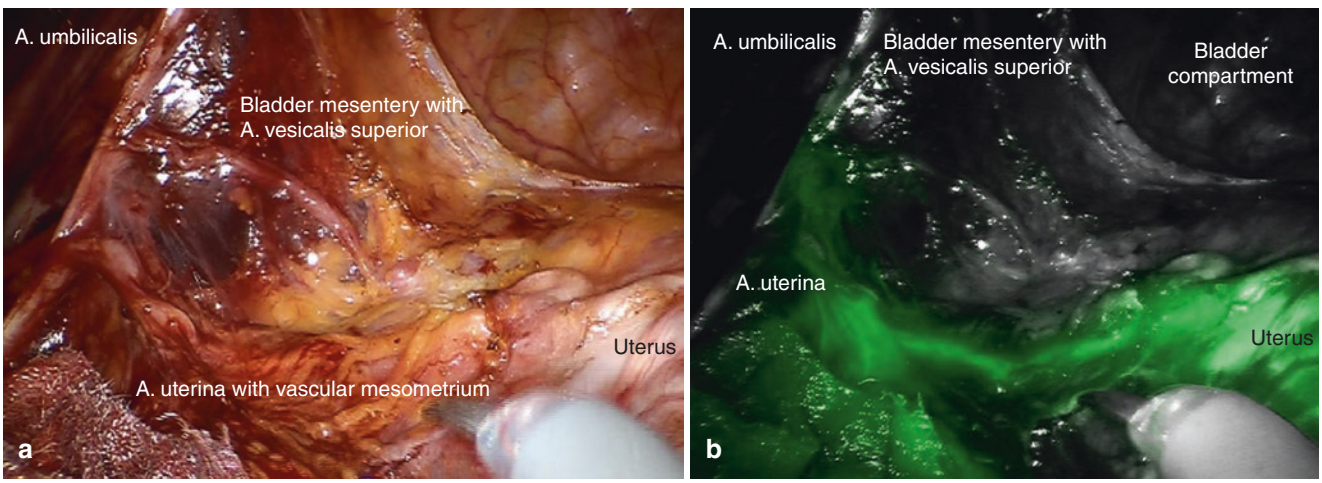

Fig. 15.4 (**a**) Preparation of the umbilical artery and identification of uterine and superior vesical artery (*left*) [3]. (**b**) Correspondent ICG lymphography of left vascular mesometrium [3]

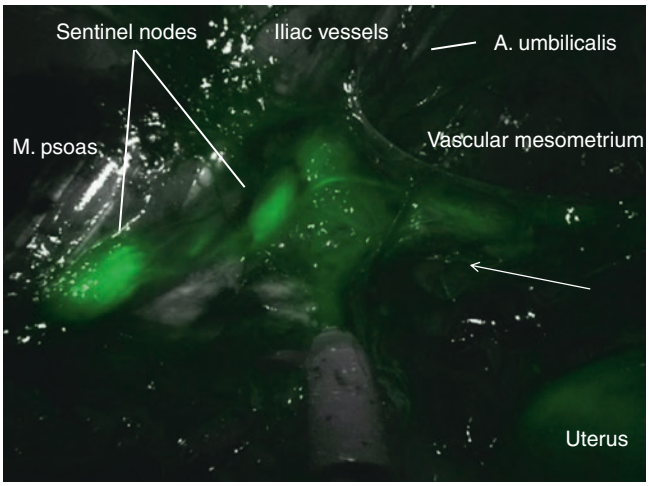

Fig. 15.5 Vascular mesometrium and iliac sentinel nodes on the left (ICG)

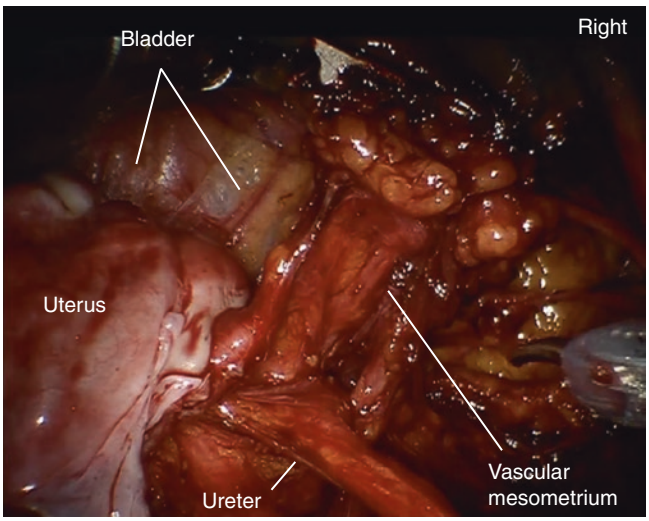

Fig. 15.7 Lifting up the entire vascular mesometrium including uterine vessels to identify the vesicouterine vessel anastomoses

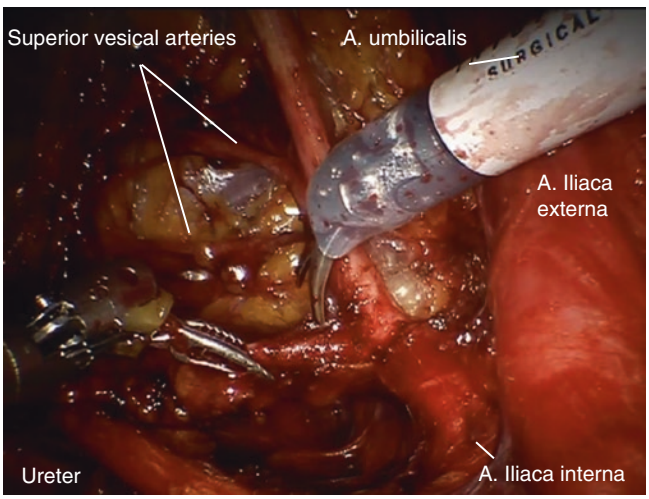

Fig. 15.6 Resection of entire vascular mesometrium including uterine vessels at the branching from internal iliac vessels on the right

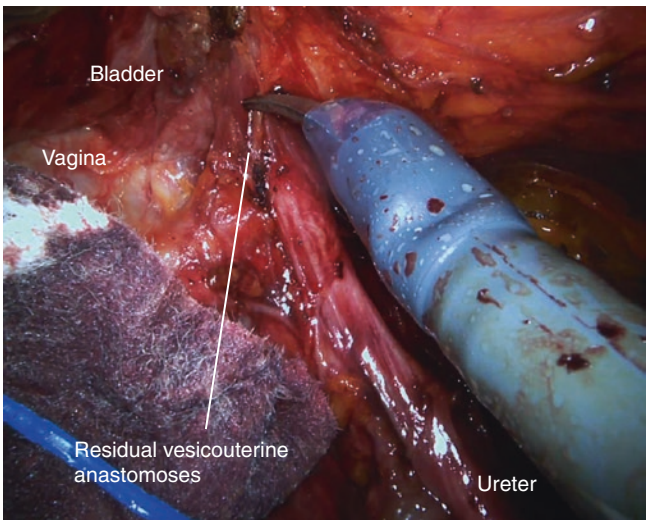

Fig. 15.8 Division of anterior vascular mesometrium anastomoses to free ureter and bladder from attachment to uterine compartment on the right developing the ureter on the right

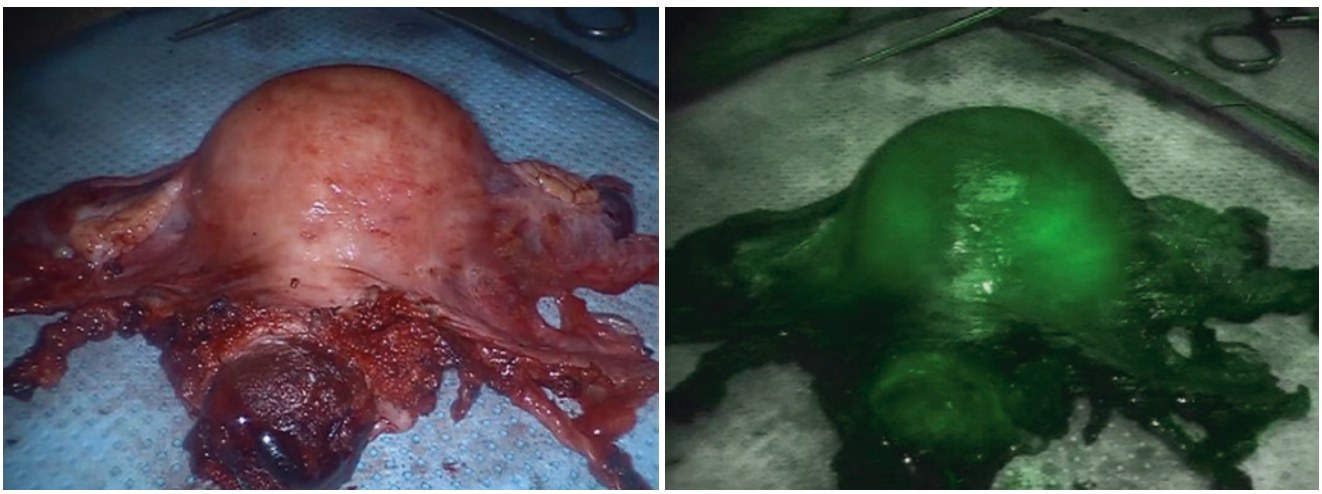

Fig. 15.9 PMMR specimen postoperatively, native and with ICG fluorescence [11]

Therapeutic Pelvic and Para-aortic Lymphadenectomy

Lymphadenectomy is done as outlined in Chapter 14 for cervical cancer with two important differences:

First, prespinal and preischiadic nodes do *not* have to be removed since they are not involved into the drainage of uterine corpus.

On the other hand, the para-aortic infrarenal lymph nodes together and in continuity with the draining ovarian lymph vessels "en bloc" *have to be* removed in all patients with indication for lymphadenectomy due to the "mesonephric" lymphatic drainage along this pathway.

The infundibulopelvic ligament containing the ovarian vessels (Fig. 15.10) will be followed dissecting the anastomoses to the colonic vessels (Fig. 15.11) as demonstrated in Fig. 15.12 for the right side. On each side up the ovarian vessels will be coagulated and cut close to their origin from the caval vein, aorta and left renal vein (Fig. 15.13). There are no direct lymph connections to the lumbar chain of para-aortic nodes. The connecting lymph vessels enter the mesenteric para-aortic lymph basin and end up around and above the inferior mesenteric artery on the right (Fig. 15.14a, b) and close to the renal vein on the left (Fig. 15.15a, b). As can be seen with ICG fluorescence, the lymphatic vessels run caudally and medially of the corresponding ovarian vessels, which is the reason why they join the para-aortic nodes lower on the right compared to the left side.

Thus the para-aortic nodal compartments may be resected in continuity with the mesonephric draining system, i.e. infundibulopelvic ligaments, and may be resected together with the uterus entirely as shown in Fig. 15.16 for the right and Fig. 15.17 for the left side. The entire PMMR specimen with adjacent pelvic and para-aortic lymph compartments is shown in Fig. 15.18.

Although it is not mandatory to remove the whole organ and lymph compartments in physical continuity as shown, it should always be done functionally.

Nota Bene

The complete procedure of lymphadenectomy and PMMR can be studied in detail in several educational videos [4–9]; the preparation of para-aortic utero-ovarian "sentinel nodes" and ICG-guided left infrarenal para-aortic lymphadenectomy is demonstrated in [10].

First Results of PMMR and Therapeutic Pelvic and Para-aortic LNE in Intermediate and High-Risk Endometrial Cancer

Assuming that compartmental surgery exerts its effect similar to cervical cancer with respect to locoregional control by removing the soil for locoregional recurrence, the PMMR and therapeutic LNE should reduce the incidence of locoregional recurrence. In a first series we could show that locoregional recurrence was as low as 2.8%, which was expected to be at least fivefold with respect to the high number of intermediate-/high-risk tumours and the low rate of adjuvant

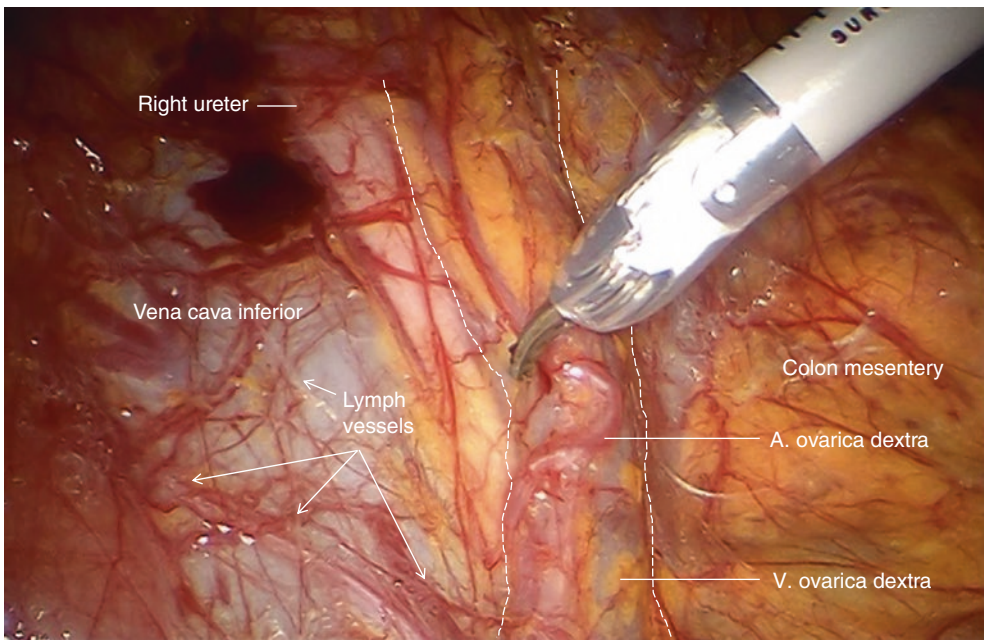

Fig. 15.10 Identification of right infundibulopelvic ligament, ureter and right colon mesentery [1]

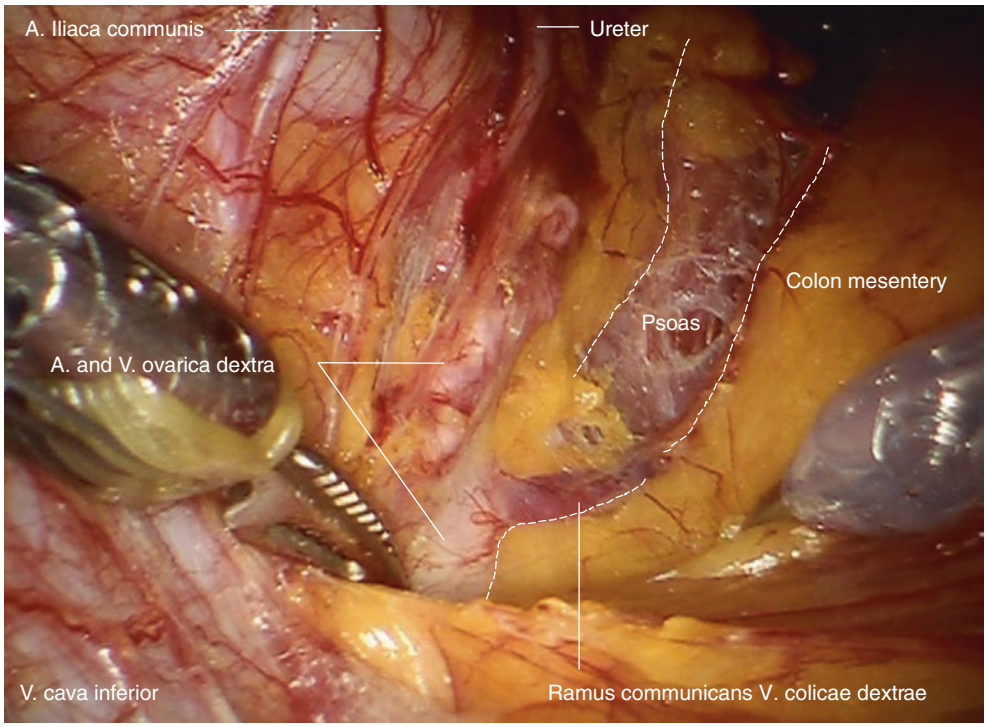

Fig. 15.11 Separation of right infundibulopelvic ligament from right colon mesentery [1]

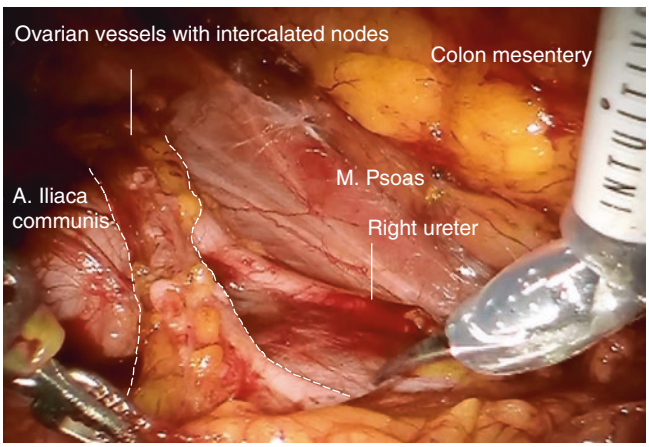

Fig. 15.12 Separation of ovarian vessel system from mesocolon, psoas muscle, ureter, and caval vein [1]

radiotherapy around 10% [11] at least encouraging further studies.

On the other hand, a lot of endometrial cancer patients experience high morbidity, and thus reduction of surgical risk could be beneficial especially by omitting para-aortic and even pelvic lymphadenectomy. Pelvic sentinel node excision has been widely investigated, and in fact, it seems reasonable to omit systematic lymphadenectomy in proven sentinel-negative patients, since the incidence of isolated positive para-aortic nodes is calculated to be about 1–2% [12–15]. This seems not to be true for pT1b, G2-3 tumours and to a lesser degree for non-endometrioid histology with significantly higher rates of isolated para-aortic nodes [16]. In these patients still systematic para-aortic lymphadenectomy should be performed, which may also be replaced by para-aortic sentinel lymph node excision. Whereas for pelvic sentinel node excision cervical application of ICG seems to work equally well, this is known not to be true for para-aortic sentinels, which should be marked by intracorporal application as demonstrated in [10].

Future Perspectives: PMMR and Pelvic Targeted Compartmental Lymphadenectomy (TCL)

With respect to current literature, it seems true that in the majority of the patients diagnostic pelvic and para-aortic lymphadenectomy may be safely replaced by pelvic sentinel lymphadenectomy which may significantly reduce surgical morbidity. However, there will still be some problems to be solved:

1. There is still a need for adjuvant irradiation due to enhanced risk of locoregional recurrence in case of risk factors increasing again morbidity.
2. There are 5–10% of patients with G1 tumours [16] having positive nodes not receiving a diagnostic lymphadenectomy because of an impaired balance of benefit/risk ratio but in fact being at risk.

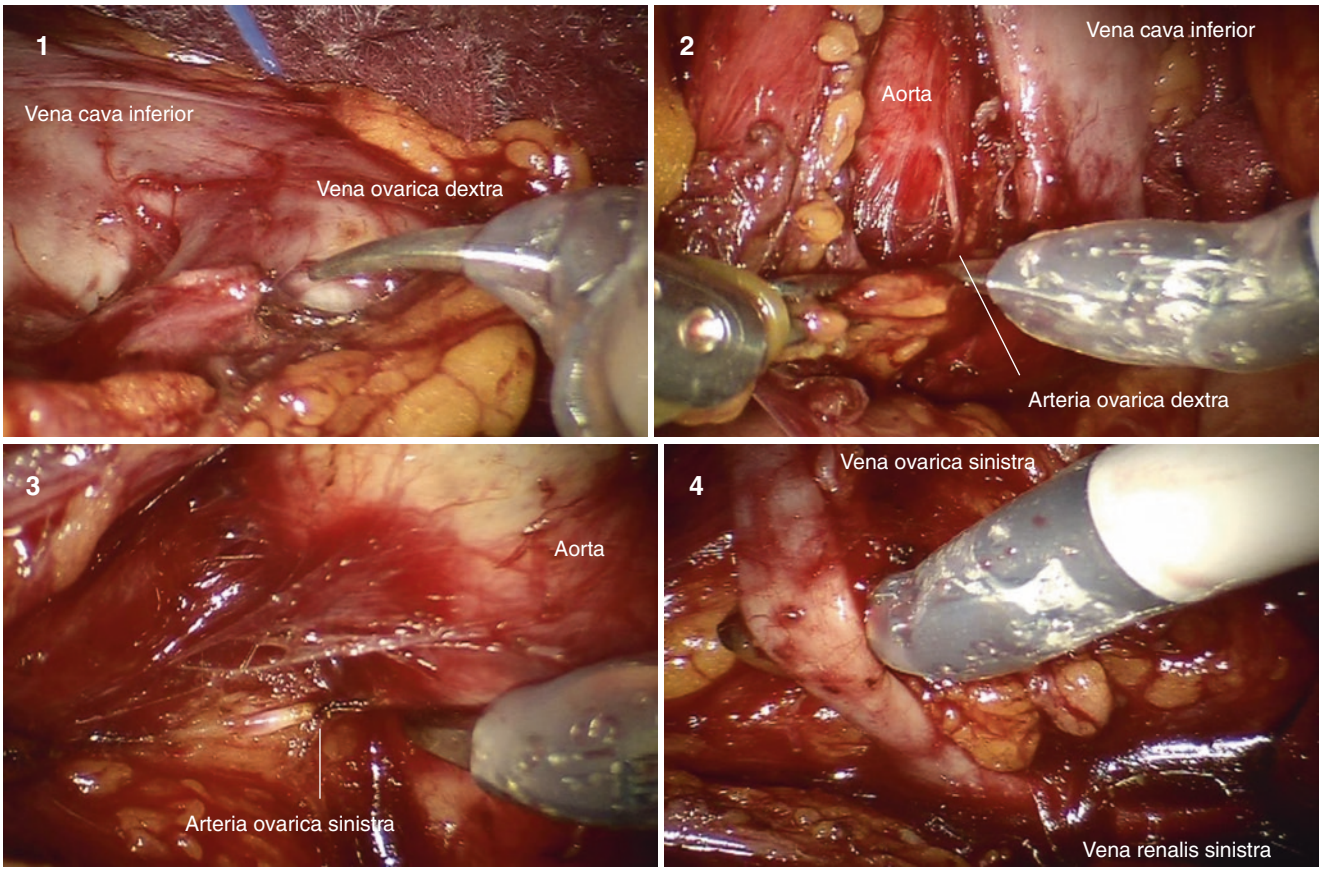

Fig. 15.13 Dissection of ovarian veins and arteries from caval and renal veins and aorta [1]

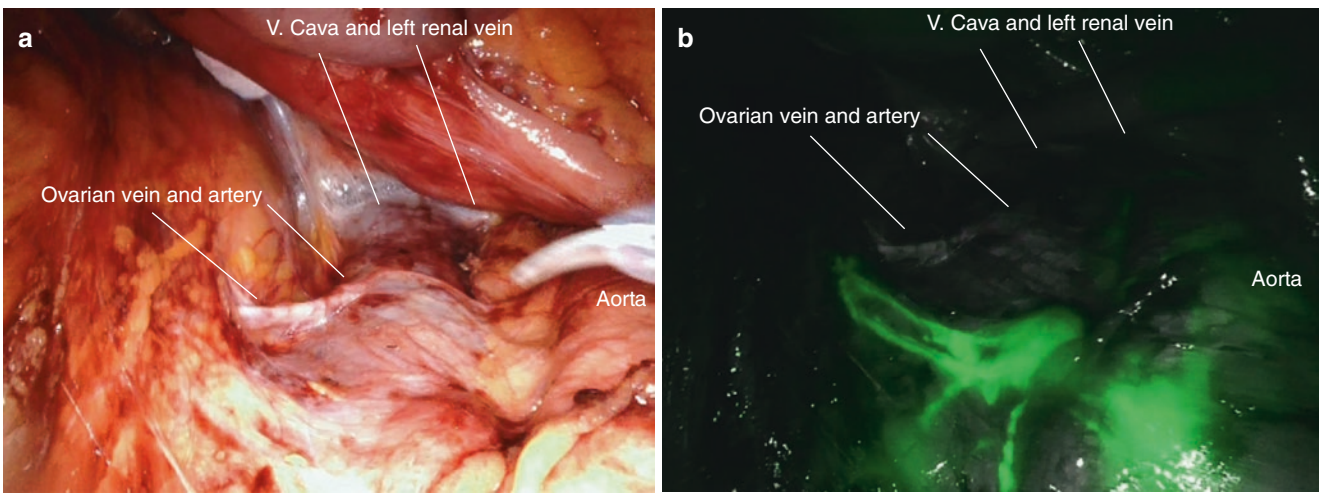

Fig. 15.14 (**a**) Right para-aortic node compartment with right ovarian vessels (normal light). (**b**) Right para-aortic node compartment with right ovarian vessels (ICG Fluorescence)

3. There are patients with up to 25% risk having isolated positive para-aortic nodes in negative pelvic sentinel, e.g. pT1b G2-3 and non-endometrioid tumours to a lesser extent

What could this procedure potentially achieve?

1. Locoregional recurrence usually occurs in the residual tissue of the Müllerian compartment including lymphatic

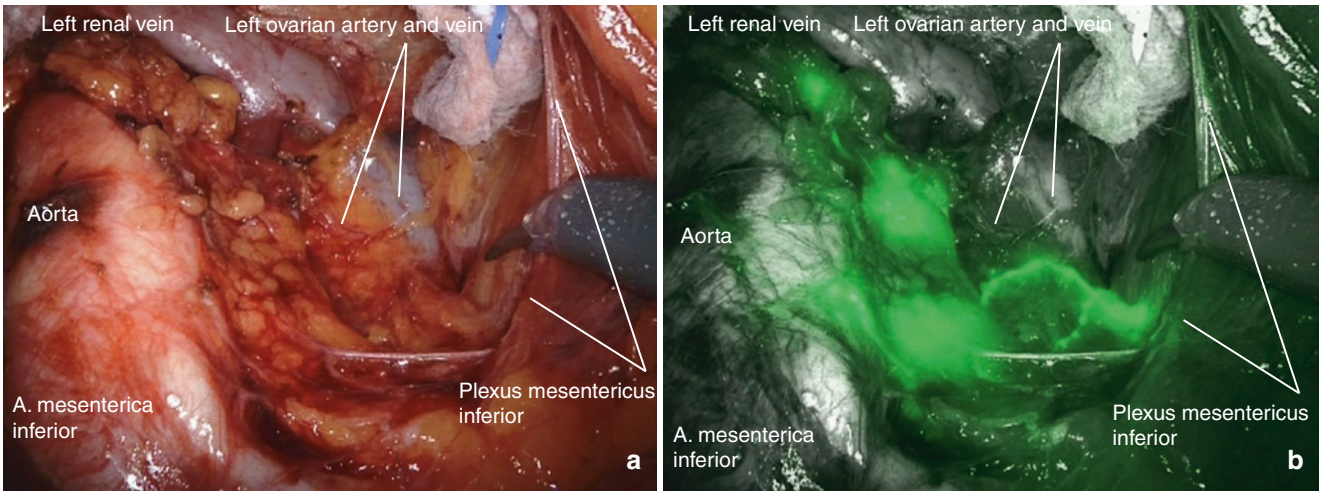

Fig. 15.15 (**a**) Left para-aortic node compartment with left ovarian vessels (normal light). (**b**) Left para-aortic node compartment with left ovarian vessels (IGC fluorescence)

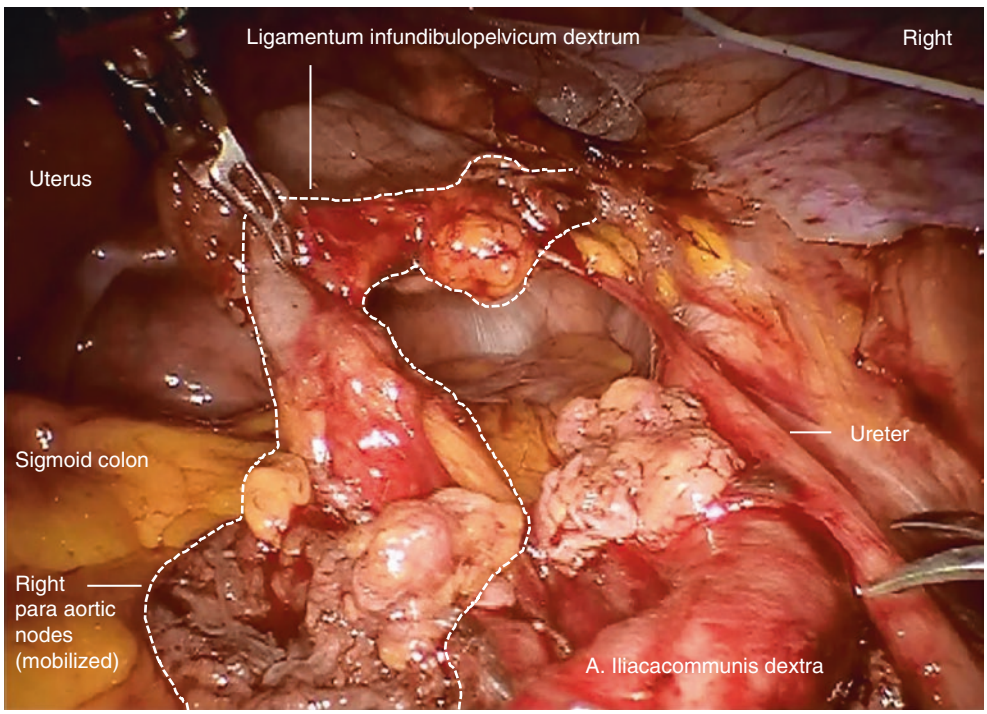

Fig. 15.16 Completely mobilized right ovarian vessel system with right para-aortic nodes [1]

drainage area. Thus, complete resection of the compartment (and not hysterectomy and sentinel node only) as PMMR and targeted pelvic (sentinel) lymphadenectomy could achieve both locoregional control without radiotherapy and reduction of surgical morbidity due to omission of systematic lymphadenectomy in node-negative disease.

2. The same procedure could detect the 5–10% patients at risk with only slightly enhanced surgical morbidity which seems to be low in sentinel lymphadenectomy and PMMR only [11, 17].
3. Additional para-aortic sentinel lymphadenectomy [10] should have the potential to detect additional patients at risk with isolated para-aortic metastases without morbidity of systematic lymphadenectomy for all patients.

Thus there could be a new strategy in surgery of endometrial cancer as proposed in [18].

1. PMMR and pelvic TCL +/− para-aortic sentinel node excision in all patients and completion of node dissection when positive nodes are present alternatively

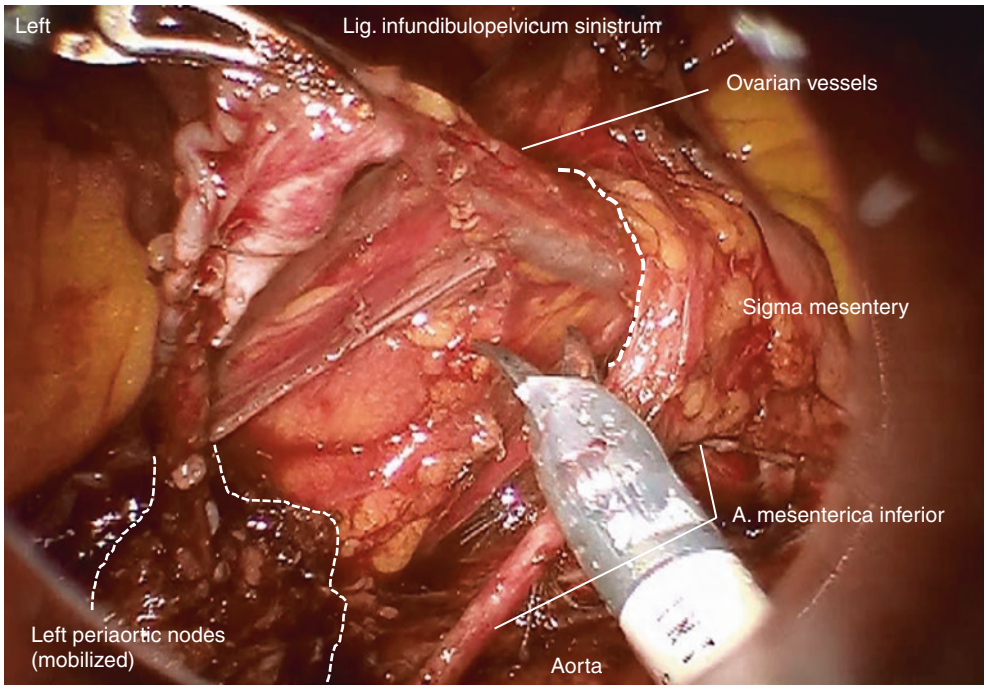

Fig. 15.17 Mobilized left ovarian vessel system entering the "sigmoid tunnel" [1]

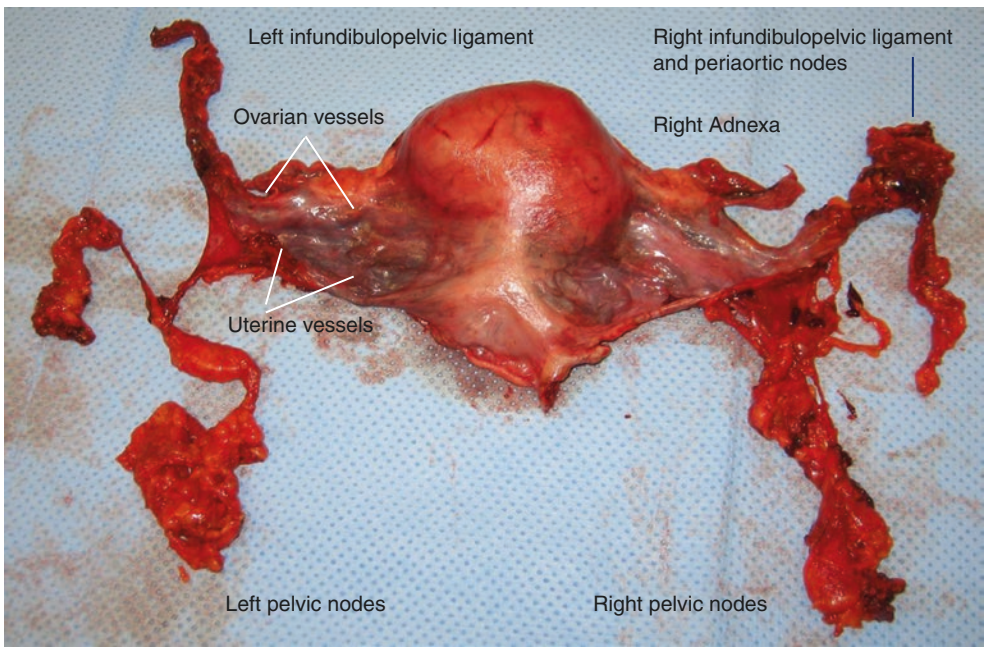

Fig. 15.18 Typical entire specimen following PMMR in endometrial cancer [1]

2. Hysterectomy and salpingo-ophorectomy only in apparently low-risk patients, if patients accept 5–10% of positive nodes not detected and eventually adjuvant radiotherapy
3. Complete lymphadenectomy pelvic and para-aortic in pT1b G2-3 tumours or non-endometrioid histology in apparently intermediate-/high-risk patients if they do not accept false-negative para-aortic sentinel nodes
4. Radio-chemotherapy instead of extended surgery in intermediate-/high-risk disease if further therapy is indicated

A prospective study is planned to evaluate the PMMR/TCL approach as a cohort study comparing with guideline-based best practice named "European collaborative multicenter study: Modular treatment with PMMR and targeted compartmental pelvic lymphadenectomy followed by therapeutic pelvic and paraaortic lymphadenectomy in node positive disease for locoregional control in endometrial cancer FIGO stages I-III".

With this study, we hope to be able to add further evidence for the effect of limited compartmental surgery on the

locoregional outcome of uterine cancer; concomitantly surgical and radio-chemotherapy-induced morbidity should decrease not injuring patients' tumour-specific life expectancy.

References

1. Kimmig R, Aktas B, Buderath P, Wimberger P, Iannaccone A, Heubner M. Definition of compartment-based radical surgery in uterine cancer: modified radical hysterectomy in intermediate/high-risk endometrial cancer using peritoneal mesometrial resection (PMMR) by M Höckel translated to robotic surgery. World J Surg Oncol. 2013;11:198. https://doi.org/10.1186/1477-7819-11-198.
2. Kimmig R, Iannaccone A, Buderath P, Aktas B, Wimberger P, Heubner M. Definition of compartment based radical surgery in uterine cancer-part I: therapeutic pelvic and periaortic lymphadenectomy by Michael Höckel translated to robotic surgery. ISRN Obstet Gynecol. 2013;2013:297921. https://doi.org/10.1155/2013/297921.
3. Kimmig R, Aktas B, Buderath P, Rusch P, Heubner M. Intraoperative navigation in robotically assisted compartmental surgery of uterine cancer by visualisation of embryologically derived lymphatic networks with indocyanine-green (ICG). J Surg Oncol. 2016;113(5):554–9. https://doi.org/10.1002/jso.24174.
4. Kimmig K. Video 1. Robotic surgery in gynaecology—therapeutic lymphadenectomy of the pelvic nodes (TPL1)—module I: common iliac, subaortic and presacral nodes. ESGO eAcademy. 10 Oct 2013;38736. http://eacademy.esgo.org/esgo/2000/dvds/38736/k.rainer.kimmig.robotic.surgery.in.gynaecology.-.therapeutic.lymphadenectomy.html?f=l5987m10.
5. Kimmig K. Video 2. Robotic surgery in gynaecology—therapeutic lymphadenectomy of the pelvic nodes (TPL1)—module II: lower paravisceral and external iliac nodes. ESGO eAcademy. 3 Oct 2013;38737. http://eacademy.esgo.org/esgo/2000/dvds/38737/k.rainer.kimmig.robotic.surgery.in.gynaecology.-.therapeutic.lymphadenectomy.html?f=s49121m10.39.
6. Kimmig K. Video 3. Robotic surgery in gynaecology—therapeutic paraaortic lymphadenectomy (TPL2)—module IV: inframesenteric periaortic nodes. ESGO eAcademy. 8 Oct 2013; 95407. http://eacademy.esgo.org/esgo/2000/dvds/95407/k.rainer.kimmig.robotic.surgery.in.gynaecology.-.therapeutic.paraaortic.html?f=l5987m10.
7. Kimmig K. Video 4. Robotic surgery in gynecology—therapeutic paraaortic lymphadenectomy (TPL2)—module V2: infrarenal periaortic nodes with resection of 'mesonephric' compartment of ovarian vessels. ESGO eAcademy. 3 Jun 2014; 95406. http://eacademy.esgo.org/esgo/2000/dvds/95406/k.rainer.kimmig.robotic.surgery.in.gynecology.-.therapeutic.paraaortic.html?f=s49121m10.
8. Kimmig K. Video 5. Robotic surgery in gynecology—peritoneal mesometrial resection (PMMR) in endometrial cancer—part one: compartmental lymphatic network of uterine corpus and its drainage. ESGO eAcademy. 18 Jan 2017; 166631. https://eacademy.esgo.org/esgo/2016/video.library/166631/k.rainer.kimmig.pmmr.in.endometrial.cancer.-.part.one.-.compartmental.html?f=menu=14*media=10*speaker=49121
9. Kimmig K. Video 6. Robotic surgery in gynecology—peritoneal mesometrial resection (PMMR) in endometrial cancer—part two: surgical technique. ESGO eAcademy. 18 Jan 2017; 166632. https://eacademy.esgo.org/esgo/2016/video.library/166632/k.rainer.kimmig.pmmr.in.endometrial.cancer.-.part.two.-.surgical.technique.html?f=menu=14*media=10*speaker=49121
10. Kimmig R, Rusch P, Buderath P, Aktas B. Aortic utero-ovarian sentinel nodes and left infrarenal aortic lymph node dissection by ICG supported navigation. Educational video. Gynecol Oncol Rep. 2017;20:22–3.
11. Kimmig R, Iannaccone A, Aktas B, Buderath P, Heubner M. Embryologically based radical hysterectomy as peritoneal mesometrial resection (PMMR) with pelvic and para-aortic lymphadenectomy for loco-regional tumor control in endometrial cancer: first evidence for efficacy. Arch Gynecol Obstet. 2016;294(1):153–60. https://doi.org/10.1007/s00404-015-3956-y.
12. Abu-Rustum NR, Gomez JD, Alektiar KM, Soslow RA, Hensley ML, Leitao MM Jr, Gardner GJ, Sonoda Y, Chi DS, Barakat RR. The incidence of isolated paraaortic nodal metastasis in surgically staged endometrial cancer patients with negative pelvic lymph nodes. Gynecol Oncol. 2009;115(2):236–8. https://doi.org/10.1016/j.ygyno.2009.07.016.
13. Kim TH, Kim HS, Kim TJ, Chang SJ, Kim DY, Ryu SY, Kim BG, Kim YT, Bae DS, Ryu HS, Nam JH. Survival impact based on the thoroughness of pelvic lymphadenectomy in intermediate- or high-risk groups of endometrioid-type endometrial cancer: a multi-center retrospective cohort analysis. Gynecol Oncol. 2016;141(3):440–6. https://doi.org/10.1016/j.ygyno.2016.03.031.
14. Holloway RW, Gupta S, Stavitzski NM, Zhu X, Takimoto EL, Gubbi A, Bigsby GE, Brudie LA, Kendrick JE, Ahmad S. Sentinel lymph node mapping with staging lymphadenectomy for patients with endometrial cancer increases the detection of metastasis. Gynecol Oncol. 2016;141(2):206–10. https://doi.org/10.1016/j.ygyno.2016.02.018.
15. Zahl Eriksson AG, Ducie J, Ali N, McGree ME, Weaver AL, Bogani G, Cliby WA, Dowdy SC, Bakkum-Gamez JN, Abu-Rustum NR, Mariani A, Leitao MM Jr. Comparison of a sentinel lymph node and a selective lymphadenectomy algorithm in patients with endometrioid endometrial carcinoma and limited myometrial invasion. Gynecol Oncol. 2016;140(3):394–9. https://doi.org/10.1016/j.ygyno.2015.12.028.
16. Kumar S, Podratz KC, Bakkum-Gamez JN, Dowdy SC, Weaver AL, McGree ME, Cliby WA, Keeney GL, Thomas G, Mariani A. Prospective assessment of the prevalence of pelvic, paraaortic and high paraaortic lymph node metastasis in endometrial cancer. Gynecol Oncol. 2014;132(1):38–43. https://doi.org/10.1016/j.ygyno.2013.10.002.
17. Tschernichovsky R, Diver EJ, Schorge JO, Goodman A. The role of lymphadenectomy versus sentinel lymph node biopsy in early-stage endometrial cancer: a review of the literature. Am J Clin Oncol. 2016;39(5):516–21. https://doi.org/10.1097/COC.0000000000000302.
18. Kimmig R, Buderath P, Rusch P, Aktas B. Technique of ICG-guided targeted compartmental pelvic lymphadenectomy (TCL) combined with pelvic peritoneal mesometrial resection (PMMR) for locoregional control of endometrial cancer—a proposal. Educational video. Gynecol Oncol Rep. 2017;20:125–6.

Pelvic Lymphadenectomy

16

Jordi Ponce, Marc Barahona, and M. Jesus Pla

Introduction

Pelvic lymphadenectomy has different indications in gynaecology oncology including endometrial, cervical and ovarian cancer. There are different surgical approaches: laparotomy, laparoscopy and robotic. Minimally invasive surgery (laparoscopy and robotics) has many advantages over laparotomy. These include less complications, less bleeding, shorter hospital stay and a faster return to normal activity. The Da Vinci system (*Intuitive Surgical, Sunnyvale, CA, USA*) was approved in 2005 by the Food and Drug Administration (FDA). Since then, the number of surgical procedures performed robotically has increased more than threefold due to the benefits of laparoscopic approach compared to open surgery and the increased number of robots available, especially in the USA.

If we compare robotic surgery to laparoscopy, we will find some advantages and disadvantages. Most of the advantages are related to the surgeon and include improved ergonomics [1], a faster learning curve [2], better vision (3D), a high-grade articulation (wristed instruments), and increasing from four to seven degrees of motion compared with conventional laparoscopy. Disadvantages are mostly related to the high cost and the lack of tactile sensibility.

In this chapter, we are going to describe the technique, tips and tricks of robotic pelvic lymphadenectomy, with *Da Vinci S®* and *Da Vinci Xi®* system [3–12].

Robotic Device: Da Vinci System

There are five different Da Vinci systems currently in use: *Da Vinci S®*, *Da Vinci Si®*, *Da Vinci Xi®*, *Da Vinci SP® and Da Vinci X®*.

Newer versions have evolved from previous designs:

- The Da Vinci S® evolved from the original Da Vinci standard® providing an additional arm to the original model with more manoeuvrability.
- The *Da Vinci Si®* evolved from the Da Vinci S® (Video 16.1).
- The differences are related to the surgeon console with new technologies such as *Firefly®* to visualise previously marked structures with indocyanine green (ICG) via a vascular map or sentinel lymph node. There are no differences in the arms of the robot between the two models, and the docking procedure is the same in both systems.
- The development of the *Da Vinci Xi®* (Video 16.2) brought in a semiautomated docking which was easier and faster. Additionally, it can make a full rotation of the arms without moving the robotic tower position which is especially useful if you need a double-docking approach in order to access the aortic field.
- The Da Vinci X® is a simpler and cheaper version of the Da Vinci Xi® without the four-quadrant accessibility, and the Da Vinci SP® is designed for single-incision surgery.

Due to this, the technique of docking is different depending on the model used. However, the technique of performing pelvic lymphadenectomy is the same for all models.

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Ports and Instruments Location for Pelvic Lymphadenectomy

Da Vinci S®and Da Vinci Si® (Fig. 16.1)

Ports

The camera port needs a 12 mm trocar and is positioned at umbilicus or supraumbilical level depending on uterine size.

Three 8 mm robotic trocars will be positioned with a distance of 8–10 cm from each other: one placed in a right paraumbilical position and two others placed on each side about 2 cm superior and medially to the anterior superior iliac crest.

An 11 mm laparoscopic accessory trocar is used for the assistant at the left side of the umbilicus.

The robotic arms are placed between the patient's legs or beside the right leg when a hysterectomy is performed in order to use a uterine manipulator.

Instruments

A robotic 0° scope is inserted through the 12 mm trocar.

Monopolar robotic scissors are inserted through the right paraumbilical robotic trocar.

Robotic bipolar or Maryland forceps are placed through the left pelvic robotic port.

A Prograsp or bipolar robotic grasper is introduced through the right pelvic robotic port.

An Endobag for lymph node extraction, a suction irrigator and other devices are inserted through the 11 mm laparoscopic trocar.

Da Vinci Xi® (Fig. 16.2)

Ports

Four 8 mm robotic trocars are positioned at a distance of 8–10 cm from each other, in a straight line.

An 8–10 mm laparoscopic accessory trocar is used for the assistant at the left side above the line of the robotic trocars.

Due to the versatility of the Da Vinci Xi, docking is usually done laterally when performing a pelvic lymphadenectomy.

Instruments

An 8 mm robotic scope is used so it can be placed through any trocar. Usually, the arm number 2 is used for a 0° scope, and the position of other arms is automatically determined by the robot once the camera placement is made.

Monopolar robotic scissors are inserted through arm number 3.

Robotic bipolar or Maryland forceps at arm number 1.

Prograsp or a bipolar robotic grasper at arm number 4.

An Endobag for lymph node extraction, a suction irrigator and other devices needed are inserted through the 8–10 mm laparoscopic trocar.

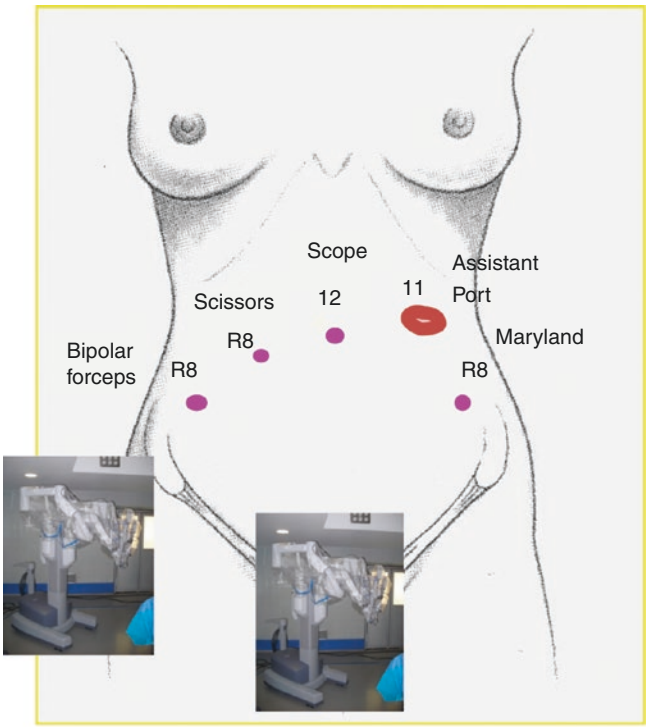

Fig. 16.1 *Da Vinci Si®* trocar location

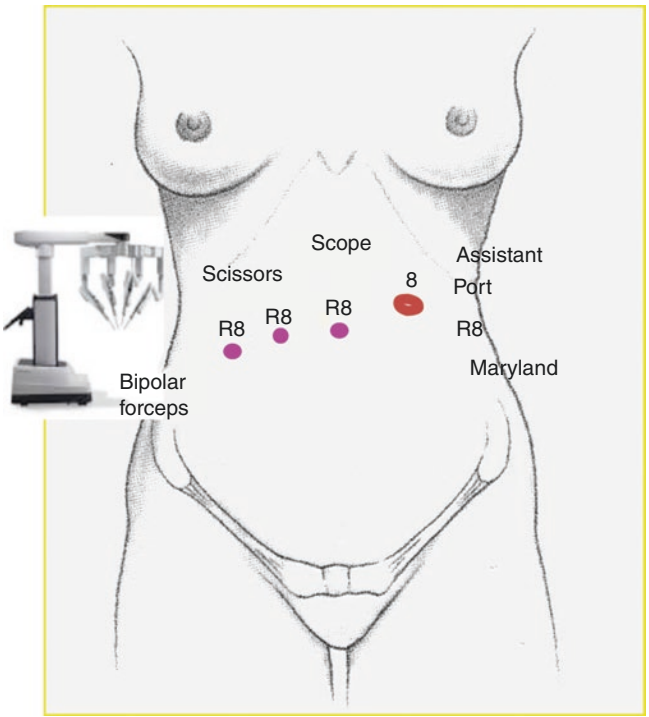

Fig. 16.2 *Da Vinci Xi®* trocar location

Surgical Technique

Pelvic Lymphadenectomy Boundaries

1. Lateral: psoas muscle, common iliac artery and obturator internus muscle
2. Medial: superior vesical artery
3. Posterior (deep): obturator nerve
4. Cranial: the ureter crossing the common iliac artery
5. Caudal: circumflex iliac vein

Step-by-Step Surgical Approach

We start opening the peritoneum from the lateral side of the external iliac artery on top of the psoas muscle at the point where the ureter crosses the common iliac artery and extend the dissection as far as the circumflex iliac vein. If we identify the genitofemoral nerve, we try and conserve it to avoid sensitivity symptoms (Video 16.3).

We then start the dissection from the superior vesical artery (medial limit of our dissection and a terminal branch of internal iliac/hypogastric artery) again through an avascular space to the obturator nerve (deep limit). The obturator nerve must be dissected and preserved as if injury occurs, it causes a leg adduction deficiency. Below the obturator nerve, we find the obturator vein accompanying it. It is not necessary to go deeper than this landmark avoiding injury to the deep pelvic plexus of veins.

Then we will change the dissection field to the opposite site, following on external iliac artery surface, following to external iliac vein, trying to obtain monoblock mobilisation of lymphatic tissue (Video 16.4).

Once the external iliac vein is completely identified, we proceed inferior to the vein and as lateral as possible extending through the avascular space until reaching the obturator fossa where we identify the obturator muscle and Cooper's ligament (Video 16.5).

When the whole dissection is completed (lateral, medial and deep), we remove all the lymphatic tissue isolated, taking care of the structures dissected and identified previously (Video 16.6).

Finally, we check the dissected field to confirm haemostasis and check for injuries (Video 16.7).

We retrieve the lymph nodes in an Endobag through the biggest trocar incision or through the vagina if a hysterectomy has been performed.

Avoiding Complications

Vascular Complications

If a major vessel injury occurs such as to the external iliac artery or vein, firstly it should be contained with gauze compression. This is usually a successful manoeuvre on its own if the injury is small. If the bleeding doesn't stop, it should be sutured with Prolene 4/0 or 5/0. The robot facilitates extremely precise movements enabling intracorporeal knot tying to be performed easily (Video 16.8).

If the injury is made to small vessels such as the obturator vein, corona mortis or other venous branches, the best option is just apply gauze compression which is usually successful. If not, it is necessary to dissect and visualise the bleeding vessel. Then you will be able to coagulate it with bipolar energy or another vessel sealer device. Another option to keep in mind is to apply a haemostatic product.

Nervous Injury

If the obturator nerve is not completely identified, it is at risk of transection either partially or completely. If section does occur, it should be repaired with a 5/0 Prolene (Video 16.9).

Avoiding Complete Lymphadenectomy: Sentinel Node by ICG Fluorescence

For sure, the best way to avoid complications is to escape performing complete lymphadenectomy, just doing a sentinel node detection, if this procedure is considered strictly indicated in your protocol (standard or research) (Video 16.10).

Top Ten Tips and Tricks

1. Take care with trocar locations to avoid collisions of the robotic arms. Be careful with medial incisions as the epigastric vessels can run close by.
2. Before docking, ensure that the table is in a good Trendelenburg position, retract bowels and release adhesions to ensure a good field of exposure. Never move the patient table with the robot docked unless utilising the new Trumpf table which allows for this.
3. Take note of landmarks and regularly check the boundaries of the dissection: medial landmark, from the superior vesical artery to the obturator nerve; lateral landmark, from the external iliac vein, extending caudally to Cooper's ligament; and deep landmark, the obturator nerve and vessels.
4. Identify the avascular pelvic spaces.
5. The arterial walls are more resistant than venous tissue. Therefore, it is best to start the dissection on arterial surface. Dissection is facilitated if an appropriate opening of the vascular sheath occurs avoiding collateral vasa vasorum.
6. If you find fixed nodes, try to go dissect around the more mobile parts of the node before trying to detach the fixed part.

7. If bleeding occurs, keep calm. The first step is to control the bleeding and ensure good visualisation. Failure of this needs to result in a quick laparotomy.
8. If a venous injury occurs, use gauze compression and wait. Most venous bleeding will stop using this method after a few minutes. Never apply electric coagulation on a vein wall, and be careful with clips. If suturing is required, use a 4/0 or 5/0 monofilament suture. Compression to both cranial and caudal aspects of the defect will assist in decreasing bleeding flow.
9. Protected extraction of dissected tissue in a bag is recommended. Removal should be made through the port with the greatest calibre, or if a hysterectomy has occurred, through the vagina.
10. Move your fingers and wrists and not your arms. This is not conventional laparoscopy. Take advantage of the microsurgical precision of the instrument.

References

1. Balasubramani L, Milliken DA, Shepherd JH, Ind TEJ. Differences in hand movements and task completion times between laparoscopic, robotically assisted, and open surgery: An in vitro study. J Robot Surg. 2011;5(2):137–40.
2. Rashid T, Kini M, Ind TEJ. Comparing the learning curve for robotically assisted and straight stick laparoscopic procedures in surgical novices. Int J Med Robot. 2010;6:306–3010.
3. Magrina JF. Robotic surgery in gynecology. Eur J Gynaecol Oncol. 2007;28(2):77–82. Epub 2007/05/08.
4. Magrina JF, Long JB, Kho RM, Giles DL, Montero RP, Magtibay PM. Robotic transperitoneal infrarenal aortic lymphadenectomy: technique and results. Int J Gynecol Cancer. 2010;20(1):184–7. Epub 2010/02/05.
5. Ponce J, Barahona M, Marti MD, Pla MJ, Gine L, Pola E, Salazar A, Bartolome C, Corbella X, García A. Combined robotic procedures, pelvis and upper abdomen. Standardization with two surgical approaches: high aorto-cava limphadenectomy by transperitoneal robotic approach using double docking and 180° rotation of operation table. J Robot Surg. 2012;6(Sup 1):S13.
6. Hudry D, Ahmad S, Zanagnolo V, Narducci F, Fastrez M, Ponce J, Tucher E, Lecuru F, Conri V, Leguevaque P, Goffin F, Kolher C, Leblanc E, Maggioni A, Holloway RW, Houvenaeghel G, Lambaudie E. Robotic-assisted para-aortic lymphadenectomy: surgical results. J Robot Surg. 2012;6(Suppl 1):S11.
7. Fastrez M, Goffin F, Vergote I, Vandromme J, Petit P, Leunen K, et al. Multi-center experience of 331 robot-assisted laparoscopic para-aortic lymphadenectomy for staging of locally advanced cervical 332 carcinoma. Acta Obstet Gynecol Scand. 2013;92:895–901.
8. Zanagnolo V, Rollo D, Tomaselli T, et al. Robotic-assisted transperitoneal aortic lymphadenectomy as part of staging procedure for gynaecological malignancies: single institution experience. Obstet Gynecol Int. 2013;2013:931318.
9. Brown JV III, Mendivil AA, Abaid LN, Rettenmaier MA, Micha JP, Wabe MA, et al. The safety and feasibility of robotic-assisted lymph node staging in early-stage ovarian cancer. Int J Gynecol Cancer. 2014;24(8):1493–8. Epub 2014/08/01.
10. Hudry D, Ahmad S, Zanangnolo V, Narducci F, Fastrez M, Ponce J, Tucher F, Lécuru F, Conri V, Leguevaque P, Goffin F, Holloway RW, Lambaudie E. With the collaboration of the SERGS group. Robotically assisted paraaortic lymphadenectomy: surgical results in a cohort study of 487 patients. Int J Gynecol Cancer. 2015;25:504–11.
11. Franke O, Narducci F, Chereau-Ewald E, et al. Role of a double docking to improve lymph node dissection: when robotically assisted laparoscopy for para-aortic lymphadenectomy is associated to a pelvic procedure. Int J Gynecol Cancer. 2015;25:331–6.
12. Ponce J, Barahona M, Pla MJ, Rovira J, Gil-Ibañez B, Gaspar HM, Sabria E, Bartolome C, Marti L. Robotic transperitoneal infrarenal para-aortic lymphadenectomy with double docking: technique, learning curve and perioperative outcomes. J Minim Invasive Gynecol. 2016;23(4):622–7. DOI 10.1016/j.jmig.2016.02.005. Epub 2016 Feb 16.

Robotic Para-aortic Lymph Node Dissection

17

Brooke A. Schlappe and Mario M. Leitao Jr

Introduction

The first robotic surgical platform was introduced for civilian use in the 1980s as a tool to enable minimally invasive surgery [1]. Since that time, its popularity among surgeons has continued to increase due to improved dexterity, better visualization, increased primary surgeon independence, and increased comfort over conventional laparoscopic equipment [2, 3]. This is particularly true of para-aortic lymphadenectomies, which require careful dissection of lymphatic tissue near the aorta and vena cava. In this chapter, the background, surgical technique, and complications of a robotic-assisted para-aortic lymph node dissection are discussed.

Background

Para-aortic lymph node dissection is a part of the staging procedure for ovarian malignancies and has historically been a part of the primary surgical management of endometrial and cervical malignancies, although this has decreased recently with the increased use of sentinel lymph node dissection [4]. Although there are no data from randomized trials, the robotic-assisted surgical management of endometrial, cervical, and select primary and recurrent ovarian cancers has been shown to be safe and feasible compared to conventional laparoscopy and laparotomy in a number of nonrandomized studies [5–14]. Several reports have demonstrated specifically that robotic-assisted para-aortic lymph node dissection, as part of these staging procedures, is safe and feasible [15–19]. Reported rates of successful robotic-assisted para-aortic lymph node dissections to the renal vein range from 70 to 90% and have been shown to increase with increasing surgeon experience [16, 20]. James et al. described their experience with robotic-assisted staging in 97 patients with apparent early-stage endometrial cancer. Para-aortic lymph node dissection to the renal vein was achieved in 90.7% of cases; the remainder were completed to the inferior mesenteric artery due to poor exposure. All patients had some para-aortic lymph nodes removed without conversion to laparotomy [16].

Robotic-assisted para-aortic lymph node dissection alone in the management of gynecologic malignancies has been reported, although less frequently than in combination with other procedures [21–26]. Fastrez et al. reported their initial experience using the robotic platform for para-aortic lymphadenectomy in locally advanced cervical carcinoma. In this preliminary report of eight patients, they identified one patient with para-aortic nodal metastases who subsequently received extended-field radiation. There were no intraoperative complications, and the postoperative morbidity was low in this small series [25]. A subsequent larger, multicenter study from the same group demonstrated the continued safety and feasibility of this approach in locally advanced cervical cancer. Intraoperative (5.4%) and postoperative (13.5%) complication rates were low, and the rate of conversion to laparotomy was 1.4% (1 in 74 patients) [24]. Although not as commonly performed, para-aortic lymph node dissection in the absence of concomitant procedures for the management of gynecologic malignancies may be safely performed using the robotic platform.

Treatment Options

Two robotic-assisted para-aortic lymphadenectomy techniques have been described: the transperitoneal and extraperitoneal approaches [21, 23, 25–28]. Reported advantages of the extraperitoneal approach include increased exposure of the para-aortic lymph nodes in obese patients, decreased bowel injuries, and the avoidance of entering the abdominal cavity, which potentially decreases the formation of intra-abdominal adhesions and decreases the possibility of encountering adhesions from prior surgeries [29–31].

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Reports vary on the superiority of one technique over the other with regards to lymph node count and operating time [28, 29]. There are more lymphoceles associated with the extraperitoneal approach, which is decreased with peritoneal marsupialization [31–33].

If an extraperitoneal approach is used, robotic-assisted laparoscopy appears to have similar perioperative outcomes compared to conventional laparoscopy. Diaz-Feijoo et al. compared perioperative outcomes in patients with locally advanced cervical cancer undergoing robotic-assisted extraperitoneal para-aortic lymphadenectomy to a historical cohort of similar patients undergoing the same procedure with conventional laparoscopy. There was no difference in operating time, length of hospital stay, or postoperative complications between the two groups. Estimated blood loss was lower in the robotic-assisted group (20 mL vs. 90 mL; $p < 0.05$), and the median number of lymph nodes removed was higher (17 vs. 14 nodes; $p < 0.05$) [23]. We do not generally use the extraperitoneal approach via either robotic-assisted or conventional laparoscopy, as the majority of the time an intraperitoneal procedure is performed simultaneously with a para-aortic lymphadenectomy, which necessitates a transperitoneal operation. The transperitoneal approach is discussed in detail in this chapter.

Surgical Technique

Room Setup

The robotic surgical platform requires more equipment than what is needed for a conventional laparoscopy; therefore, optimizing the room setup is especially important to maximize patient and staff safety. The specific setup will depend upon the specific operating room, but in general the room should be arranged such that there is a clear view of the patient from the surgeon console, the cords connecting the carts are not on tension, and there is enough space between equipment for the operating room staff to move safely and efficiently [34]. The patient bed may be rotated to accommodate access for the robot if the typical head-of-patient-at-anesthesia arrangement is not optimal. There is extra long tubing available for ventilation. Head and neck robotic procedures are usually performed with the patient's head opposite of the anesthesiologist. For para-aortic lymph node dissections, this is particularly important if using a *da Vinci S*® or *Si*® platform, because there needs to be enough room to rotate the patient for over-the-shoulder docking to improve access to the infrarenal para-aortic lymph nodes if necessary. If using the *da Vinci Xi*® platform, the boom can be rotated to achieve the same access without requiring any movement of the patient bed or the robotic cart. Figure 17.1 depicts an example of the setup used at our institution.

Patient Positioning

A variety of patient positions for robotic-assisted para-aortic lymph node dissection have been described [22, 35]; however, we prefer the patient in the low dorsal lithotomy position. The patient's arms, including the hands, should be tucked at their side and padded to prevent inadvertent injury while hidden from view under sterile drapes (Fig. 17.2). Measures should be taken at the beginning of the case to prevent the patient from sliding on the operating room table. A variety of pads are available for the operating table to prevent sliding, including pink foam, egg crate, beanbag, and gel pad. A variety of shoulder braces are also available to prevent sliding, but these must be used with caution as misuse can lead to brachial plexus injuries [36]. It is of utmost importance to avoid placing any type of restraint too medially and close to the neck, as this will increase the risk of stretch injury to the brachial plexus. A variety of face shields are also available to protect the patient's face and prevent

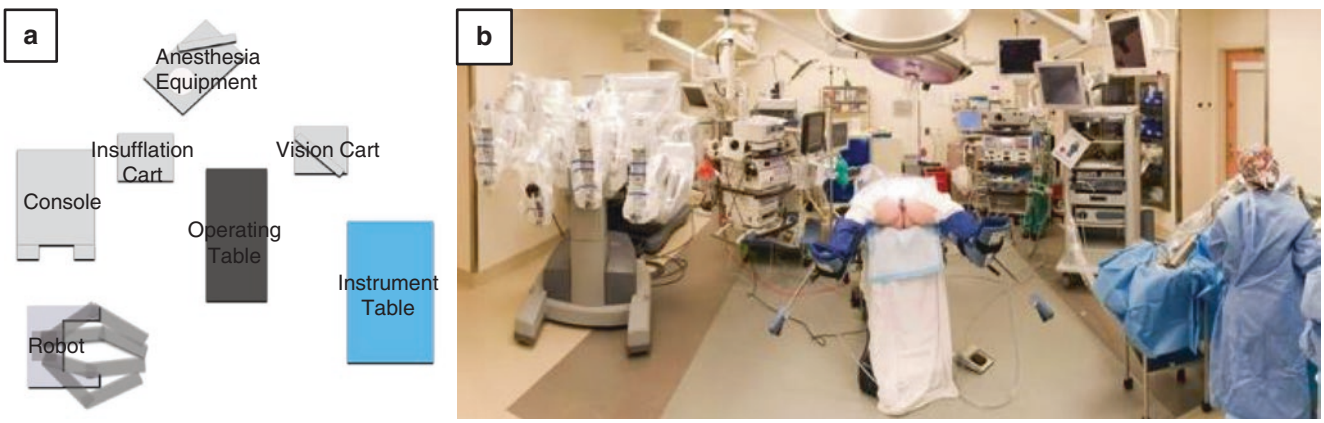


Fig. 17.1 Operating room setup diagram (**a**) and intraoperative example (**b**) for a robotic procedure

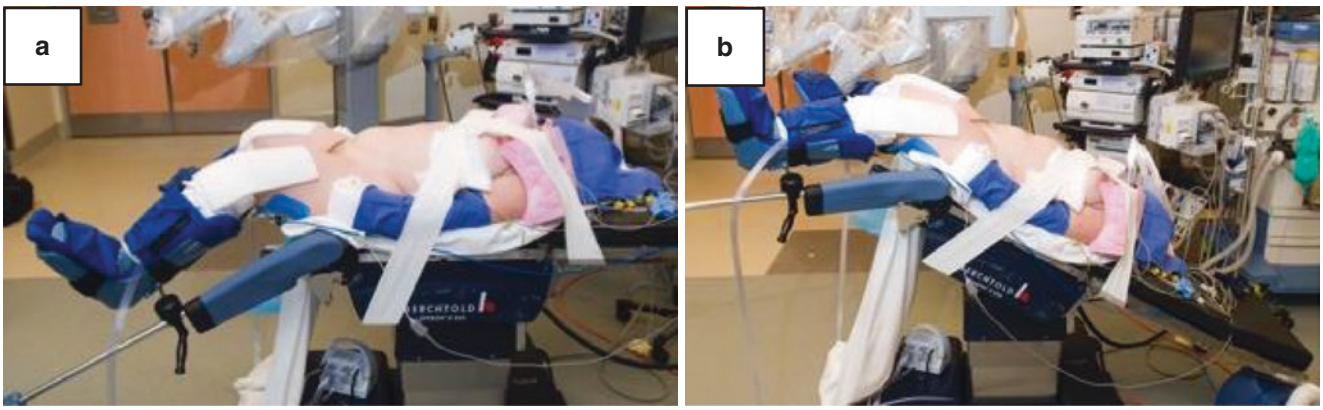


Fig. 17.2 Patient in dorsal lithotomy position with arms tucked at her sides and appropriate padding over hands, shoulders, and knees. (**a**) Neutral position. (**b**) Steep Trendelenburg position

endotracheal tube dislodgement from robotic arms or other instruments. In our experience, these are generally unnecessary if careful attention is paid to protecting the patient's face during setup. Also, some can be rather bulky and may limit the range of motion of the robotic arms.

Abdominal Entry

Entry into the abdomen should be performed in the manner in which the surgeon is most comfortable obtaining access to the peritoneal cavity for a laparoscopic procedure. If the surgeon is most comfortable using an open technique, this can be done at the camera port when using the *da Vinci S*® or *Si*®. Since the *da Vinci Xi*® has a smaller camera and all trocars are 8 mm, an open technique is difficult, especially in obese patients. A 12-mm accessory port placed at Palmer's point is often useful during the procedure and can be the initial point of access if the surgeon prefers an open technique.

Trocar Placement

When using the *da Vinci S*® or *Si*®, the trocars should be arranged in an arc toward the operative field, and the trocars need to be at least 10 cm apart at an approximate 30° angle. The incisions for these ports should be 8 mm wide, with the exception of the camera port, which should be 12 mm wide. With the *da Vinci Xi*®, the trocars can be placed in a straight line and need only to be 8 cm apart. All *da Vinci Xi*® trocars are the same size due to the smaller camera, and 8-mm incisions should be made for all port sites. An accessory port can be placed in the left upper quadrant or in the suprapubic region. The accessory port is particularly useful in a para-aortic lymphadenectomy for peritoneal retraction, bowel retraction, and specimen removal. The left upper quadrant is generally easier for the bedside assistant to access and operate from. As with conventional laparoscopy, trocars should be placed under direct visualization when possible.

Historically, ports were placed more cranially for the *da Vinci S*® and *Si*® when a para-aortic lymph node dissection was planned. We no longer feel that "high" abdominal placement of trocars is necessary, regardless of robotic platform used. Generally, placement of a camera trocar at the umbilicus is adequate for most cases. If the para-aortic nodal dissection extends to the infrarenal region, we prefer to rotate the patient and dock over the shoulder or rotate the arms on the *da Vinci Xi*® rather than place the trocars high. The *da Vinci Xi*® allows for more freedom of movement, and even when using trocar placement for a pelvic procedure, the para-aortic dissection can be carried up to the inferior mesenteric artery without rotating the arms. If a dissection to the renal veins is planned, the robotic arms on the *da Vinci Xi*® may be rotated 180° facing the upper abdomen without rotating the patient. This allows the para-aortic lymph node dissection to be performed to the renal veins without placing any extra trocars. An example of port placement for a para-aortic lymph node dissection in conjunction with a pelvic procedure and to facilitate access to the infrarenal region (with docking over the patient's shoulder or rotating the *da Vinci Xi*® arms) is shown in Fig. 17.3a, b, respectively. Over-the-shoulder docking is discussed in more detail in the next section.

We prefer to use two robotic instruments to the right of the camera trocar and one to the left, with the assistant trocar also to the left, as shown in Fig. 17.3a. This configuration allows the surgeon to have two opposable grasping instruments, as a bipolar grasping instrument is placed in the left-sided trocar and another grasping instrument is placed in one of the right-sided trocars. This applies to right-handed surgeons and may be reversed for a left-handed surgeon if necessary. Some surgeons use two robotic instrument trocars on the left side, but in this scenario, when both are grasping instruments, it allows for one grasping instrument to be used

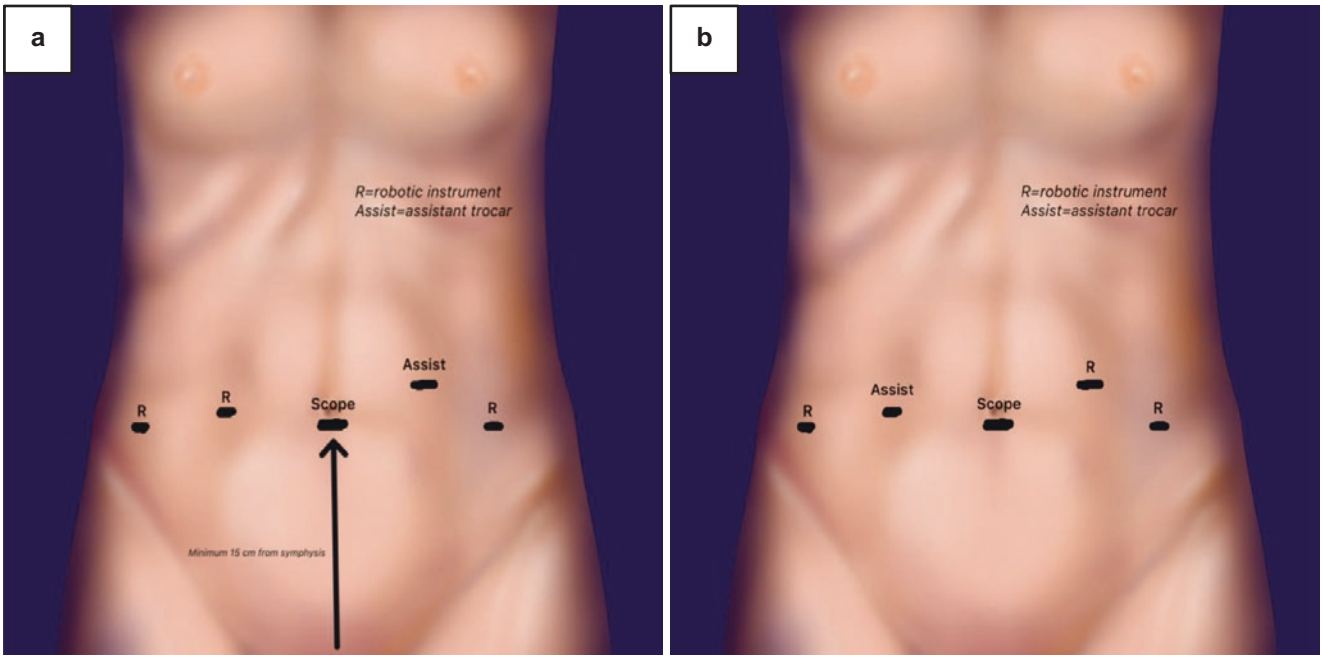


Fig. 17.3 Trocar placement for a para-aortic lymph node dissection. (**a**) In conjunction with a pelvic procedure. (**b**) With the *da Vinci S*® or *Si*® docked over the shoulder or with rotation of the *da Vinci Xi*® robotic arms 180°

at a time or it requires the switching of instruments from one side to the other if needed.

When rotating the patient or the robotic arms, the surgeon must remember that in this configuration, the fourth robotic arm will be on the opposite side of the patient. This may disorient the surgeon, especially if she or he is accustomed to having two robotic arms on the other side. If an accessory port has been placed, this issue can be resolved by switching the accessory port trocar and the trocar for the fourth robotic arm. This creates a configuration similar to that shown in Fig. 17.3b.

Camera placement at the umbilicus will depend on patient body habitus, as it may be highly variable, especially in the morbidly obese. As a rule of thumb, we place the camera trocar at the umbilicus as long as it is a minimum of 15 cm from the symphysis pubis. Other trocars are then placed, with the planned camera trocar site as the reference.

Docking

The patient should be placed in a steep Trendelenburg position prior to docking, and the bowel should be swept into the upper abdomen as much as possible to improve visualization. Docking can be performed in a variety of positions depending upon the surgeon's preference and the surgical procedures being performed in addition to the para-aortic lymphadenectomy. The robot can be docked in the center, offset center, on the side, or over the shoulder. Center and offset center docking refers to placing the robot between the patient's legs (Fig. 17.4a). Offset center docking places the boom of the patient cart between the patient's legs but not directly in the midline (Fig. 17.4b), thus allowing the assistant access to the perineum. Center docking can be more challenging but does allow increased access to the para-aortic lymph node region and may be preferable if the only procedure to be performed is a para-aortic lymphadenectomy. This is generally not the case, however, as the para-aortic lymphadenectomy is often coupled with a pelvic procedure. In this case, side-docking is preferable and more commonly used, as it allows the greatest perineal access, is easier to perform, and provides adequate access to the pelvis and lower para-aortic region (Fig. 17.5). For the *da Vinci S*® and *Si*®, the base of the patient cart can either be parallel to the operating table (Fig. 17.5a) or slightly rotated toward the patient (Fig. 17.5b). Either works well as long as the camera can be docked. Due to the enhanced range of motion of the robotic arms in the *da Vinci Xi*®, the best docking method is on the side, with the base of the patient cart perpendicular to the operating table. The flexibility of the *da Vinci Xi*® system allows for a much greater range of docking capabilities.

For access to the infrarenal para-aortic region, the robotic arms may be rotated if using the *da Vinci Xi*® or the robot may be docked over the patient's shoulder (Fig. 17.6). If performing a para-aortic lymphadenectomy to the renal veins in combination with a pelvic procedure using the *da Vinci S*® or *Si*®, the patient will need to be rotated. With advanced communication between the surgical team and the anesthesia

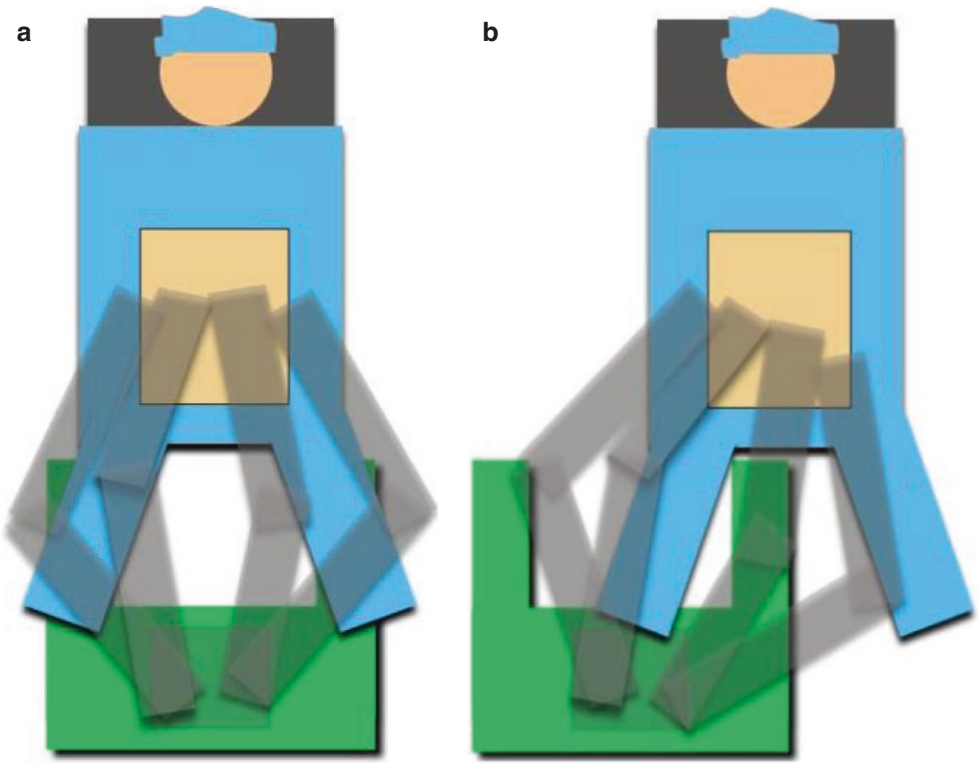
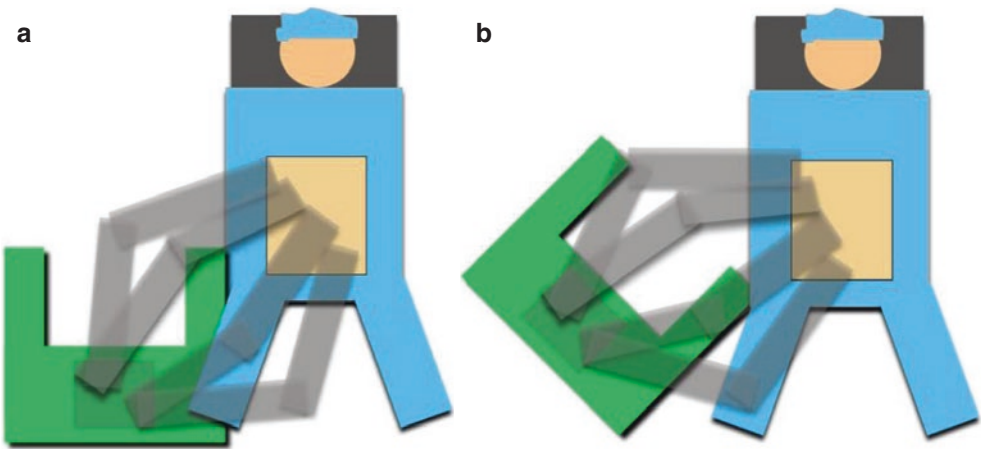


Fig. 17.4 Options for docking the *da Vinci S*® and *Si*® for para-aortic lymph node dissection with pelvic procedures. (**a**) Diagram of center docking. (**b**) Diagram of offset center docking (robot base in *green*)



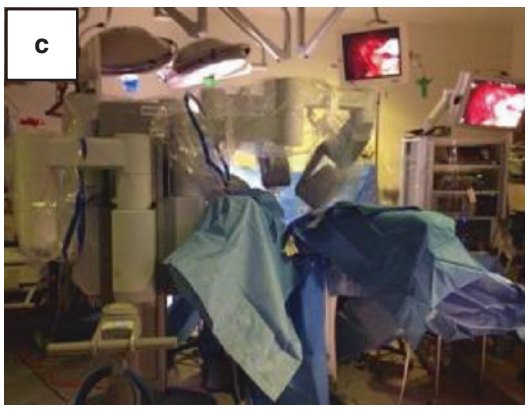


Fig. 17.5 Side-docking options. (**a**) Diagram of side-docking for the *da Vinci S*® or *Si*®. (**b**) Diagram of side-docking for the *da Vinci S*®, *Si*®, or *Xi*® (robot base in *green*). (**c**) Intraoperative example of side-docking

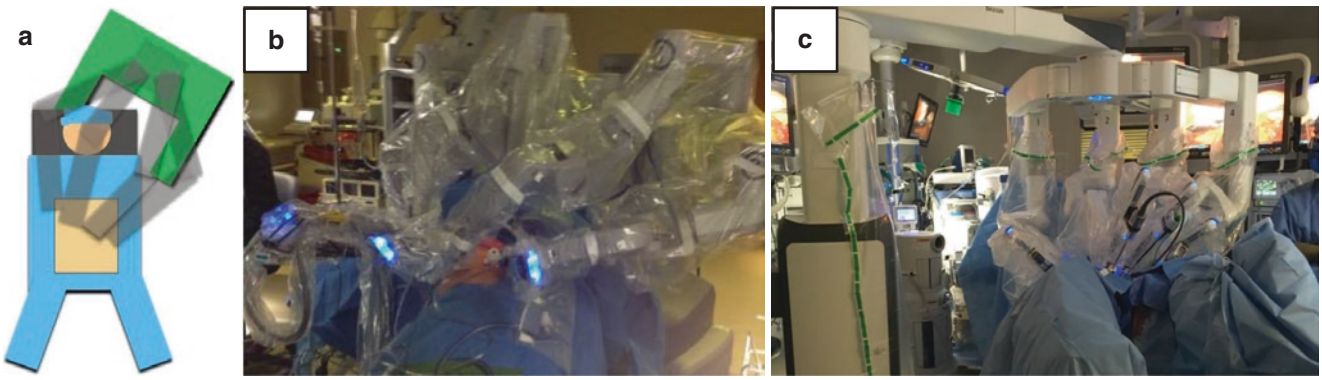


Fig. 17.6 Docking for access to the infrarenal para-aortic lymph node region. (**a**) Diagram of over the shoulder docking using the *da Vinci S*® or *Si*® (robot base in *green*). (**b**) Intraoperative example of over the shoulder docking. (**c**) Intraoperative example of an upper abdominal procedure with the *da Vinci Xi*® docked at the patient's side as shown in Fig. 17.5b. Note that the upper abdomen is accessible with side-docking by rotating the robotic arms 180°

team, this can be accomplished smoothly. Instruments should be removed, the robot undocked, and the trocars removed. A sterile transparent wound dressing (such as Tegaderm™, 3M™) should be placed over the incisions and the drapes should be removed. The patient is then rotated 180°, prepped, and draped. The wound dressing is then removed, and the trocars replaced. The accessory trocar and the trocar for the fourth robotic arm may be switched at this time, as previously described in section "Trocar Placement". The robot is then docked over the patient's shoulders, and the procedure is continued.

If using the *da Vinci Xi*®, only the robotic arms will need repositioning; the patient does not need to be rotated. The boom housing of the robotic arms on the *da Vinci Xi*® is capable of rotating 180°, so docking is performed as previously described for a para-aortic lymph node dissection in combination with a pelvic procedure with the *Xi*®.

Instrument Selection

A number of robotic instruments are available and can be used in a para-aortic lymph node dissection. It is helpful to have both a monopolar and a bipolar cautery instrument, placed typically in robotic arms one and two. The monopolar instruments available are the *Hot Shears*™ monopolar curved scissors, the permanent cautery hook, and the permanent cautery spatula. The monopolar curved scissors is our preferred monopolar cautery instrument, because it provides more versatility as it can be used to cut tissue without cautery, and closed it provides similar blunt dissection to that of the cautery hook or the cautery spatula. A variety of bipolar cautery instruments are available. The two most commonly used are the Maryland bipolar forceps and the fenestrated bipolar forceps. Both have pros and cons. The Maryland bipolar forceps is our preferred instrument for a para-aortic lymph node dissection, because it is better for dissection and working in small areas. It does, however, have less cautery area, and tissue slips more easily from it. The fenestrated bipolar forceps, on the other hand, is not as good for dissection and is harder to use in small spaces, but it has a large cautery area and grasps tissue well. Non-cautery forceps are also available and are frequently used in the fourth robotic arm to aid with retraction. The two most used in our experience are the *ProGrasp*™ forceps and the cadiere forceps. The cadiere forceps has less grasping force and is harder to use on heavy or tough tissue. The *ProGrasp*™ forceps has more grasping force but must be used with caution when grasping delicate tissue. The choice of instruments should be based on patient specifics, possible combined procedures, as well as surgeon comfort and preference.

Procedure

Once the robot is docked and the instruments are inserted, the steps to a robotic-assisted para-aortic lymphadenectomy are the same as those followed in a conventional laparoscopy or laparotomy. Prior to initiating the dissection, it can be useful to insert a radiopaque sponge into the abdomen through the accessory trocar. This may be used to tamponade any bleeding or improve visualization by blotting the area of dissection. It can also be used to retract the duodenum from the operative field if necessary.

In general, the peritoneum is opened over the right common iliac artery and extended to the aortic bifurcation. The right ureter is mobilized laterally, and the nodal tissue overlying the inferior vena cava is identified and gently elevated using blunt dissection. Careful dissection will allow visualization of the many perforating vessels from the inferior vena cava to the nodal packet. These vessels may be cauterized with bipolar cautery and transected sharply. As mentioned,

the previously placed sponge can be used to pack the duodenum away from the field, exposing the superior-most aspect of the dissection. Lymph nodes lateral to the vena cava should also be removed in a similar, careful fashion, noting the location of the lumbar veins and the right ureter. The dissection on the right should extend to the level of the right ovarian vein insertion into the inferior vena cava [37]. This nodal packet may be placed in a laparoscopic bag and removed if it will fit through the accessory trocar. If there is concern that the trocar will need to be removed and/or the incision extended in order to extract the packet, the bag may be cinched tight and left in the abdomen to be removed at the end of the procedure. Or, if a hysterectomy is also being performed, these bags may be removed through the vagina prior to closure of the colpotomy. As with sponges, a note should be made of the number of bags in the abdomen.

The inter-aortocaval nodes are removed next in a similar fashion. Care should be taken to note the location of the lumbar vessels and the right renal artery. The left para-aortic dissection is performed next. The ureter is again identified and mobilized laterally. The nodal tissue overlying the aorta is grasped and carefully dissected, as previously described. The inferior mesenteric artery's origin from the aorta should be carefully dissected and identified, and the nodal tissue surrounding it should be removed without sacrificing the inferior mesenteric artery if at all possible [37]. The specimens may be removed, as previously described.

Results

Initial concern surrounding the use of the robotic system for para-aortic lymph node dissection centered on adequate sampling, primarily due to the challenges of accessing the entire para-aortic region when using a trocar configuration designed for an associated pelvic procedure [19]. This is no longer as difficult with the latest *da Vinci*® model, the *Xi*®, as previously described in section "Surgical Technique". A number of series have confirmed that para-aortic nodal counts are not diminished when the dissection is performed using a robotic-assisted laparoscopic approach compared to conventional laparoscopy or laparotomy [6, 38–40]. Boggess et al. compared endometrial cancer staging using robotic-assisted laparoscopy (103 patients), conventional laparoscopy (81 patients), and laparotomy (138 patients). They found that the number of para-aortic lymph nodes removed was significantly different between the groups but that the most were removed using robotic-assisted laparoscopy (mean, 12.0 nodes; SD 9.0) compared to conventional laparoscopy (mean, 6.3 nodes; SD 3.7) and laparotomy (mean, 3.0 nodes; SD 2.9) ($p < 0.0001$) [6]. In 2014, Cardenas-Goicoechea et al. confirmed no difference in para-aortic nodal counts between robotic-assisted and conventional laparoscopic endometrial cancer staging. They also demonstrated no difference in the 3-year disease-free survival rates (83.2% vs. 88.4%; $p > 0.05$) and 3-year overall survival rates (93.3% vs. 93.6%, $p > 0.05$) in patients with endometrial cancer staged using a robotic-assisted versus conventional laparoscopic approach, respectively [40]. Similarly, Magrina et al. compared outcomes from 67 patients undergoing robotic-assisted endometrial cancer staging to age, stage, body mass index, and histology-matched patients undergoing staging by conventional laparoscopy ($n = 37$), vaginal hysterectomy/adnexectomy with laparoscopic nodal dissection ($n = 47$), and laparotomy ($n = 99$). They found no difference in the number of para-aortic lymph nodes removed across all four groups ($p = 0.56$) and no difference in recurrence rates across the four groups ($p = 0.16$) [14]. These data indicate that the use of the robotic platform to perform a para-aortic lymphadenectomy either alone or in conjunction with surgical staging does not adversely affect surgical outcomes.

Complications

Complications associated with robotic-assisted para-aortic lymph node dissection include vascular injury, ureteral injury, and lymphocele formation. Other complications such as chylous ascites have been reported, but these are rare and will not be discussed in detail here [41].

Vascular Injuries

The rate of vascular injuries during robotic-assisted para-aortic lymphadenectomy ranges from 1.4 to 6.3% [24, 42, 43]. Hudry et al. evaluated complications in a series of 487 patients undergoing robotic-assisted para-aortic lymphadenectomy for a gynecologic malignancy. Their rate of intraoperative vascular injury was 1.4% (7 patients in 487), with only 2 patients (0.4%) requiring conversion to laparotomy for vascular repair [42]. Coronado et al. compared perioperative outcomes between 32 patients undergoing robotic-assisted versus 30 patients undergoing conventional laparoscopic para-aortic lymph node dissection for gynecologic cancers. They experienced two inferior mesenteric artery injuries in the robotic group (6.3%) and none in the laparoscopic group ($p = 0.49$). Both injuries were managed robotically and did not require conversion [43]. These rates are consistent with vascular injury rates in para-aortic lymphadenectomies performed with conventional laparoscopy or laparotomy for gynecologic malignancies [7, 44, 45].

Should a vascular injury occur, it may be repaired robotically, depending on the comfort of the surgeon. Perutelli et al. reported a venous injury during lymphadenectomy

repaired robotically with the assistance of vascular bulldog clamps [46]. Use of the ProGrasp® forceps in the fourth robotic arm may be helpful in controlling the bleeding, while suction, suture, and clamps (if necessary) are obtained and brought into the field. Immediate recognition and patient stabilization are the most important aspects of a repair and laparotomy, and emergent consultation with a vascular surgeon should be considered if required for patient safety [47].

Ureteral Injuries

Prevention of injury should occur first and foremost and begins with knowing the anatomy and blood supply of the ureter throughout its course. Once an iatrogenic ureteral injury occurs during a robotic para-aortic lymph node dissection, the most important aspect of management is the identification of the injury as early as possible so that it may be repaired [48]. The upper- and mid-ureter segments are most likely to be injured during a para-aortic lymphadenectomy and can be repaired in a variety of ways. Small defects in these regions can frequently be repaired with a primary ureteroureterostomy after debridement of any devascularized or injured tissue. Larger defects or small defects that cannot be repaired with a ureteroureterostomy without tension on the anastomosis can be repaired using a Boari tubularized bladder flap, a transureteroureterostomy or, rarely, ureteral substitution with a segment of bowel. Depending upon the comfort of the surgeon, all of these procedures can be performed robotically without conversion to laparotomy [49]. Consultation with a urologist may be considered, depending on the specific clinical situation and the comfort of the primary surgeon.

Lymphocele Formation

Formation of a lymphocele or lymphocyst is a known complication of lymphadenectomy. Most of these cysts are identified incidentally on postoperative imaging but may sometimes become symptomatic and require drainage if they become large or secondarily infected [50]. In Hudry et al.'s series of 487 patients undergoing robotic-assisted para-aortic lymphadenectomy for gynecologic malignancies, symptomatic lymphoceles were identified in 32 patients—25 (5.8%) in the patients undergoing transperitoneal lymphadenectomy and 7 (12%) in those undergoing extraperitoneal lymphadenectomy [42]. This is similar to the 14.9% rate of symptomatic lymphocele formation reported by Sonoda et al. following extraperitoneal lymphadenectomy via conventional laparoscopy [32]. The transperitoneal symptomatic lymphocele formation rate is comparable to the rates of 1.0–9.9% previously reported for pelvic and para-aortic lymphadenectomies performed for gynecologic malignancy via conventional laparoscopy and laparotomy [51–53].

Conclusion

The robotic platform is a safe and feasible minimally invasive means by which to perform a para-aortic lymph node dissection for gynecologic malignancies. Data demonstrate that nodal yield and complication rates are similar or improved when the robotic platform is used. Several clinical pearls are important to remember:

1. Knowledge of the anatomy is the most important factor to safely perform any procedure, regardless of the surgical technique utilized.
2. The robotic platform is simply a tool to perform minimally invasive surgery.
3. Access to the infrarenal para-aortic lymph nodes or even the upper abdomen is not limited by robotic surgery, and as such, the need for access to these areas alone should not be an indication for laparotomy.
4. Robotic surgery has been demonstrated to be a safe method for a number of gynecologic oncology procedures, including para-aortic lymphadenectomy.

References

1. Visco A, Advincula AP. Robotic gynecologic surgery. Obstet Gynecol. 2008;112:1369–84.
2. Conrad LB, Ramirez PT, Burke W, Naumann RW, Ring KL, Munsell MF, et al. Role of minimally invasive surgery in gynecologic oncology: an updated survey of members of the Society of Gynecologic Oncology. Int J Gynecol Cancer. 2015;25(6):1121–7.
3. Nick AM, Ramirez PT. The impact of robotic surgery on gynecologic oncology. J Gynecol Oncol. 2011;22(3):196–202.
4. Eriksson AGZ, Ducie J, Ali N, McGree ME, Weaver AL, Bogani G, et al. Comparison of a sentineal lymph node and selective lymphadenectomy algorithm in patients with endometrioid endometrial carcinoma and limited myometrial invasion. Gynecol Oncol. 2016;140(3):394–9.
5. Mario M, Leitao J, Briscoe G, Santos K, Winder A, Jewell EL, Hoskins WJ, et al. Introduction of a computer-based surgical platform in the surgical care of patients with newly diagnosed uterine cancer: outcomes and impact on approach. Gynecol Oncol. 2012;125:394–9.
6. Boggess JF, Gehrig PA, Cantrell L, Shafer A, Ridgway M, Skinner EN, et al. A comparative study of 3 surgical methods for hysterectomy with staging for endometrial cancer: robotic assistance, laparoscopy, laparotomy. Am J Obstet Gynecol. 2008;199:360.e1–9.
7. Gaia G, Holloway RW, Santoro L, Ahmad S, Di Silverio E, Spinillo A. Robotic-assisted hysterectomy for endometrial cancer compared with traditional laparoscopic and laparotomy approaches: a systematic review. Obstet Gynecol. 2010;116(6):1422–31.
8. Brudie LA, Backes FJ, Ahmad S, Zhu X, Finkler NJ, Bigsby GE IV, et al. Analysis of disease recurrence and survival for women with uterine malignancies undergoing robotic surgery. Gynecol Oncol. 2013;128:309–15.
9. Soliman PT, Frumovitz M, Sun CC, dos Reis R, Schmeler KM, Nick AM, et al. Radical hysterectomy: a comparison of surgical

approaches after adoption of robotic surgery in gynecologic oncology. Gynecol Oncol. 2011;123:333–6.
10. Chen C-H, Chiu L-H, Chang C-W, Yen Y-K, Huang Y-H, Liu W-M. Comparing robotic surgery with conventional laparoscopy and laparotomy for cervical cancer management. Int J Gynecol Cancer. 2014;24(6):1105–11.
11. Feuer GA, Lakhi N, Barker J, Salmieri S, Burrell M. Perioperative and clinical outcomes in the management of epithelial ovarian cancer using a robotic or abdominal approach. Gynecol Oncol. 2013;131:520–4.
12. Chen C-H, Chiu L-H, Chen H-H, Chan C, Liu W-M. Comparison of robotic approach, laparoscopic approach and laparotomy in treating epithelial ovarian cancer. Int J Med Robot. 2016;12(2):268–75.
13. Magrina JF, Cetta RL, Chang Y-H, Guevara G, Magtibay PM. Analysis of secondary cytoreduction for recurrent ovarian cancer by robotics, laparoscopy and laparotomy. Gynecol Oncol. 2013;129:336–40.
14. Magrina JF, Zanagnolo V, Giles D, Noble BN, Kho RMC, Magtibay PM. Robotic surgery for endometrial cancer: comparison of perioperative outcomes and recurrence with laparoscopy, vaginal/laparoscopy and laparotomy. Eur J Gynaecol Oncol. 2011;32(5):476–80.
15. Franke O, Narducci F, Chereau-Ewald E, Orsoni M, Jauffret C, Leblanc E, et al. Role of a double docking to improve lymph node dissection: when robotically assisted laparoscopy for para-aortic lymphadenectomy is associated to a pelvic procedure. Int J Gynecol Cancer. 2015;25:331–6.
16. James JA, Rakowski JA, Jeppson CN, Stavitzski NM, Ahmad S, Holloway RW. Robotic transperitoneal infra-renal aortic lymphadenectomy in early-stage endometrial cancer. Gynecol Oncol. 2015;136:285–92.
17. Magrina JF, Long JB, Kho RM, Giles DL, Montero RP, Magtibay PM. Robotic transperitoneal infrarenal aortic lymphadenectomy: technique and results. Int J Gynecol Cancer. 2010;20:184–7.
18. Ponce J, Barahona M, Pla MJ, Rovira J, Garcia-Tejedor A, Gil-Ibanez B, et al. Robotic transperitoneal infrarenal para-aortic lymphadenectomy with double docking: technique, learning curve, and perioperative outcomes. J Minim Invasive Gynecol. 2016;23:622–7.
19. Zanagnolo V, Rollo D, Tomaselli T, Rosenberg PG, Bocciolone L, Landoni F, et al. Robotic-assisted transperitoneal aortic lymphadenectomy as part of staging procedure for gynaecological malignancies: single institution experience. Obstet Gynecol Int. 2013;2013:931318.
20. Ekdahl L, Salehi S, Falconer H. Improving double docking for robotic-assisted para-aortic lymphadenectomy in endometrial cancer staging: technique and surgical outcomes. J Minim Invasive Gynecol. 2016;23:818–24.
21. Vergote I, Pouseele B, Van Gorp T, Vanacker B, Leunen K, Cadron I, et al. Robotic retroperitoneal lower para-aortic lymphadenectomy in cervical carcinoma: first report on the technique used in 5 patients. Acta Obstet Gynecol. 2008;87:783–7.
22. Chon HS, Bush WD, Kang CW, Hoffman M. Robotic-assisted resection of isolated paraaortic lymph node recurrence with right lateral decubitus position. J Robot Surg. 2013;7:205–7.
23. Diaz-Feijoo B, Gil-Ibanez B, Perez-Benavente A, Martinez-Gomez X, Colas E, Sanchez-Iglesias JL, et al. Comparison of robotic-assisted vs conventional laparoscopy for extraperitoneal paraaortic lymphadenectomy. Gynecol Oncol. 2014;132:98–101.
24. Fastrez M, Goffin F, Vergote I, Vandromme J, Petit P, Leunen K, et al. Multi-center experience of robot-assisted laparoscopic para-aortic lymphadenectomy for staging of locally advanced cervical carcinoma. Acta Obstet Gynecol Scand. 2013;92(8):895–901.
25. Fastrez M, Vandromme J, George P, Rozenberg S, Dequeldre M. Robot assisted laparoscopic transperitoneal para-aortic lymphadenectomy in the management of advanced cervical carcinoma. Eur J Obstet Gynecol Reprod Biol. 2009;147(2):226–9.
26. Narducci F, Lambaudie E, Mautone D, Hudry D, Bresson L, Leblanc E. Extraperitoneal para-aortic lymphadenectomy by robot-assisted laparoscopy in gynecologic oncology: preliminary experience and advantages and limitations. Int J Gynecol Cancer. 2015;25:1494–502.
27. Narducci F, Lambaudie E, Houvenaeghel G, Collinet P, Leblanc E. Early experience of robotic-assisted laparoscopy for extraperitoneal para-aortic lymphadenectomy up to the left renal vein. Gynecol Oncol. 2009;115:172–4.
28. Pakish J, Soliman PT, Frumovitz M, Westin SN, Schmeler KM, Dos Reis R, et al. A comparison of extraperitoneal versus transperitoneal laparoscopic or robotic para-aortic lymphadenectomy for staging of endometrial carcinoma. Gynecol Oncol. 2014;132:366–71.
29. Akladios C, Ronzino V, Schrot-Sanyan S, Afors K, Fernandes R, Baldauf JJ, et al. Comparison between transperitoneal and extraperitoneal laparoscopic paraaortic lymphadenectomy in gynecologic malignancies. J Minim Invasive Gynecol. 2015;22:268–74.
30. Huang M, Slomovitz BM, Ramirez PT. Transperitoneal versus extraperitoneal para-aortic lymphadenectomy in patients with cervical cancer. Rev Obstet Gynecol. 2009;2(2):101–6.
31. Sonoda Y, Akladios CY, Querleu D, Leblanc E. Extraperitoneal lymph node dissection. In: Abu-Rustum NR, Barakat RR, Levine DA, editors. Atlas of procedures in gynecologic oncology. 3rd ed. Boca Raton: CRC/Taylor & Francis Group; 2013. p. 74–82.
32. Sonoda Y, Leblanc E, Querleu D, Castelain B, Papageorgiou TH, Lambaudie E, et al. Prospective evaluation of surgical staging of advanced cervical cancer via a laparoscopic extraperitoneal approach. Gynecol Oncol. 2003;91:326–31.
33. Leblanc E, Narducci F, Frumovitz M, Lesoin A, Castelain B, Baranzelli MC, et al. Therapeutic value of pretherapeutic extraperitoneal laparoscopic staging of locally advanced cervical carcinoma. Gynecol Oncol. 2007;105:304–11.
34. Higuchi TT, Gettman MT. Robotic instrumentation and operating room setup. In: Hemal AK, Menon M, editors. Robotics in genitourinary surgery. London: Springer; 2011. p. 25–36.
35. Jacob KA, Zanagnolo V, Magrina JF, Magtibay P. Robotic transperitoneal infrarenal aortic lymphadenectomy for gynecologic malignancy: a left lateral approach. J Laparoendosc Adv Surg Tech. 2011;21(8):733–6.
36. Shveiky D, Aseff JN, Iglesia CB. Brachial plexus injury after laparoscopic and robotic surgery. J Minim Invasive Gynecol. 2010;17:414–20.
37. Leitao MM Jr, Sonoda Y. Laparoscopic and robotic staging procedures for gynecologic malignancies. In: Abu-Rustum NR, Barakat RR, Levine DA, editors. Atlas of procedures in gynecologic oncology. 3rd ed. Boca Raton: CRC/Taylor & Francis Group; 2013. p. 44–53.
38. Seamon LG, Cohn DE, Henretta MS, Kim KH, Carlson MJ, Phillips GS, et al. Minimally invasive comprehensive surgical staging for endometrial cancer: robotics or laparoscopy? Gynecol Oncol. 2009;113:36–41.
39. Cardenas-Goicoechea J, Adams S, Bhat SB, Randall TC. Surgical outcomes of robotic-assisted surgical staging for endometrial cancer are equivalent to traditional laparoscopic staging at a minimally invasive surgical center. Gynecol Oncol. 2010;117(2):224–8.
40. Cardenas-Goicoechea J, Shepherd A, Momeni M, Mandeli J, Chuang L, Gretz H, et al. Survival analysis of robotic versus traditional laparoscopic surgical staging for endometrial cancer. Am J Obstet Gynecol. 2014;210:160.e1–e11.
41. Soto E, Soto C, Nezhat FR, Gretz HF, Chuang L. Chylous ascites following robotic lymph node dissection on a patient with metastatic cervical carcinoma. J Gynecol Oncol. 2011;22(1):61–3.
42. Hudry D, Ahmad S, Zanagnolo V, Narducci F, Fastrez M, Ponce J, et al. Robotically assisted para-aortic lymphadenectomy: surgical results, a cohort study of 487 patients. Int J Gynecol Cancer. 2015;25:504–11.

43. Coronado PJ, Fasero M, Magrina JF, Herraiz MA, Vidart JA. Comparison of perioperative outcomes and cost between robotic-assisted and conventional laparoscopy for transperitoneal infrarenal para-aortic lymphadenectomy (TIPAL). J Minim Invasive Gynecol. 2014;21:674–81.
44. Querleu D, Leblanc E, Cartron G, Narducci F, Ferron G, Martel P. Audit of preoperative and early complications of laparoscopic lymph node dissection in 1000 gynecologic cancer patients. Am J Obstet Gynecol. 2006;195:1287–92.
45. Walker JL, Piedmonte MR, Spirtos NM, Eisenkop SM, Schlaerth JB, Mannel RS, et al. Laparoscopy compared with laparotomy for comprehensive surgical staging of uterine cancer: gynecologic oncology group study LAP2. J Clin Oncol. 2009;27(32):5331–6.
46. Perutelli A, Garibaldi S, Gargini A, Baldacci C, Basile S, Salerno MG. Robotic management of major vessel injury during pelvic lymphadenectomy. J Minim Invasive Gynecol. 2013;20:115–8.
47. Sandadi S, Johannigman JA, Wong VL, Blebea J, Altose MD, Hurd WW. Recognition and management of major vessel injury during laparoscopy. J Minim Invasive Gynecol. 2010;17:692–702.
48. Lee Z, Kaplan J, Giusto L, Eun D. Prevention of iatrogenic ureteral injuries during robotic gynecologic surgery: a review. Am J Obstet Gynecol. 2016;214(5):566–71.
49. Burks FN, Santucci RA. Management of iatrogenic ureteral injury. Ther Adv Urol. 2014;6(3):115–24.
50. Weinberger V, Cibula D, Zikan M. Lymphocele: prevalence and management in gynecological malignancies. Exp Rev Anticancer Ther. 2014;14(3):307–17.
51. Ditto A, Martinelli F, Reato C, Kusamura S, Solima E, Fontanelli R, et al. Systematic para-aortic and pelvic lymphadenectomy in early stage epithelial ovarian cancer: a prospective study. Ann Surg Oncol. 2012;19:3849–55.
52. Konno Y, Todo Y, Minobe S, Kato H, Okamoto K, Sudo S, et al. A restrospective analysis of postoperative complications with or without para-aortic lymphadenectomy in endometrial cancer. Int J Gynecol Cancer. 2011;21(2):385–90.
53. ASTEC study group. Efficacy of systematic pelvic lymphadenectomy in endometrial cancer (MRC ASTEC trial): a randomised study. Lancet. 2009;373:126–36.

18 Extraperitoneal Para-aortic Lymphadenectomy by Robot-Assisted Laparoscopy (S, SI, and XI Systems)

Fabrice Narducci, Lucie Bresson, Delphine Hudry, and Eric Leblanc

Introduction: Background

Para-aortic lymphadenectomy is a component of lymph node staging in gynecologic oncology. The strategies for para-aortic lymphadenectomy have increased since the development of mini-invasive surgery by Querleu and Leblanc in 1991 [1]. An alternative to transperitoneal para-aortic lymphadenectomy is the extraperitoneal route, which is well known [2, 3]. Extraperitoneal procedures by robot-assisted laparoscopy have been reported since 2008 [4–10]. We report the differences in the procedures as the positions of the trocars regarding the type of robot (S or SI, XI) with surgical and oncologic results.

Presentations, Investigations, and Treatment Options

The indications for para-aortic lymphadenectomy in gynecologic oncology are generally as follows: cervical cancer tumor less than 4 cm with involved pelvic lymph nodes; cervical cancer tumor greater than 4 cm with negative positron tomography imaging findings of the para-aortic area, tailored to the upper level of concurrent chemoradiation; high-risk endometrial cancer; low-risk apparent endometrial cancer with high-risk factors for the definitive histologic results after total hysterectomy and bilateral adnexectomy, including lymphovascular space invasion, grade 3 with myometrial invasion greater than 50%, high-risk histology, or occult International Federation of Gynecology and Obstetrics (FIGO) stage III or above; and restaging for apparent FIGO stage I adnexal cancer.

The superior limit of the para-aortic lymphadenectomy is the left renal vein, except in cervical cancer, where we have dissected up to the inferior mesenteric artery (IMA) since 2013. Leblanc et al. reported that only 3.3% of the patients with locally advanced cervical cancer and para-aortic pN1 had positive lymph nodes exclusively located above the IMA [11].

The treatment options depend on the patient and the disease (organ and stage). Routinely in our department, we have used transperitoneal and extraperitoneal approaches by conventional laparoscopy or robot-assisted laparoscopy.

- *For adnexal tumors* with apparent stage I disease, we prefer the transperitoneal approach with double docking to include sufficient numbers of lymph nodes up to the left renal vein [12].
  - In cases of BMI >30, we initiate surgery by the extraperitoneal route for para-aortic lymphadenectomy with the robot on the right and then follow with the transperitoneal approach.

    For the S, SI system, the robot is in line with the lateral face of the right shoulder and left iliac spine (arm 2 is not used); then, we continue with transperitoneal upper abdominal surgery (omentectomy, etc.).

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Finally, the robot is docked in the right lateral position parallel to the leg for transperitoneal pelvic surgery.

For the Xi system, the robot is on the right lateral flank first in the lower abdominal position (general surgery) and then the pelvic position.

- *For endometrial cancer* in high-risk cases, we initiate surgery by extraperitoneal para-aortic lymphadenectomy (generally BMI >30) and then the transperitoneal pelvic approach. The positions of the systems are similar to cases with stage I adnexal tumor and BMI >30.
- *For locally advanced cervical cancer*, we prefer the extraperitoneal route up to IMA to have fewer adhesions. Additionally, we perform peritoneal marsupialization to diminish the risk of lymphocysts. However, in cases of involved or suspicious para-aortic lymph nodes, we do not perform marsupialization because of the risk of spillage. The positions of the systems are similar to those of cases with stage I adnexal tumors and BMI >30.

Pictures and Videos of the Surgical Technique

Limits of the Lymphadenectomy

For para-aortic lymphadenectomy up to the left renal artery, we dissect all the tissues between the left renal vein cranially, both common iliac artery bifurcations caudally, both ureters laterally, and both psoas muscles dorsally, taking care in manipulating the tissue in the Cuneo-Marcille fossa (lateral and dorsal to the left common iliac artery), aortocaval space, precaval area, and ventral and lateral space to the right common iliac vein.

Docking and Positioning of the Trocars

S, Si System [10]

We use the camera's arm, arm 3, and arm 1 switched on arm 3's side. Arm 2 is blocked. The position of the patient is 10° of Trendelenburg and 5° of right tilt. A strap to maintain the patient in this position is placed between the right shoulder and left axillary area (Fig. 18.1). The patient's right arm is tucked to his/her side, and the left arm is positioned at 90° with soft dorsal translation for additional space for the movements of robotic arm 1. The legs are positioned with 5° of hip flexion and 90° of knee flexion.

A 2-cm incision is made approximately 1 cm above and medially to the left iliac spine up to the peritoneum. The left index creates the extraperitoneal space with the left psoas muscle as a landmark. Next, a 12-mm balloon trocar is placed, and the robotic camera is used to control the left psoas muscle (insufflation with 10 mmHg and 2 L/min of gas) (Video 18.1). An 8-mm trocar for arm 3 (fenestrated bipolar forceps [30 w]) is visually placed 6–7 cm lateral to the left iliac trocar just above the iliac crest. An 8-mm trocar for arm 1 (left switch; monopolar scissors [25 w]) is visually placed 6–7 cm lateral to arm 3 and approximately 5 cm above the left iliac crest. A 12-mm trocar for the assistant (suction or fenestrated forceps) is placed visually just above the left iliac crest between arm 3 and arm 1 (Video 18.2). The robot is on the right of the patient in line between the lateral face of the right shoulder and the left iliac spine (Fig. 18.2).

Xi System

With the new Xi system, we must position differently the trocars for the extraperitoneal route. The position of the patient's arms and legs is the same as that reported for the S system. The position of the robot is in the right flank with

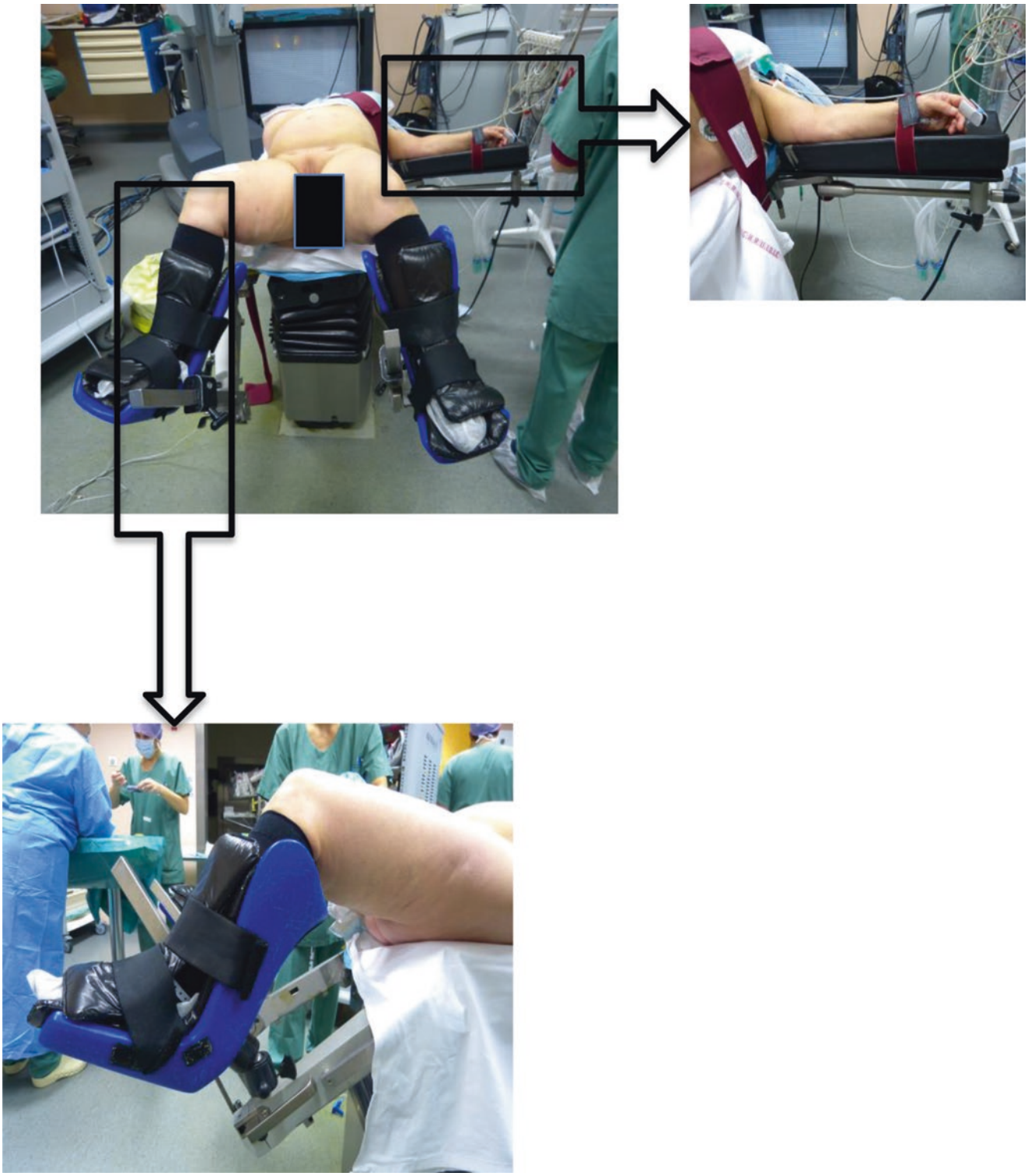
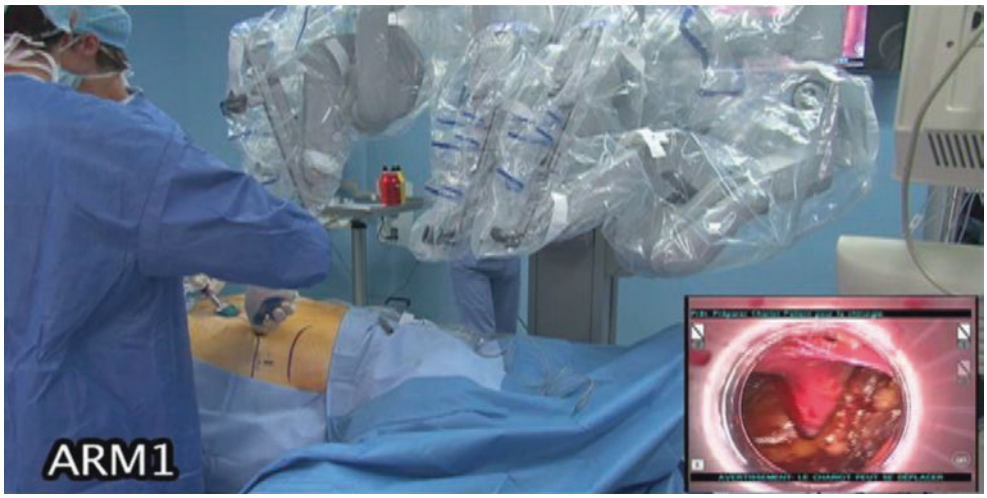


Fig. 18.1 The extraperitoneal para-aortic lymphadenectomy by robot-assisted laparoscopy technique, showing the ,position of the patient (10° Trendelenburg, 5° of right tilt, left arm positioned at 90° with soft dorsal translation, right arm tucked to the patient's side, legs with 5° flexion hip and 90° flexion knee, and a strap between the right shoulder and the left axillary area to restrain the patient) (S, Si sytems). Narducci et al IJGC 2015,25:1494 [10]

Video 18.1 Placement of left iliac spine trocar

the "lower abdominal" setting. We initiate the dissection with the left iliac spine incision as described for the S system chapter. We use an 8-mm trocar with a cone by Storz° or we place a suture on the fascia to reduce leakage or balloon trocar with telescoping 8-mm robotic trocar. We temporarily use this left iliac spine trocar for the camera to control the placement of the three other trocars (two 8-mm robotic trocars and one 12-mm assistant trocar). The two other 8-mm trocars are placed in line between the left iliac spine and the medial part of the costal margins. The space between trocars is 5–6 cm. The assistant trocar is more dorsal (Fig. 18.3). After placement of the left iliac trocar and the medial 8-mm trocar, it is necessary to push the peritoneal sac with a conventional fenestrated forceps from the psoas and from the lateral wall. When the space is sufficient, with help from



Video 18.2 Placement of others trocars

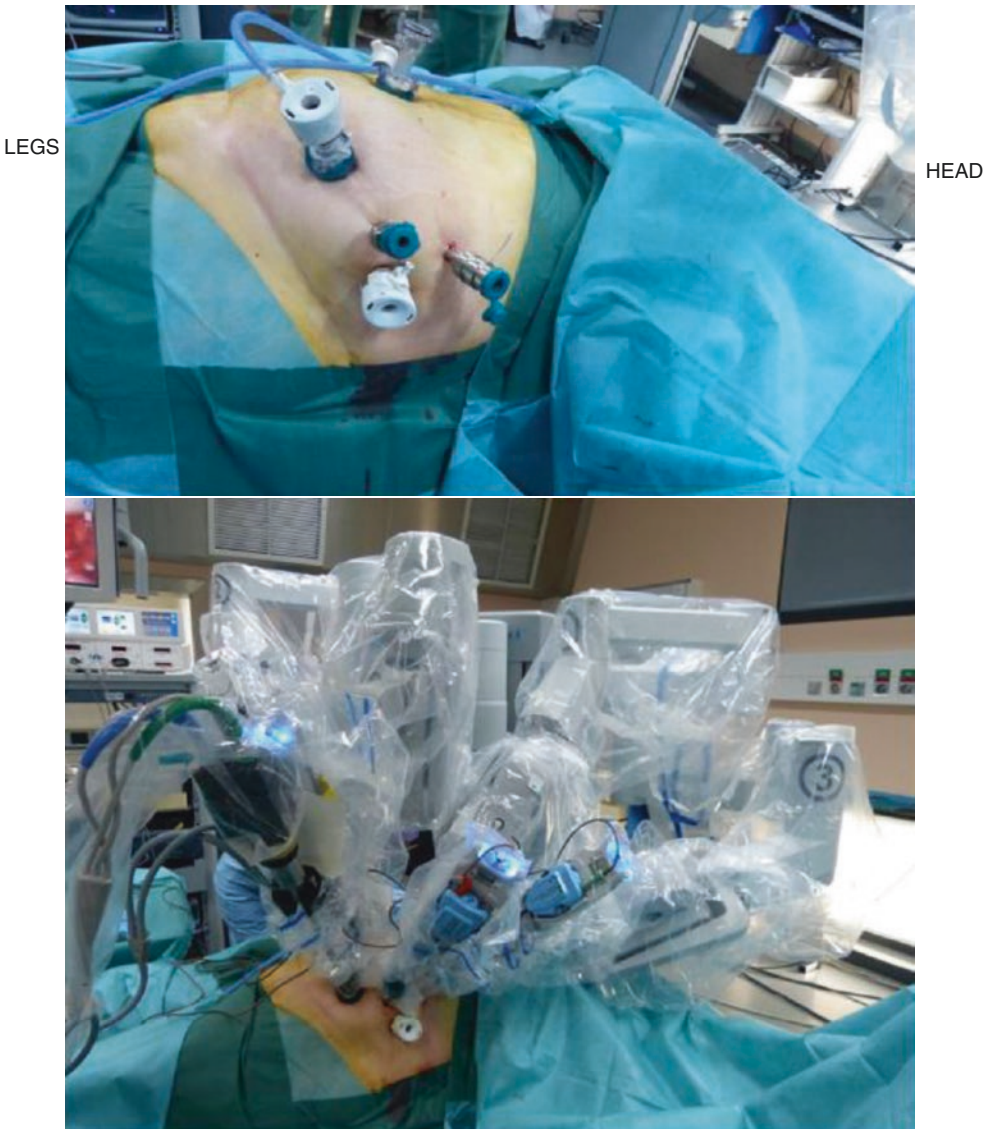


Fig. 18.2 The extraperitoneal para-aortic lymphadenectomy by robot-assisted laparoscopy technique, showing the position of the ports and robotic arms (S, Si sytems). Narducci et al IJGC 2015,25:1494 [10]

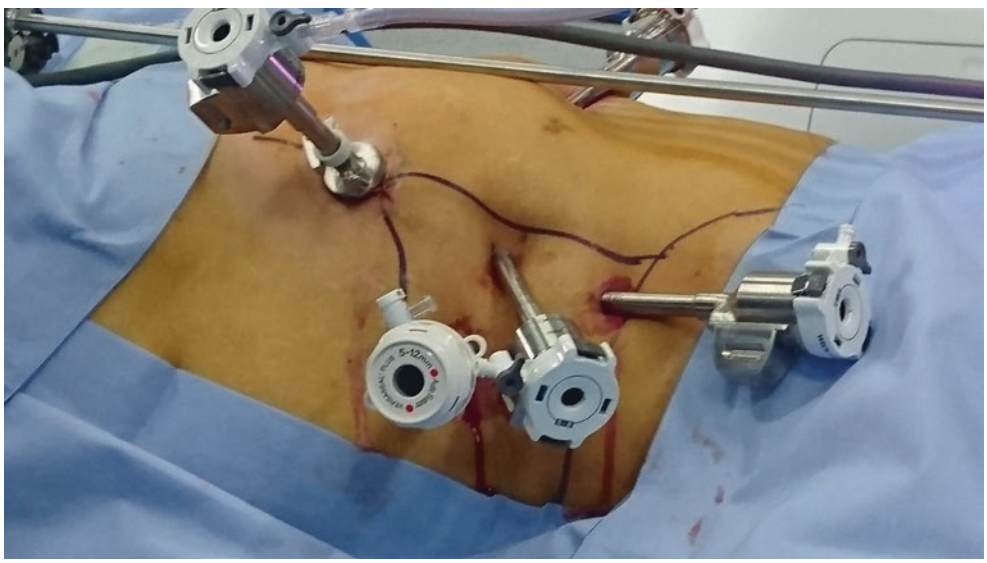
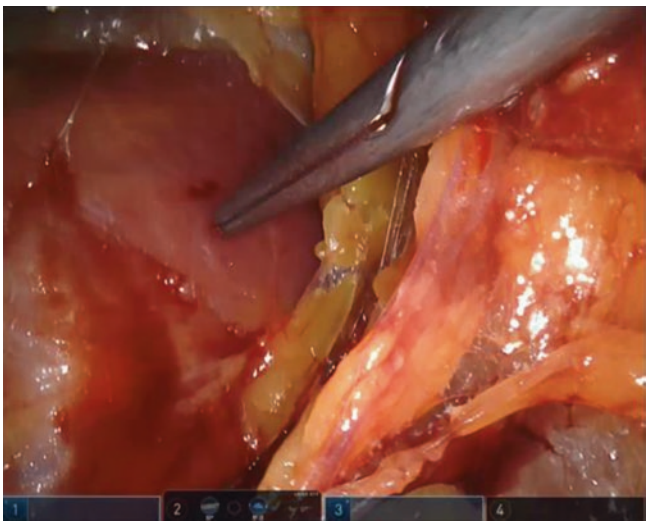


Fig. 18.3 The extraperitoneal para-aortic lymphadenectomy by robot-assisted laparoscopy technique, showing the position of the trocars (Xi system)

the camera, we introduce the more cephalic 8-mm trocar and the 12-mm assistant trocar (Video 18.3) in the left iliac trocar. The robot comes from the right of the patient's flank, and we target the medial 8-mm trocar, which will be the camera's trocar for the dissection (Fig. 18.4). We dock arm 2 for the camera with the medial 8-mm trocar. The camera is introduced in the medial 8-mm trocar, and we target the presumed position of IMA above the psoas (Fig. 18.5) (Video 18.4). We use a fenestrated bipolar forceps in the caudal 8-mm trocar (arm 1) and monopolar scissors in the cephalic 8-mm trocar (arm 3). The general view of the procedure is reported in Fig. 18.6.



Video 18.3 Increase in the extraperitoneal space and placement of the cephalic 8-mm trocar and the 12-mm assistant trocar

Para-aortic Dissection

- *The first point of the procedure is, always the same: identify and clean the landmarks.*
  - *The first landmark is the left ureter* because it is easily injured. We push it to the roof and we identify the left interiliac bifurcation (lower limit to the para-aortic lymphadenectomy) (Video 18.5).
  - *Identification of the left renal vein.*
    The left ureter and the left gonadal vein are pushed to the roof, and we dissect the plane between the renal fat and the fat of left para-aortic lymphadenectomy. Then, we open the space medially to the left gonadal vein, and we identify left renal vein (sometimes the left renal artery is lower than the vein) (Video 18.6).
  - *Left common iliac artery and aortic bifurcation.*

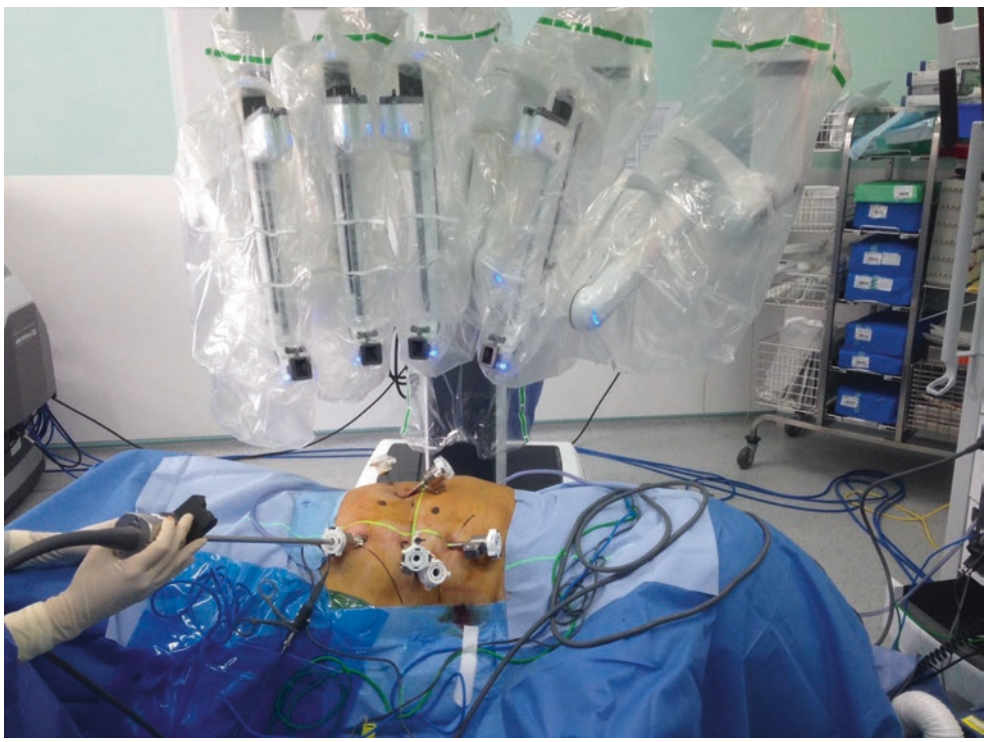


Fig. 18.4 Approach of arm 2 to the medial 8-mm trocar for camera (Xi system)

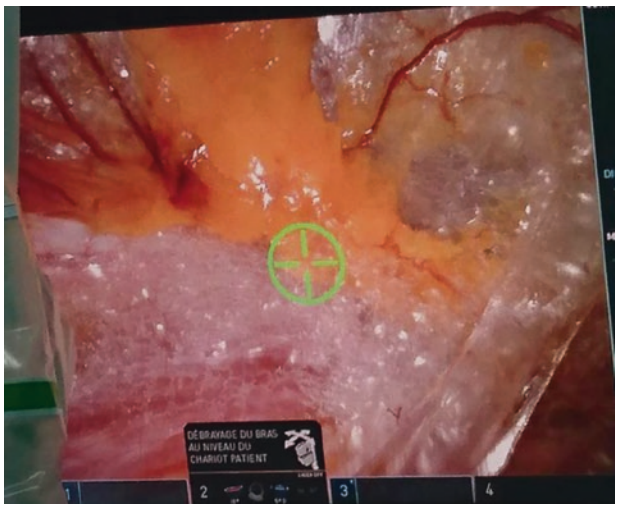
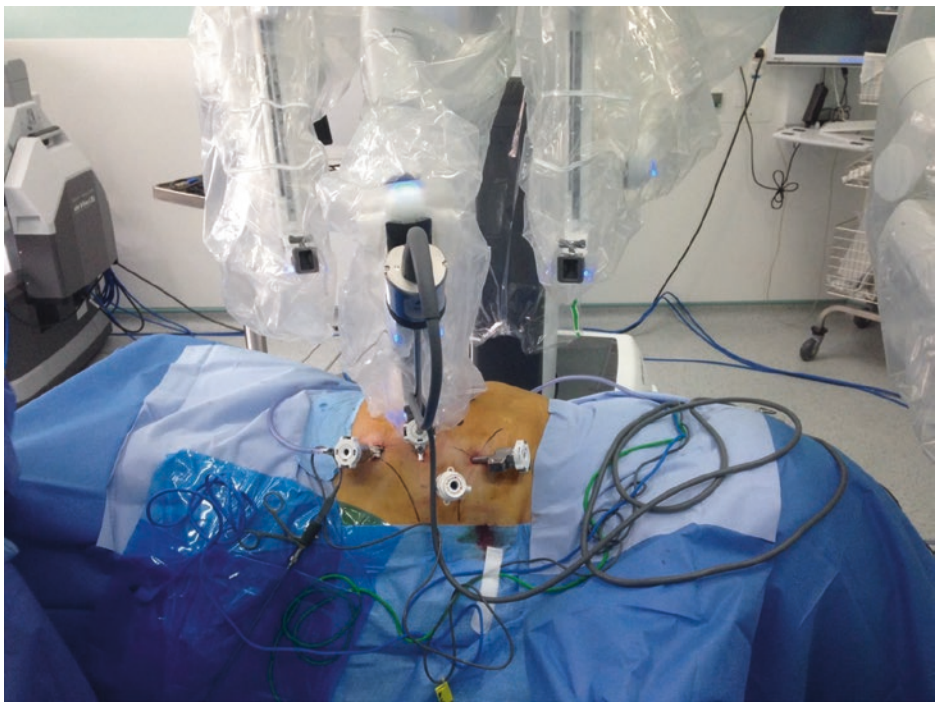
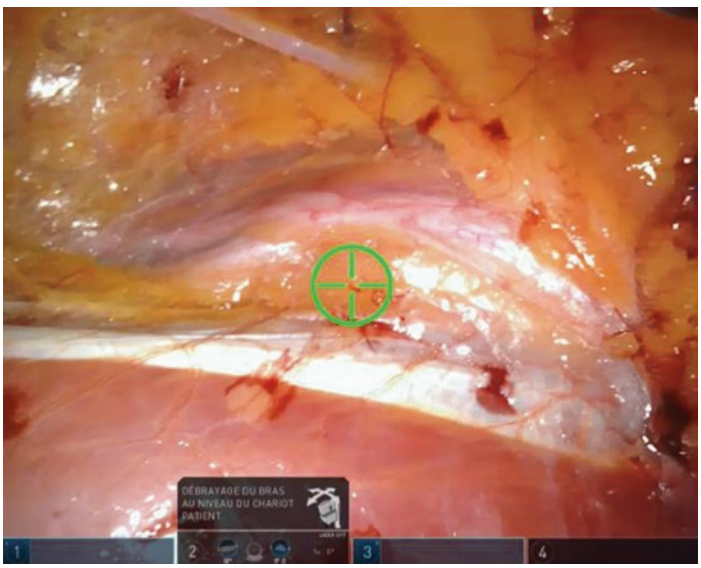


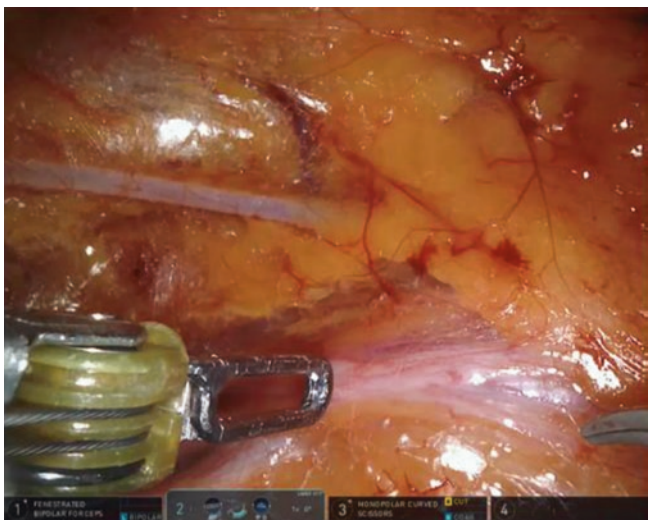
Fig. 18.5 Arm 2 in the medial 8-mm trocar and targeting above the psoas to the presumed position of IMA (Xi system)



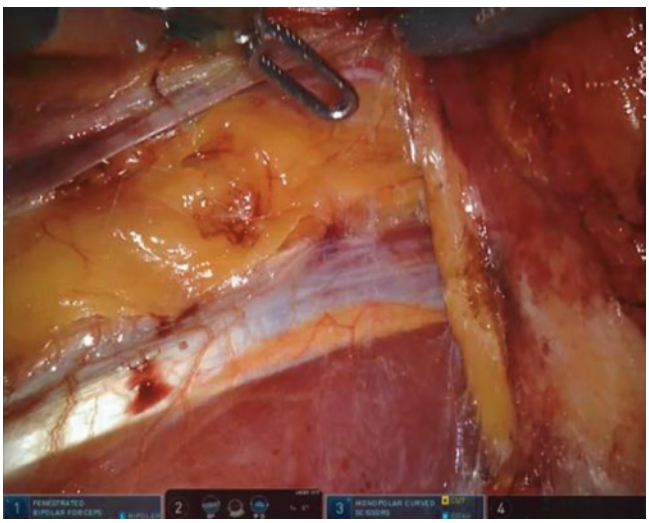


Video 18.4 Targeting in the presumed direction of IMA

Fig. 18.6 General view of the procedure (Xi system)



Video 18.5 Identification of left ureter and left interiliac bifurcation



Video 18.6 Identification of left renal vein

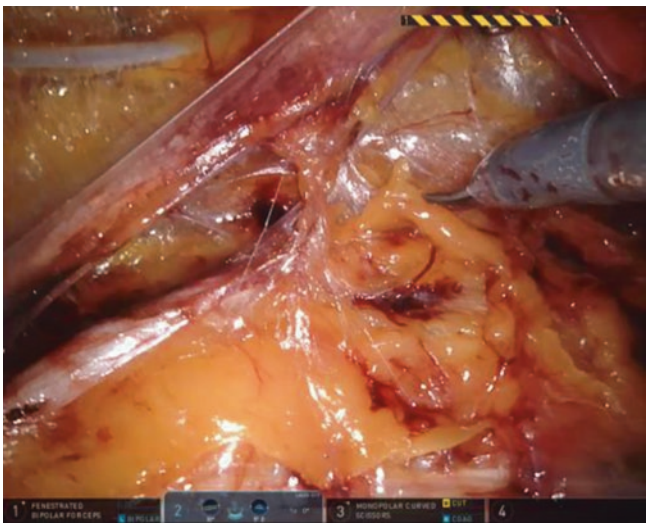
The space above the left common iliac artery is opened, and following the ventral face of left common iliac artery, we identify the aortic bifurcation.

– *Right common iliac artery—right interiliac bifurcation—right ureter.*

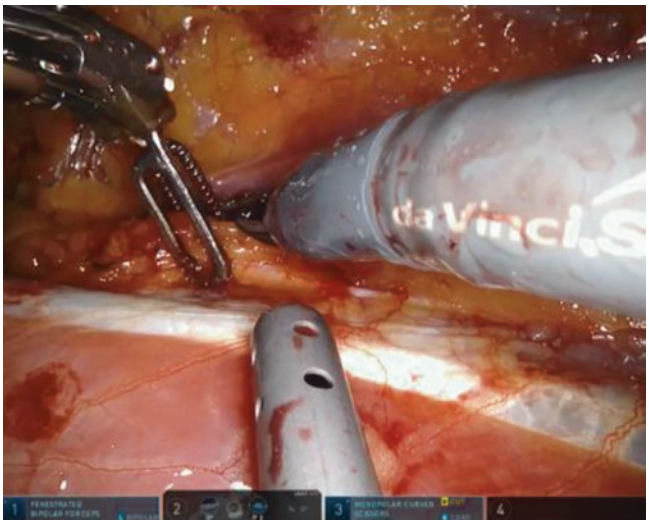
We follow the ventral face of the right common artery (Video 18.7). Generally, it is easy to follow the ventral face of the right common artery to identify the right interiliac bifurcation, and just above it, we identify the right ureter, which must be followed up to the level of the vena cava. The ventral face of the right psoas muscle is cleaned. When this step is complete, the lymph nodes of the right common iliac artery are detached from the right ureter and from lateral fat, so they are well delimited (Video 18.8).

- *Dissection of lymph nodes*
  - *Left para-aortic lymph nodes*

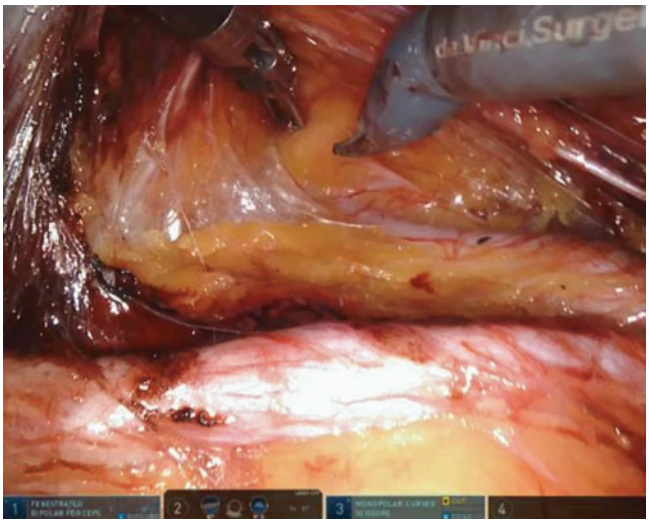
    We initiate the procedure at the level of the left interiliac bifurcation. At this limit, we cut the lymph node fat and pull it cranially. We take care to dissect all the lymph nodes in the Cuneo-Marcille fossa laterally and dorsally to the left common iliac artery. We must be careful with the left common iliac vein and its branches. We progress cranially and we take care of the lumbar vessels just before the level of the aortic bifurcation.



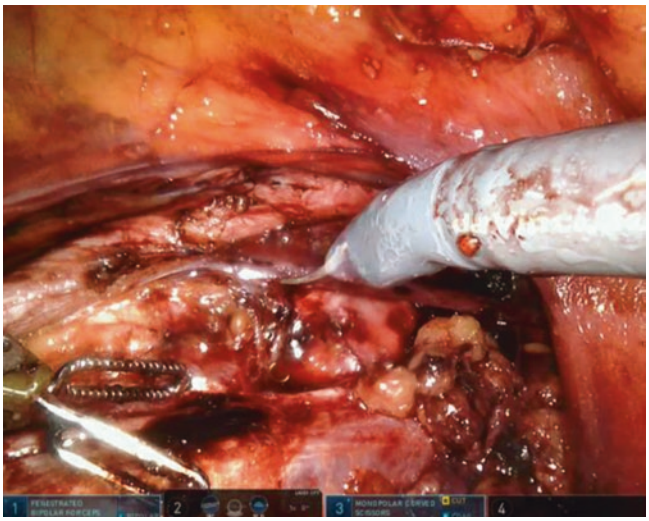
Video 18.7 Identification of common iliac arteries and aortic bifurcation



Video 18.9 Dissection of left para-aortic lymph nodes



Video 18.8 Identification of right common iliac bifurcation, right ureter



Video 18.10 Dissection of sacral area

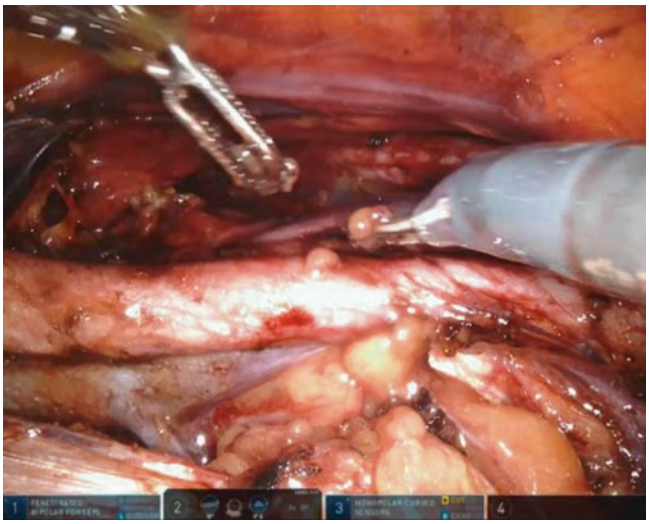
After the aortic bifurcation, we meet the superior hypogastric nerves, which come from the roof and are parallel to IMA. This dissection is sometimes difficult because this is an area with many branches, and it is not easy to dissect and conserve the nerves. We try to conserve a maximum number of nerves, but in cases of difficult dissection, we cut it (risking problems with sensation of hot/cold in the left leg). Additionally, we may observe venous branches between the azygos vein, lumbar veins, and left common iliac vein. It is often necessary to use the assistant's suction. The assistant pushes the left ureter and the left gonadal vein laterally and ventrally. After the level of IMA, we separate the left para-aortic lymph nodes from the pre-aortic lymph nodes (Video 18.9).

– *Sacral lymph nodes*

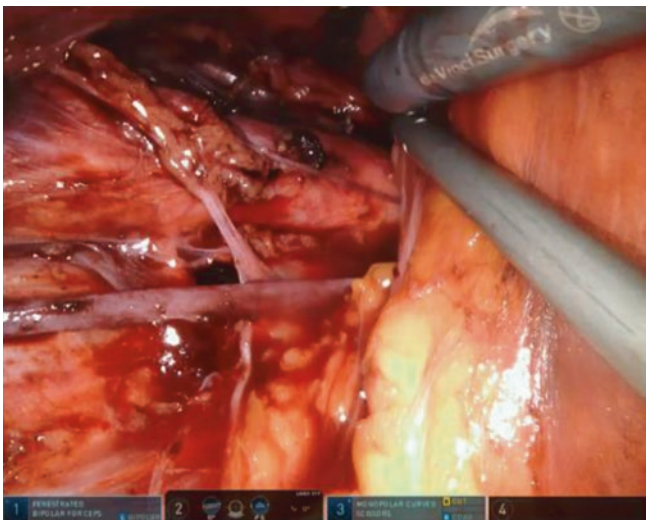
First, we use the left tilt with the Trumpf° connected table to obtain a better view in the right area (see beginning of Video 18.10). Using the suction, the assistant pushes the roof ventrally to obtain more space in front of the presacral area. The lymph nodes are pulled ventrally and we coagulate all the branches between the lymph nodes and common iliac vein (Video 18.10).

– *Right common iliac and precaval infra-mesenteric lymph nodes*

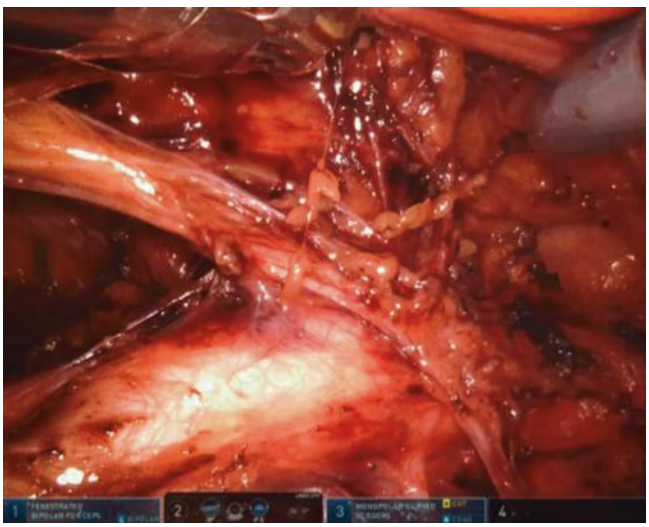
We continue the dissection with the assistant who pushes the roof ventrally just above the dissection area. The assistant must push gently because of risk of pneumoperitoneum. We dissect an extremity of lymph nodes just lateral to the right interiliac bifurcation, and we push it ventrally and cranially. All the branches between the right common iliac vein



Video 18.11 Dissection of right common iliac lymph nodes and pre-cava, infra-mesenteric lymph nodes



Video 18.13 Final view



Video 18.12 Dissection of aorta, vena cava supra-mesenteric lymph nodes

and vena cava are isolated and systematically coagulated (Video 18.11).

– *Aorta, vena cava supra-mesenteric lymph nodes*
The dissection is performed between the two ureters laterally. The layer between the vessels dorsally and the duodenum ventrally is separated step by step. We take care to separate and coagulate all the branches between the lymph nodes and aorta or vena cava (remaining aware of the two gonadal arteries). It is important to see the level of the left gonadal vein before this dissection. Between the aorta and vena cava, we dissect slowly because of the presence of the lumbar vessels and lower right renal artery (Videos 18.12 and 18.13).

Results and Complications

In our institute, we performed, extraperitoneal para-aortic lymphadenectomy by robot-assisted laparoscopy in 41 patients: 31 patients with an S system and 10 patients with a Xi system. The characteristics are reported in Table 18.1.

According to the Oslo classification for per-operative complications, we reported operative data in Table 18.2 [13]. There was one true failure in a 57-year-old patient with a BMI of 42 who had a single hysterectomy first without adnexectomy and occult IBG1 with lymph vascular space involvement in the endometrioid. Endometrial cancer was found with definitive histologic results. Therefore, there was an indication for restaging: para-aortic lymphadenectomy and adnexectomy. There was a failure of the extraperitoneal route with a pneumoperitoneum, but transperitoneal para-aortic lymphadenectomy was not possible. Two other patients had failure with pneumoperitoneum, but they had transperitoneal para-aortic lymphadenectomy by robot-assisted laparoscopy. One patient had hemorrhage lateral to the IMA, so we used extraperitoneal laparoscopy for coagulation (hemorrhage, 600 mL, but no transfusion).

Postoperative follow-up is reported in Table 18.3 with 32% postoperative complications.

Six patients had recurrence. Five patients with recurrence had locally advanced cervical cancer (with one patient with para-aortic pN1 status), and one patient had serous endometrial adenocarcinoma. The patient with 1BG3 serous endometrial adenocarcinoma had recurrence with bone and liver metastasis. The patient with locally advanced cervical cancer and para-aortic pN1 status had recurrence with peritoneal carcinomatosis, bone metastasis, and abdominal and thoracic lymph nodes. The other four patients with initial pN0 para-aortic lymphadenectomy had an initial cervical

Table 18.1 Characteristics of patients undergoing extraperitoneal para-aortic lymphadenectomy by robot-assisted laparoscopy

	Total
Number of patients	41
Age (years)	51.8 (±12.3)
BMI (kg/m^2)	28.4 (±6.5)
Disease	
– Cervical cancer	27
– Endometrial cancer	9
– Fallopian tube or ovarian cancer	4
– Vaginal cancer	1
Preoperative FIGO stage cervical cancer	
– IB2	10
– IIA	2
– IIB	12
– III	2
– Pelvic recurrence	1
Preoperative FIGO stage of endometrial cancer	
– IAG12 (lymph vascular space involvement)	2
– IAG3 (type 2)	2
– IBG12 (lymph vascular space involvement)	2
– IBG3	1
– IIIC1 (pelvic lymph node involvement)	2
Preoperative FIGO stage of tube or ovarian cancer	
– IAG3	1
– IC	2
– II	1
Preoperative FIGO stage of vaginal cancer	
– IIIA	1

Table 18.2 Operative data of patients undergoing extraperitoneal para-aortic lymphadenectomy by robot-assisted laparoscopy

	Total
Number of patients	41
Skin-to-skin operative time (min)	207.2 (±61.2)
Mean lymph node count	19.7 (±10.5)
EBL (mL) Transfusion	104.8 (±126.8) 0
Conversion to laparotomy	0
Conversion to extraperitoneal para-aortic laparoscopy	1
Conversion to transperitoneal para-aortic lymphadenectomy by robot	2
Failure	1 (2.5%) Pneumoperitoneum at the beginning of the extraperitoneal approach in an obese patient (BMI 42) in which the transperitoneal para-aortic route was not performed
Severe intraoperative complications (≥grade 2 Oslo classification)	1 (2.5%)
– Hemorrhage	– With hemorrhage = 600 mL and conversion to extraperitoneal laparoscopy (no transfusion)
Mean postoperative hospital stay (days)	2.4 (±1.2)

Table 18.3 Postoperative follow-up of patients undergoing extraperitoneal para-aortic lymphadenectomy by robot-assisted laparoscopy

	Total
Number of patients	41
Postoperative complications	*13 patients (32%)*
– Lymphocyst with drainage	7
– Leg dysesthesia	3
– Lymphedema	3
– Latero-aortic hematoma (medical treatment without transfusion)	1
– Abdominal wall pain (medical treatment)	1
– Venous thrombosis	1
Note: three patients had two complications	
Recurrence	6
– Local	1
– Metastatic	2
– Both	3
Death to disease progression	4
Survival (months)	33.1 (±26.9)

tumor size between 40 and 100 mm. The recurrences were groin lymph nodes and bone metastasis ($n = 1$), peritoneal carcinomatosis ($n = 1$), local and distant metastasis ($n = 1$), and vaginal, bladder, and rectal recurrence ($n = 1$, treated by exenteration and in complete remission at 20 months).

Conclusion

Extraperitoneal para-aortic lymphadenectomy by robot-assisted laparoscopy exhibited rates of failure, preoperative complications, and postoperative complications of 2.5%, 2.5%, and 32%, respectively. Most postoperative complications included drainage of lymphocysts, lymphedema, and dysesthesia. Peritoneal marsupialization could be useful to reduce symptomatic lymphocysts except in cases of macroscopically involved para-aortic lymph nodes.

References

1. Querleu D, Leblanc E, Castelain B. Laparoscopic pelvic lymphadenectomy in the staging of early carcinoma of the cervix. Am J Obstet Gynecol. 1991;164:579–81.
2. Dargent D, Ansquer Y, Mathevet P. Technical development and results of left extraperitoneal laparoscopic paraaortic lymphadenectomy for cervical cancer. Gynecol Oncol. 2000;77:87–92.
3. Leblanc E, Narducci F, Frumovitz M, et al. Therapeutic value of pretherapeutic extraperitoneal laparoscopic staging of locally advanced cervical carcinoma. Gynecol Oncol. 2007;105:304–11.
4. Vergote I, Pouseele B, Van Gorp T, et al. Robotic retroperitoneal lower para-aortic lymphadenectomy in cervical carcinoma: first report on the technique used in 5 patients. Acta Obstet Gynecol Scand. 2008;87:783–7.
5. Magrina JF, Kho R, Montero RP, et al. Robotic extraperitoneal aortic lymphadenectomy: development of a technique. Gynecol Oncol. 2009;113:32–5.
6. Narducci F, Lambaudie E, Houvenaeghel G, et al. Early experience of robotic-assisted laparoscopy for extraperitoneal para-aortic lymphadenectomy up to the left renal vein. Gynecol Oncol. 2009;115:172–4.

7. Fastrez M, Goffin F, Vergote I, et al. Multi-center experience of robot-assisted laparoscopic para-aortic lymphadenectomy for staging of locally advanced cervical carcinoma. Acta Obstet Gynecol Scand. 2013;92:895–901.
8. Diaz-Feijoo B, Gil-Ibanez B, Pe'rez-Benavente A, et al. Comparison of robotic-assisted vs conventional laparoscopy for extraperitoneal paraaortic lymphadenectomy. Gynecol Oncol. 2014;132: 98–101.
9. Bats AS, Mimouni M, Bensaid C, et al. Robotic extraperitoneal paraaortic lymphadenectomy in gynecological cancers: feasibility, safety, and short-term outcomes of isolated and combined procedures. Int J Gynecol Cancer. 2014;24:1486–92.
10. Narducci F, Lambaudie E, Mautone D, Hudry D, Bresson L, Leblanc E. Extraperitoneal para-aortic lymphadenectomy by robot-assisted laparoscopy in gynecologic oncology. Int J Gynecol Cancer. 2015;25:1494–502.
11. Leblanc E, Katdare N, Narducci F, Bresson L, Gouy S, Morice P, Ferron G, Querleu D, Martinez A. Should systematic infrarenal para-aortic dissection be the rule in the pretherapeutic staging of primary or recurrent locally advanced cervix cancer patients with a negative preoperative para-aortic PET imaging? Int J Gynecol Cancer. 2016;26:169–75.
12. Lambaudie E, Narducci F, Leblanc E, et al. Robotic assisted laparoscopy for paraaortic lymphadenectomy: technical description and results of an initial experience. Surg Endosc. 2012;26:2430–5.
13. Kazaryan A, Rosok B, Edwin B. Morbidity assessment in surgery: refinement proposal based on a concept of perioperative adverse events. ISRN Surg. 2013; article ID 625093, 7 pages.

Robotic Debulking Surgery in Advanced Ovarian Cancer

19

Javier F. Magrina, Vanna Zanagnolo, Paul M. Magtibay III, and Paul M. Magtibay

Introduction

Robotic surgery has been shown to provide perioperative patient advantages and similar cure rates for the treatment of endometrial and cervical cancer [1–4]. There has been increasing interest in studying its role in ovarian cancer. Some studies have shown a favorable role in the staging of early disease [5–8] as well as for the performance of primary or secondary cytoreduction in highly selected patients [8–11].

One of the reasons why robotics has not received widespread acceptance is due to the technical limitations of the da Vinci S and Si systems to reach the four quadrants of the abdomen, making it necessary to execute double or multiple dockings and utilizing additional trocars. Some have resorted to a hybrid robotic-laparoscopic procedure [8, 12] to circumvent these limitations and eliminate multiple dockings to obtain adequate exploration and cytoreduction [13]. Different surgical strategies related to the resection of different locations of disease in the same patient have been proposed [13].

The advent of the Xi system has corrected some of the limitations of the previous systems to reach the four quadrants of the abdomen due to the possibility of interchanging the camera location with the working trocars to access disease in different locations. The 180° rotation of the robotic arms allows operating in the pelvis and upper abdomen without rotating the operating table. However, undocking and redocking are required.

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Clinical Evidence for Robotic Debulking Surgery

Evidence regarding robotic debulking surgery in women with advanced or relapsed ovarian cancer is scarce and only limited to small case series [7–11]. In 2011, Magrina et al. [7] reported a comparison of the surgical and oncological outcomes of 76 women with advanced stage disease operated by robotics (25 cases), laparoscopy (27 cases), or laparotomy (119 cases). Patients were classified according to the number of major procedures performed in addition to hysterectomy, oophorectomy, omentectomy, and removal of peritoneal nodules (Type I debulking). Type II included one additional major procedure such as any type of bowel resection, full-thickness diaphragmatic resection, partial liver resection, and splenectomy. Type III debulking included patients with two or more additional major procedures to hysterectomy.

Patients with early disease undergoing Type I debulking showed improved perioperative outcomes when operated by robotics or laparoscopy relative to blood loss and hospital stay [7]. The operating times and complications were similar for the three groups [7]. For Type II debulking patients, the robotic and laparoscopy group had improved results relative to blood loss, complications, and hospital stay [7]. Robotics mean operating times were longer than laparoscopy or laparotomy [7].

Patients with Type III debulking underwent the highest number and extent of procedures [7]. Robotic patients had reduced blood loss and intraoperative complications, but the mean operating time was 138 min longer, and postoperative complications and hospital stay were similar to laparotomy [7]. Although limited by the low number of robotic patients undergoing Type III debulking, the study suggested at the present time patients with advanced ovarian cancer requiring a Type III debulking are best approached by laparotomy [7].

In regard to survival, the type of surgical approach, robotics, laparoscopy, or laparotomy did not influence overall survival [7]. Complete debulking, not the type of surgical

A. El-Ghobashy et al. (eds.), *Textbook of Gynecologic Robotic Surgery*, https://doi.org/10.1007/978-3-319-63429-6_19

approach, was the important factor influencing survival [7]. The study's conclusion was that robotics and laparoscopy appear preferable to laparotomy for the surgical treatment of ovarian cancer patients requiring Type I and Type II debulking [7]. Laparotomy remains preferable for patients requiring Type III debulking [7].

Another study [9] compared 63 robotic and 26 laparotomy patients undergoing surgical staging (40% robotics and 26% laparotomy) or resection of advanced disease. This is the only study that has shown a higher overall survival in the robotic group, but due to a different extent of disease and type of procedures among both groups. For instance, bowel resection was not performed in any robotic patient, while it was in 38% of laparotomy patients [9].

In 2014, Nezhat et al. [8] reported the results of advanced stage/recurrent ovarian cancer operated by robotics (10 patients), laparoscopy (29 patients), and laparotomy (8 patients). In case of diffuse abdominal implants, laparotomy was the surgical approach of choice. A significantly higher blood loss and hospital stay was observed in patients who underwent laparotomy in comparison with laparoscopy or robotic surgery, while operative time and intraoperative and postoperative complications were not significantly different among groups [8]. The authors concluded that minimally invasive surgery (MIS) seems to be an acceptable approach in highly selected patients due to similar perioperative outcomes compared to laparotomy [8].

There is limited evidence for robotic secondary cytoreduction. The reported benefits are similar to primary disease and apply to a highly selected group of patients with localized disease [8, 10, 11]. A comparison study of robotics, laparoscopy, and laparotomy for secondary cytoreduction of ovarian cancer was performed by Magrina et al. [11] to determine the feasibility and benefits of a robotic approach. A group of 10 patients operated by robotics were compared to 9 operated by laparoscopy and 33 by laparotomy. Laparotomy patients had a significantly higher blood loss and longer hospital stay compared to robotics [11]. Patients operated by robotics and laparoscopy had more localized disease, an important factor to consider in patient selection [11].

A multi-institutional retrospective study [10] was performed in 48 women who underwent secondary robotic cytoreduction for recurrent ovarian cancer in the absence of peritoneal carcinomatosis. An optimal debulking was achieved in 36 (82%) cases [10]. Complications occurred in six (13.6%) patients [10]. The authors concluded that selected patients with recurrent ovarian cancer are candidates for secondary surgical cytoreduction via a robotic approach. Surgical and postoperative outcomes appear to be favorable compared to previous reports of laparotomy in recurrent ovarian cancer [10].

Patient Selection for Robotic Cytoreduction

Patient selection starts with a preoperative evaluation to determine surgical candidacy. Patients are evaluated for nutritional status, comorbidities, physical examination, and CT findings. Patients considered not suitable for any type of surgery for one or multiple reasons will undergo neoadjuvant chemotherapy (NACT) once a pathological diagnosis is established with the hope they will become surgical candidates with chemical cytoreduction and/or an improved medical condition.

Surgical candidates will undergo a laparoscopic exploration to determine the feasibility of a complete tumor resection and the type of surgical approach or to proceed with NACT. Patients requiring a Type I or Type II debulking are also considered candidates for robotic cytoreduction as long as all disease can be resected. Type III debulking patients are best operated by laparotomy due to much longer operating time and similar complications and hospital stay [2]. In our experience (unpublished data), 22% of patients will undergo a robotic or laparoscopic procedure at primary cytoreduction. We observed the administration of NACT did not increase the odds of using robotics or laparoscopy at interval debulking, with only 23% of patients being candidates for a MIS approach.

In our operating room, the robotic system is available at the time of laparoscopic exploration. Should the patient be a candidate for robotics, the da Vinci Xi robotic system is prepared, while additional trocars are being placed. The main advantages of the da Vinci Xi system, as discussed above, are the 180° rotation of the robotic arms providing equal access to the pelvic and upper abdomen without the need of rotating the operating table, the ability to insert the camera through any of the robotic trocars, and longer robotic arms. Changing the location of the endoscopic camera to a different port site also improves exploration and allows removal of disease in remote abdominal areas.

Port-Site Metastases

An important aspect of laparoscopic exploration or robotic cytoreduction in advanced ovarian cancer is the development of port-site metastases. There is a high incidence of subclinical trocar site implantation which appears to be related to advanced disease and ascites, not to the interval time between laparoscopy and surgery or chemotherapy, and has no impact on survival. The incidence of clinical trocar site metastases is much lower [14]. The risk of port-site metastasis is increased with the presence of ascites and carcinomatosis [15].

Vergote et al. [14] reported on 173 patients with stage III or IV ovarian carcinoma undergoing diagnostic laparoscopy. At the time of debulking surgery, 71 patients underwent complete excision of port sites, and 30 (17%) had port-site metastases, of whom only 8 (5%) were clinically diagnosed [14]. There was no significant relationship between the development of port-site metastases and median time to primary chemotherapy or surgery, ascites, or stage IV disease. The outcome was similar to patients without trocar site metastases [14].

Heitz et al. [15] published a retrospective study of 66 patients with a primary diagnosis of ovarian cancer (OC) who had laparoscopy a median of 31 days before cytoreductive surgery and underwent resection of the trocar sites. The incidence of tumor cell implantation at the resected trocar sites was 47%. There was a correlation with advanced disease and ascites >500 mL but not with age at primary diagnosis, histological subtypes, or interval time between laparoscopy and cytoreductive surgery [15].

Robotic Techniques

The following paragraphs describe the surgical technique for robotic resection of pelvic disease involving rectosigmoid, surface liver metastases, diaphragm metastases (superficial and invasive), and omental disease.

Modified Posterior Pelvic Exenteration

The patient is in semilithotomy and Trendelenburg position. The robotic column must be side-docked, lateral to the patient's right knee, to provide easy access to the rectum for the anastomosis and air seal test.

For the performance of a low anterior rectosigmoid resection, the trocars are inserted as for robotic pelvic surgery [16] when using the da Vinci S or Si. In the case of the Xi, the optical trocar is at the umbilicus, and once the camera is docked to the optical trocar, the robotic system will dictate the position of the three working robotic trocars: left lateral, right lateral, and right medial. The assistant trocar is equidistant to the optical and left lateral trocar. When the proximal level of resection is above the pelvic brim, the optical trocar and the working trocars are placed above the umbilicus.

The instruments are selected as follows: a 0° or 30° scope depending on the size of the adnexal masses and uterus and bulging of the sigmoid due to mesenteric obesity, a PK EndoWrist or double fenestrated bipolar on the left lateral trocar for dissection and coagulation, a monopolar cautery spatula or scissors or vessel-sealing device on the right medial trocar for dissection and coagulation, and a double fenestrated grasper on the right lateral trocar for tissue retraction. The assistant trocar is placed between the optical trocar and the left robotic trocar. A robotic needle holder replaces the monopolar spatula or scissors or vessel-sealing device for suturing.

A second assistant trocar may be necessary suprapubically for the introduction of the Endo GIA (Ethicon Endo-Surgery Inc.) if the level of the resection of the rectosigmoid is at the rectal level, such as that the Endo GIA cannot be applied perpendicular for the rectal transection through the right lateral robotic trocar. If feasible, the right lateral trocar must be switched to a 12 mm trocar, to accommodate the diameter of the Endo GIA.

Technique

The retroperitoneum is entered lateral to the infundibulopelvic ligaments, the ureters are identified, and the infundibulopelvic ligaments are sealed and divided. The ovaries are removed if large, fixed, or interfering with exposure (Fig. 19.1). A hysterectomy is performed if the uterus is still present, since it will increase the operating field. Due to frequent obliteration of the cul-de-sac from metastatic disease, a retrograde hysterectomy technique is preferred (Fig. 19.2). The adnexal masses and uterus are removed through the open vaginal cuff in Endobags (Fig. 19.3). With an open vaginal cuff, the rectovaginal space is dissected 3–5 cm distal to the planned level of resection.

The lower left descending colon and sigmoid are mobilized medially by division along the white line of Toldt. The retroperitoneum over the bifurcation of the aorta and sacrum is entered by a peritoneal incision at both sides of the base of the sigmoid mesentery. The presacral space is dissected and the rectosigmoid mobilized from the sacrum (Fig. 19.4) distal to the planned level of transection. The proximal sigmoid is transected distal to the planned level of transection. The proximal sigmoid is transected with a robotic intestinal stapling device. If not available, a laparoscopic stapler (Fig. 19.5) is introduced through the right lateral trocar,

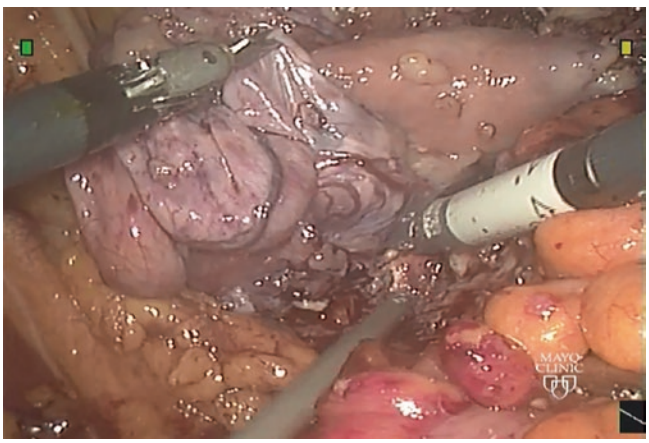

Fig. 19.1 The adnexal masses are separated first from the uterus to obtain improved exposure for the rectosigmoid resection

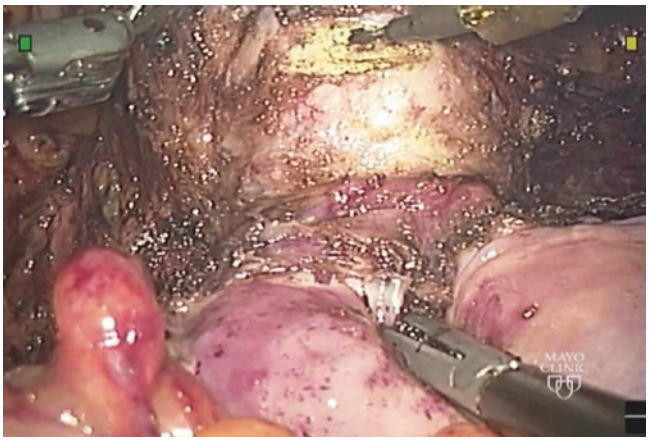

Fig. 19.2 A retrograde hysterectomy is performed due to metastases in cul-de-sac. The anterior vagina is entered first

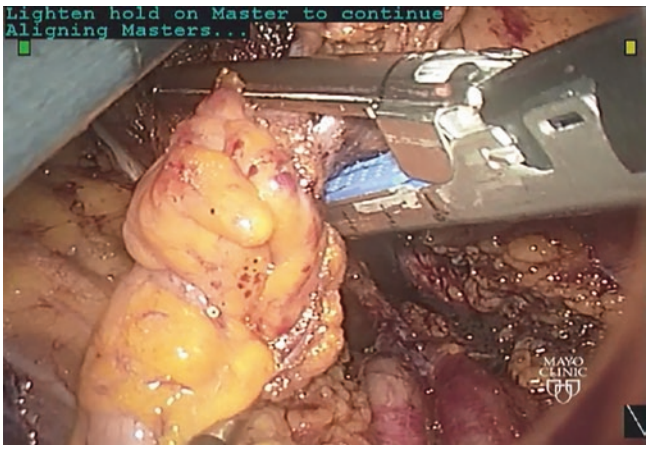

Fig. 19.5 The sigmoid is transected with an endogia above the pelvic brim

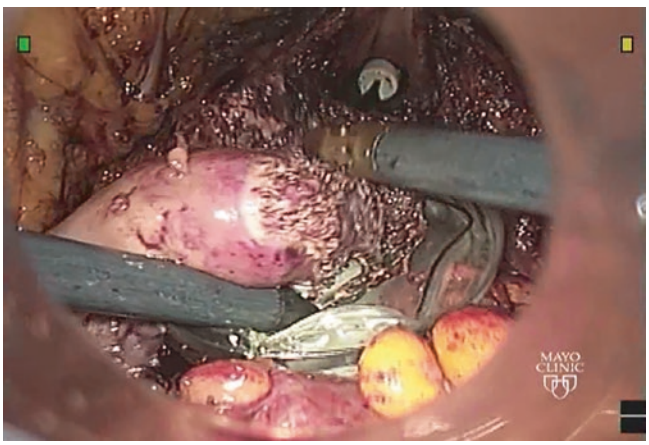

Fig. 19.3 The uterus and adnexal masses are removed thorough the open vagina

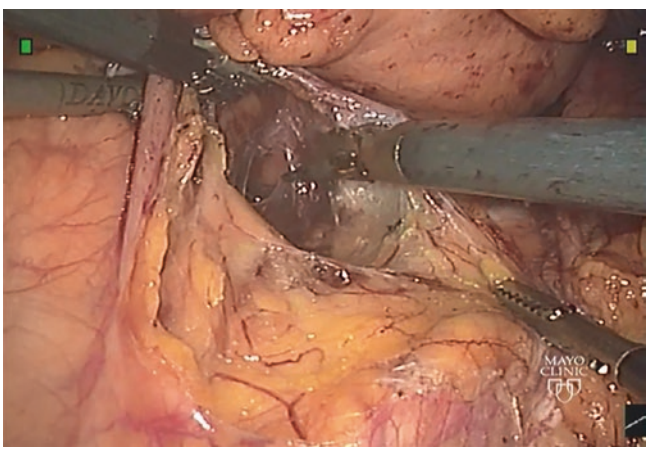

Fig. 19.4 The rectosigmoid is dissected from the presacral area and transected with an endogia above the pelvic brim

which must be replaced by a 12 mm trocar to accommodate the device. The proximal sigmoid mesentery is then completely divided, transecting the sigmoidal arteries, branches of the inferior mesenteric artery. The sigmoid is lifted out of the pelvis to facilitate the distal transection with a robotic intestinal stapling device due to its degree of articulation. If not available and the level of transection is about the midpelvis, the Endo GIA is introduced as for the proximal transection through the right lateral trocar, but if near the vaginal cuff or lower, the Endo GIA must be inserted through a 12 mm suprapubic trocar to be perpendicular to the rectal lumen (Fig. 19.6). Two successive applications of the robotic intestinal stapling device or the laparoscopic Endo GIA are usually necessary at the level of the rectum. The rectal mesentery can then be easily divided at the level of transection, but not any lower. The sigmoid is placed in an Endobag and removed vaginally if possible or through a small suprapubic incision (Fig. 19.7).

The EEA anvil is introduced in the proximal colon segment brought out through the incision if one was made. A wound retractor is applied to the incision and the specimen(s) removed (Fig. 19.7). The proximal end of the sigmoid is brought out, the staple line is cut off, and the lumen size is measured for an EEA stapler. The anvil of the EEA device is introduced in the proximal sigmoid and closed with an application of an Endo GIA or TA device. The sharp end of the anvil is pushed to perforate through the midportion of the stapled line, and the sigmoid is reintroduced in the abdominal cavity (Fig. 19.8), the incision closed, and the robotic arms redocked. If no incision was made, the anvil is introduced in the proximal colon segment intraperitoneally. The anvil is brought in through the vagina or small incision, the staple line cut, a purse string made at the previous site of the

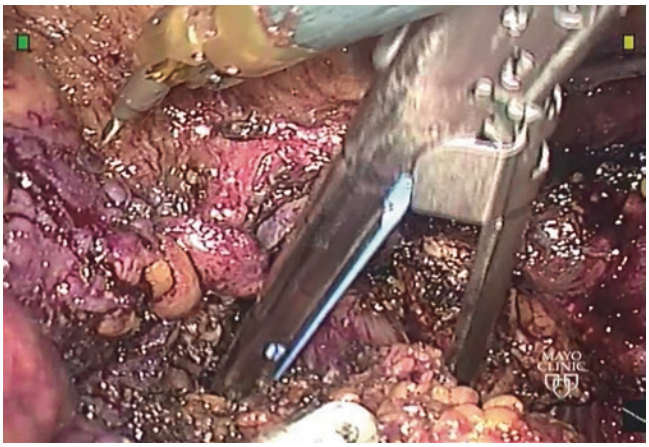

Fig. 19.6 The rectosigmoid is transected distally with one application of the endogia if is lower sigmoid or two applications is the rectum, due to the larger diameter

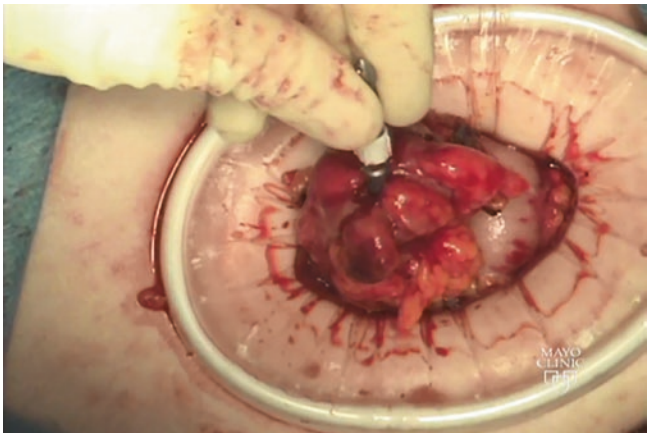

Fig. 19.8 The anvil of the EEA is inserted in the proximal end of the divided sigmoid and reintroduced into the abdominal cavity for anastomosis

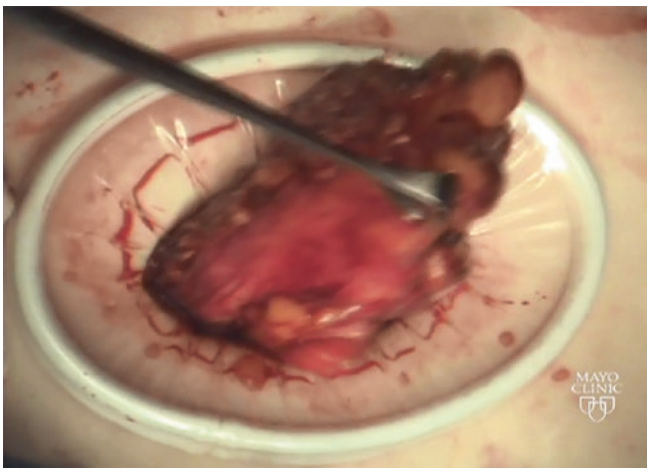

Fig. 19.7 The rectosigmoid is removed though a small incision since it could not be accommodated through the vagina

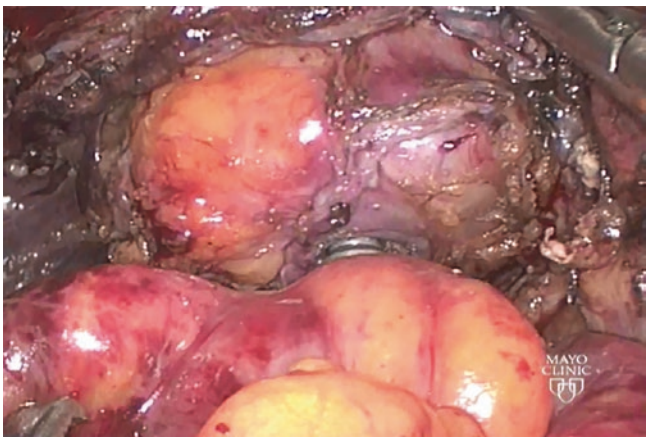

Fig. 19.9 The anvil is anchored to the EEA device introduced transanally and the device fired to complete the anastomosis

staple line, the anvil introduced in the proximal colon segment, and the purse string tied.

The proximal end of the transected colon with the anvil in place is brought into the pelvis to determine if a tension-free anastomosis is possible. If not possible, the cause must be ascertained. Sometimes division of the inferior mesenteric artery or one or several of its branches is enough. If none of the above maneuvers work, the splenic flexure must be mobilized. The robotic arms are undocked and rotated 180°, and subsequent redocking is done. With the white line of Toldt divided to the splenic flexure, the patient in right lateral decubitus, and the transverse colon under medial traction, the lateral attachments of the left splenic flexure to the paracolic area, spleen, and stomach are successively divided until the left colon descends to the mid-abdomen.

The EEA is introduced transanally to the staple line closing the rectum, and the sharp removable tip is advanced to perforate through the midportion of the staple line. The sharp tip is removed, and the anvil in the proximal sigmoid end is docked to the EEA device. Once locked, the EEA device is tightened and fired under direct visualization, which may require a 30° scope (Fig. 19.9). A bubble test is performed, and any leaks are sutured with 4-0 Ethibond or similar suture. Intraoperative antibiotics are given 1 h before the incision time and repeated 4 h later if surgery is not completed.

Diaphragm Resection

Patients are positioned in semilithotomy and reverse Trendelenburg. The robotic column is placed lateral to the patient's head. The da Vinci Xi system is preferable due to longer arms and 180° rotation of the robotic arms allowing access to the pelvis and abdomen without rotation of the operating

table. The robotic camera and trocars are placed in the upper abdomen, with the camera in the midline for bilateral lesions or to the right or left of the midline for right or left disease, respectively. Once the camera is docked to the optical robotic trocar, the robotic arm position is determined by the robotic system. For an infrahepatic approach, the camera and trocars are inserted as for pelvic surgery, with the optical trocar at the level of the umbilicus. This position of the trocars is also adequate for ventrally located right diaphragm metastases.

The instruments are selected as follows, as looking cephalad from the umbilicus: a 30° scope, a double fenestrated grasper on the left lateral trocar for liver retraction, a PK EndoWrist or double fenestrated bipolar grasper on the left medial trocar for coagulation, and a monopolar cautery spatula, scissors, or vessel-sealing device on the right robotic trocar for lesion resection. The assistant trocar is placed in between the optical trocar and the right robotic trocar. A robotic needle holder replaces the monopolar spatula to close the diaphragm defect.

Technique

A suprahepatic approach is required for most lesions. For dorsomedial lesions, the falciform and coronary ligaments must be divided to the affected area, exposing the bare area of the diaphragm, to allow complete removal of dorsal lesions. For lesions on the dorsolateral portion of the right diaphragm, an infrahepatic approach is preferable, allowing for good exposure and complete resection. A second assistant trocar is necessary for this approach for ventral retraction of the right hepatic lobe. For lateral lesions, there is no need for division of the falciform and coronary ligaments exposing the bare area of the liver, but may be necessary to divide the triangular ligament and the lateral aspect of the coronary ligament.

For resection of superficial metastases of the diaphragm, not invading the muscle, requiring a peritoneal resection only, the maximum intensity of the coagulating or cutting current must be 15 W, since a higher level will instantly contract the diaphragm muscle and the instrument will easily perforate into the pleural cavity. A maximum of 35 W is applied for full-thickness resections. The lesions are demarcated first with an adequate margin (Fig. 19.10). A dissecting plane is created between the peritoneum and the diaphragm muscle to look for any invasion. If no invasion, a peritoneal resection is adequate, as it is in any other part of the abdomen or pelvis. If there is invasion or completely adherent to the muscle, a full-thickness resection is performed (Figs. 19.11 and 19.12).

After full-thickness resection, closure is accomplished with a running, locking suture using 2-0 PDS or 2-0 Prolene on a CT-2 needle (Fig. 19.13). The suture is precut to a 15 cm in length with a Lapra-Ty (Ethicon Endo-Surgery, Inc., Cincinnati, OH) at its end. A longer suture is necessary if intracorporeal knots are used instead of a Lapra-Ty. For large defects, more than one 15 cm suture is required. The edges of the incision are inverted into the peritoneal cavity to prevent postoperative pleural effusion (Fig. 19.13). A red Robinson or other types of smooth catheter, connected to wall suction, are introduced in the pleural cavity before the last stitch is placed (Fig. 19.14), to re-expand the lung and remove any residual fluids. It is then removed during lung hyperinflation before the last stitch (Fig. 19.15). A bubble test is performed and any leaks sutured (Fig. 19.16). A chest X-ray is obtained in the operating room and repeated in the morning.

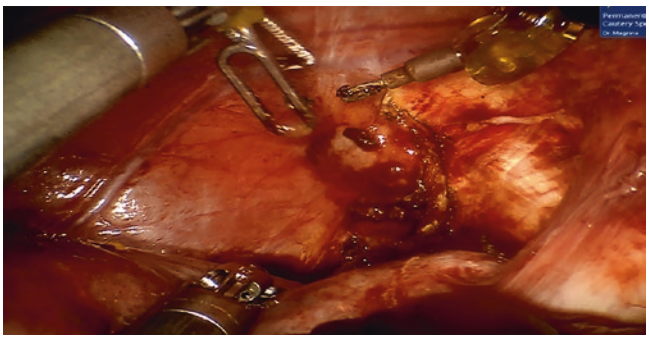

Fig. 19.10 The single metastatic lesion is being delineated with the monopolar spatula

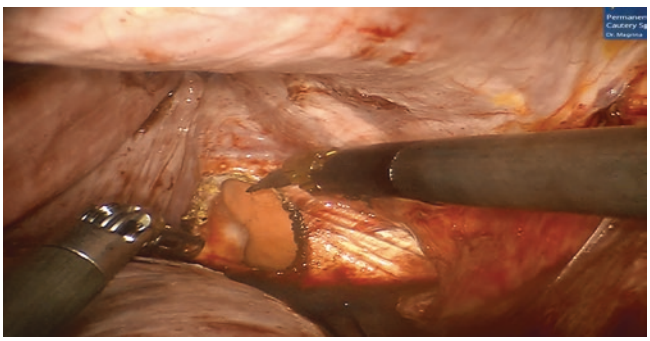

Fig. 19.11 A full thickness resection is being performed with the monopolar spatula. The transdiaphragmatic lesion can be seen bulging in the pleural cavity

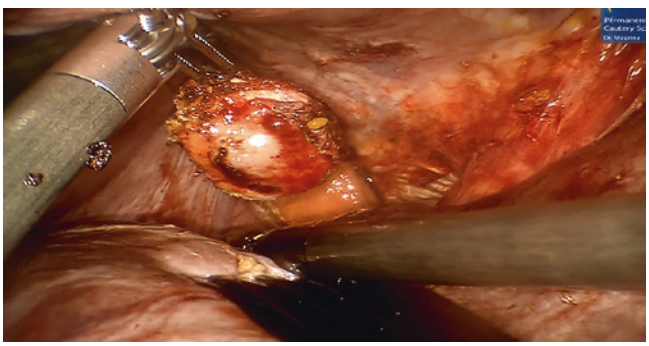

Fig. 19.12 The lesion has been resected and the diaphragm defect is seen in the backgound

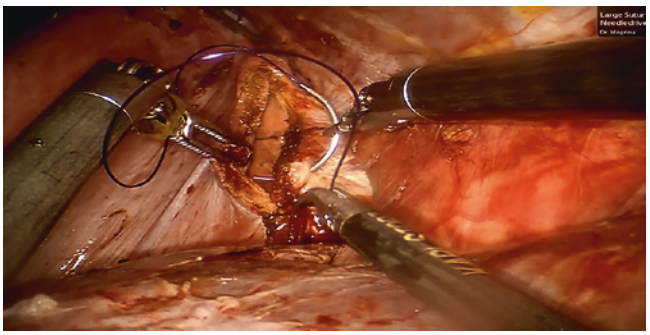

Fig. 19.13 Diaphragm closure with 2-0 PDS inverting the edges in the peritoneal cavity

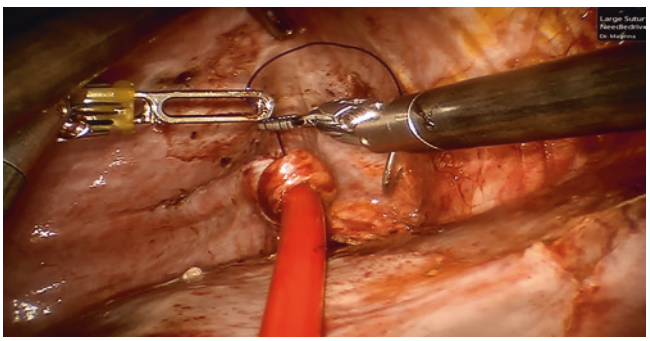

Fig. 19.14 A *red* Robinson catheter is placed in the pleural cavity connected to suction just before the last suture to remove fluids and CO_2

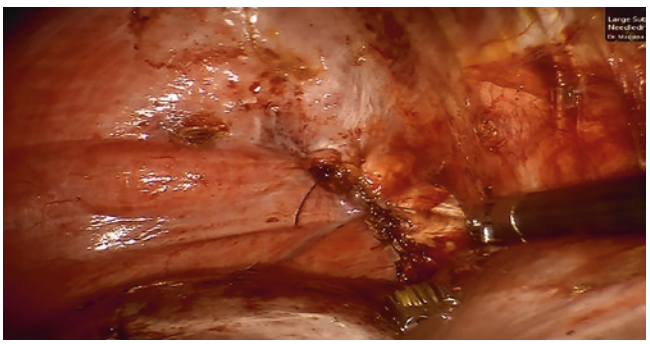

Fig. 19.15 The diaphragm defect has been closed

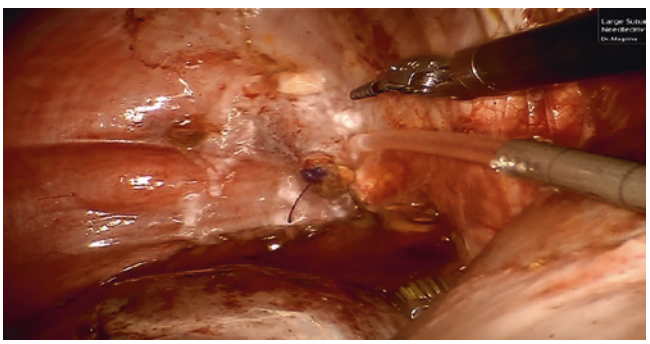

Fig. 19.16 A bubble test is performed to test the integrity of the closure by detecting any leaks

In a series of 21 patients (unpublished data) undergoing robotic diaphragm resection in the context of cytoreductive surgery, the pulmonary complication rate was 9.5% and consisted of two patients who developed postoperative pleural effusion. None developed postoperative pneumothorax. All patients had their diaphragm metastases completely resected with a mean size of 4.5 cm (range 2–14.5 cm). There were no intraoperative complications related to diaphragm resection.

Liver Resection

Patients with deep parenchymal hepatic metastases at initial diagnosis are treated with NACT and subsequently removed if still present at interval debulking by a robotic approach or laparotomy depending on size and location. Partial hepatectomies or lobectomies, full or total, are performed by a liver surgeon and usually by laparotomy. Most patients undergoing robotic liver resection have persistent, residual disease following NACT or have isolated recurrences. These are usually surface metastases superficially invasive. Some have diaphragm metastases "kissing" the liver which become invasive in the liver. These lesions are easily removed by robotics and are performed by gynecologic oncologists in our institution.

Technique

The position of the patient, robotic column, and trocars is similar as for diaphragm resection. Patients are positioned in semilithotomy and supine or reverse Trendelenburg depending on the location of the lesion(s). The robotic column is placed lateral to the patient's head. The da Vinci Xi system is preferable due to longer arms and 180° rotation of the robotic arms allowing access to the pelvis and abdomen without rotation of the operating table. The trocars are placed above the umbilicus for dorsal hepatic lesions and as for pelvic surgery if the lesions are located in the undersurface or lateral aspect of the right lobe or on the left lobe. Once the robotic scope is inserted and docked to the robotic arm, the three working robotic arms' position is determined by the Xi robotic system.

The instruments used are similar as for diaphragm resection with the addition of a saline bipolar device (Aquamantys) for the assistant. This bipolar device is a very effective coagulator, allowing deeper liver resections without major blood loss. The current is transmitted through a regulated saline drip at the tip of the instrument, coagulating the bleeding tissues very efficiently. A 30° scope is used for lesions on the dome or dorsal aspect of the liver amenable to a suprahepatic approach. A double fenestrated grasper is inserted on the left lateral trocar for liver retraction, a PK EndoWrist or double fenestrated bipolar grasper on the left medial trocar for coagulation, and a monopolar cautery spatula, scissors, or vessel-

sealing device on the right robotic trocar for lesion resection. The assistant trocar is placed in between the optical trocar and the right robotic trocar.

Lesions located on the left lobe of the liver are easier to remove than on the right hepatic lobe due to the different size and the improved exposure (Fig. 19.17). These lesions can be approached with the same trocar position as for robotic pelvic surgery, as indicated above. For lesions located on the dome or dorsal aspect of the right hepatic lobe, the falciform and coronary ligaments must be divided to expose the affected area entirely. Exposing the bare area of the diaphragm increases exposure and facilitates removal of lesions in that location. For lesions on the inferior or dorsolateral aspect of the right hepatic lobe, an infrahepatic approach is preferable, allowing for good exposure and complete resection. In that situation, ventral retraction of the right liver is necessary and achieved by a second assistant through an additional trocar inserted in the right subcostal area. Figures 19.18, 19.19, 19.20, 19.21, and 19.22 depict an infrahepatic approach for several hepatic lesions.

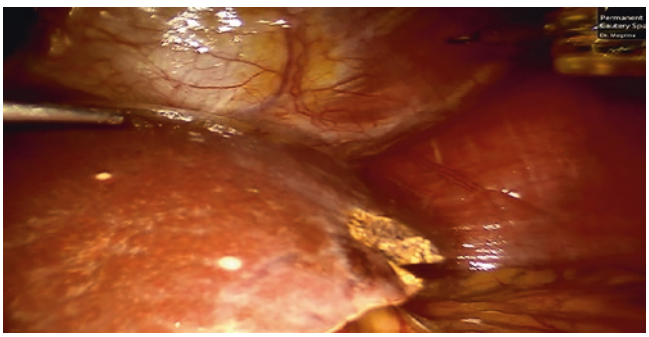

Fig. 19.17 Resection of small liver metastasis on the edge of the left hepatic lobe

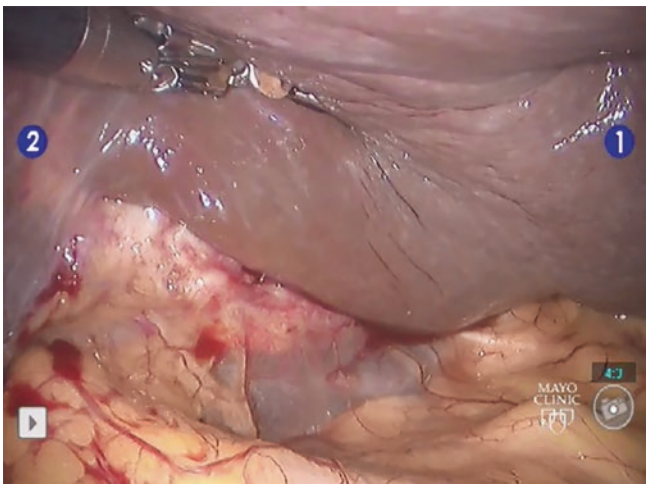

Fig. 19.18 Metastatic lesion in segment I and II

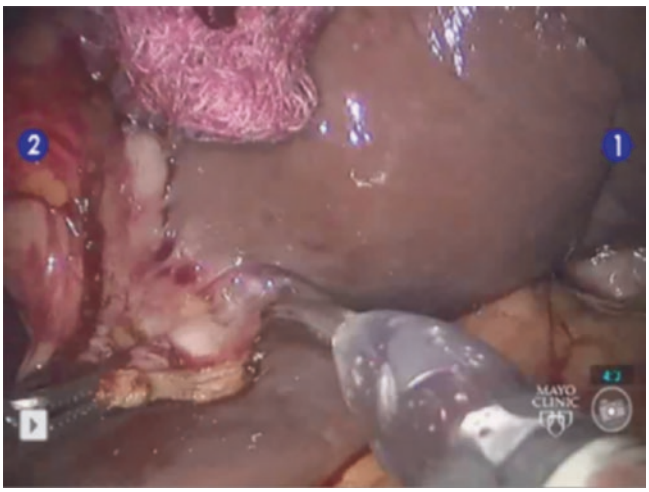

Fig. 19.19 The lesion in segment I and II has been exposed and is being resected through an infrahepatic approach

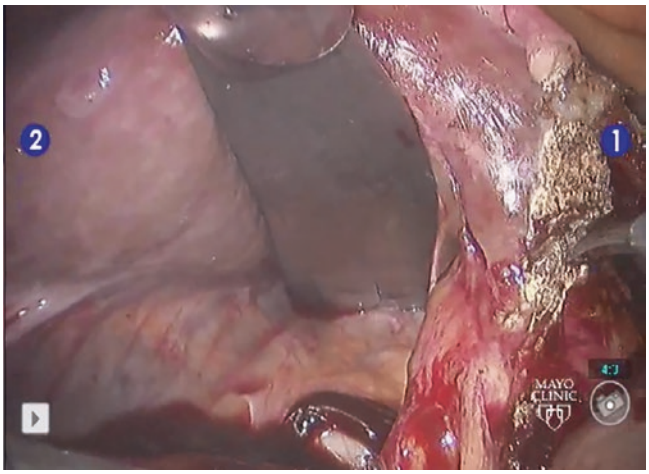

Fig. 19.20 A metastasis in segment IV (below scissors) is removed through an infrahepatic approach

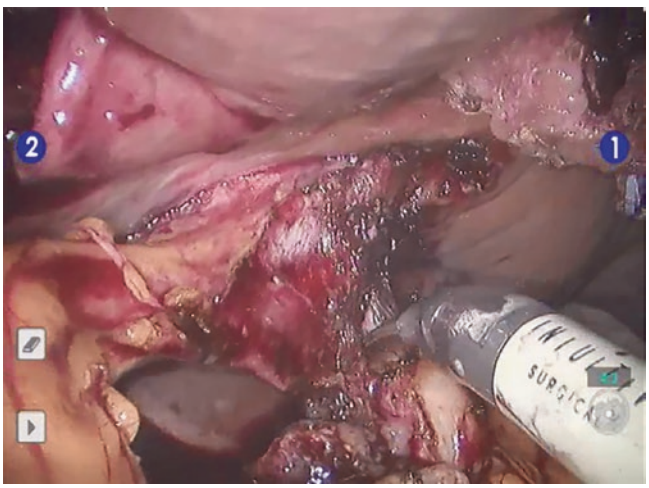

Fig. 19.21 The lesion is almost completely removed with only a small attachment remaining

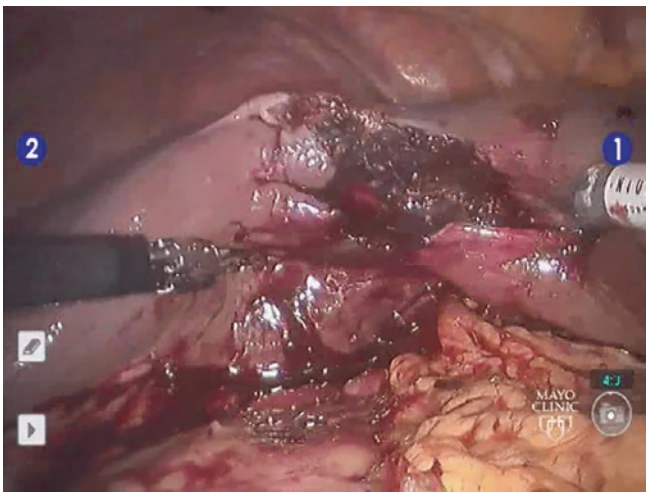

Fig. 19.22 The liver defect can be seen here after removal of the lesion

The liver lesion is demarcated with the spatula or scissors with an adequate margin. An incision is then made in the liver with the spatula or saline bipolar device depending on the estimated depth of the lesion until a clean, deep level of resection is reached. The Aquamantys is used by the assistant if bleeding is encountered during the removal which cannot be controlled with monopolar cautery. A vessel-sealing device, robotic or laparoscopic, is also useful for bleeding control. If the liver lesion is attached to and/or invading the diaphragm, it is preferable to resect it first from the diaphragm, and once free it can be retracted ventrally for a better demarcation and resection from the liver. The saline bipolar device can also be used at the completion of the liver resection to ensure hemostasis.

Omentectomy

A contraindication to robotic resection is the presence of a large, thick, fixed omental cake which will require a large incision for its removal. It is inefficient to remove large masses robotically, since it is faster through an incision, and an incision will be necessary to remove any large specimen. In the presence of omental metastases, a supracolic omentectomy is performed.

Patients are positioned in semilithotomy and supine or reverse Trendelenburg depending on what provides best exposure. The robotic column is placed lateral or above the patient's head. The da Vinci Xi system is preferable due to longer arms and 180° rotation of the robotic arms allowing access to the pelvis and abdomen without rotation of the operating table. The trocars are placed as for pelvic surgery at the level of the umbilicus, providing access to the pelvis and upper abdomen. Once the camera is placed at the umbilicus, the robotic arm position is determined by the Xi robotic system.

The instruments are selected as follows: a 0° or 30° scope, depending on omental size and location of omental adhesions. A double fenestrated grasper is inserted on the left lateral trocar, a PK EndoWrist or double fenestrated bipolar grasper on the left medial trocar for traction and coagulation, and a vessel-sealing device on the right robotic trocar for transection of the omental vessels. The assistant trocar is placed in between the optical trocar and the right robotic trocar. As an option, the assistant can use a vessel-sealing device and the surgeon monopolar spatula or scissors. The location of the robotic camera and instruments can be switched if necessary to provide efficient and safe resection. Lateral decubitus position is helpful to mobilize the small bowel away from the lateral edges of the omentum by simple gravity.

Starting on the right or the left, depending on exposure and the thinnest portion of the omentum, the lateral right or left portion of the omentum is transected with a vessel-sealing device until the loose attachments to the transverse colon are reached. The loose peritoneal attachments are transected with the monopolar spatula (Fig. 19.23) or vessel-sealing device, while the omentum is retracted with the Prograsper and also by the assistant. With ventral retraction and alternating with caudal retraction (Fig. 19.24), the last attachment to the transverse colon can be divided (Fig. 19.25). During this process, the small cavity is entered and the omentum further detached from the transverse colon or its mesentery if adhesions are present. The posterior wall of the stomach and the short gastric vessels become apparent. The short gastric vessels and left gastroepiploic artery are preserved if possible by transecting the omentum lateral to the left gastroepiploic artery, until the hilum of the spleen. However, if the omental metastases are involving the stomach wall, they are sacrificed as long as the right gastric artery is preserved. The omental attachments to the spleen, left colic splenic flexure, and left paracolic area are divided. The omentum is placed in an Endobag and subsequently removed through the vagina, if still open, or the umbilicus. Depending on the size of the omentum, adhesions, and patient's BMI, up to 45 min may be required for a supracolic omentectomy. Most of the time is spent in orienting the omentum, retraction for a safe division, keeping the small bowel away from the field, and in multiple applications of the vessel sealer.

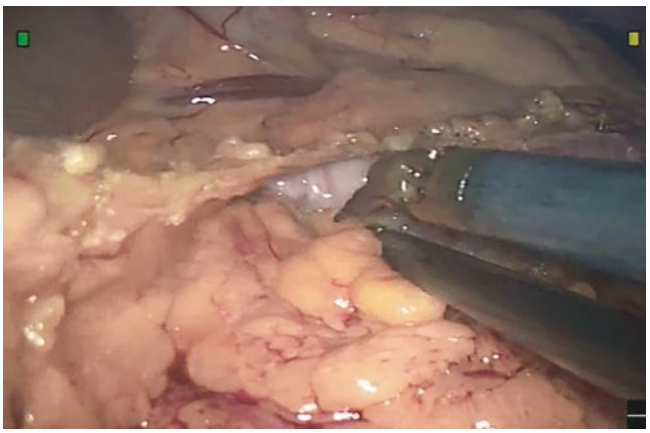

Fig. 19.23 The loose attachments can be divided with a monopolar spatula, while the main vessels are divided with a vessel sealer, in this case used by the assistant

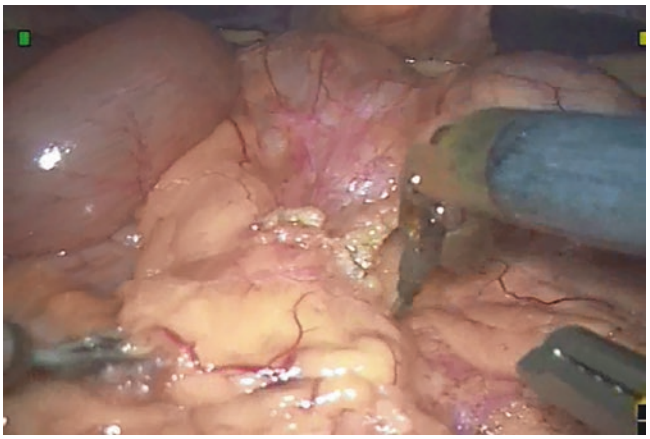

Fig. 19.24 Caudal traction on the omentum exposes the attachments to the transverse colon

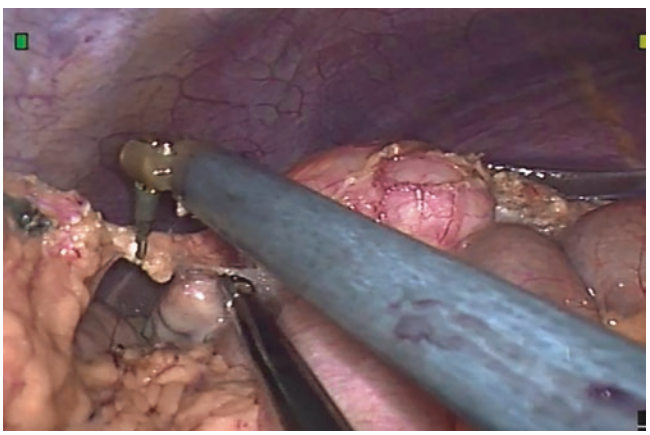

Fig. 19.25 The last attachment of the omentum to the colic right hepatic flexure is divided, completing an infracolic omentectomy

Conclusion

In conclusion, the available limited evidence suggests that robotics is safe, feasible, and preferable for selected patients with localized disease, either primary, interval, or recurrent, as long as a complete tumor resection can be performed and only two major procedures are required.

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References

1. Kim TH, et al. Robotic versus laparoscopic radical hysterectomy in cervical cancer patients: a matched-case comparative study. Int J Gynecol Cancer. 2014;24(8):1466–73.
2. Magrina JF, et al. Robotic radical hysterectomy: comparison with laparoscopy and laparotomy. Gynecol Oncol. 2008;109(1):86–91.
3. Magrina JF, et al. Robotic surgery for endometrial cancer: comparison of perioperative outcomes and recurrence with laparoscopy, vaginal/laparoscopy and laparotomy. Eur J Gynaecol Oncol. 2011;32(5):476–80.
4. Ran L, et al. Comparison of robotic surgery with laparoscopy and laparotomy for treatment of endometrial cancer: a meta-analysis. PLoS One. 2014;9(9):e108361.
5. Brown JV III, et al. The safety and feasibility of robotic-assisted lymph node staging in early-stage ovarian cancer. Int J Gynecol Cancer. 2014;24(8):1493–8.
6. Chen CH, et al. Comparison of robotic approach, laparoscopic approach and laparotomy in treating epithelial ovarian cancer. Int J Med Robot. 2016;12(2):268–75.
7. Magrina JF, et al. Robotic approach for ovarian cancer: perioperative and survival results and comparison with laparoscopy and laparotomy. Gynecol Oncol. 2011;121(1):100–5.
8. Nezhat FR, et al. Comparison of perioperative outcomes and complication rates between conventional versus robotic-assisted laparoscopy in the evaluation and management of early, advanced, and recurrent stage ovarian, fallopian tube, and primary peritoneal cancer. Int J Gynecol Cancer. 2014;24(3):600–7.
9. Escobar PF, et al. Feasibility and perioperative outcomes of robotic-assisted surgery in the management of recurrent ovarian cancer: a multi-institutional study. Gynecol Oncol. 2014;134(2):253–6.
10. Feuer GA, et al. Perioperative and clinical outcomes in the management of epithelial ovarian cancer using a robotic or abdominal approach. Gynecol Oncol. 2013;131(3):520–4.
11. Magrina JF, et al. Analysis of secondary cytoreduction for recurrent ovarian cancer by robotics, laparoscopy and laparotomy. Gynecol Oncol. 2013;129(2):336–40.
12. Nezhat FR, et al. Role of minimally invasive surgery in ovarian cancer. J Minim Invasive Gynecol. 2013;20(6):754–65.
13. Minig L, et al. Robotic surgery in women with ovarian cancer: surgical technique and evidence of clinical outcomes. J Minim Invasive Gynecol. 2016;23(3):309–16.
14. Vergote I, et al. Port-site metastases after open laparoscopy: a study in 173 patients with advanced ovarian carcinoma. Int J Gynecol Cancer. 2005;15(5):776–9.
15. Heitz F, et al. Abdominal wall metastases in patients with ovarian cancer after laparoscopic surgery: incidence, risk factors, and complications. Int J Gynecol Cancer. 2010;20(1):41–6.
16. Kho RM, et al. Robotic hysterectomy: technique and initial outcomes. Am J Obstet Gynecol. 2007;197(1):113.e1–4.

Robotic Urological Procedures in Gynaecology

20

Anna E. Wright, Sarvpreet Ubee, Kanagasabai Sahadevan, and Peter W. Cooke

Introduction

Robotics in Urology

Robotic-assisted laparoscopy was first introduced to the field of urology in the late 1980s and accounts for the largest single speciality increase in robotic procedures in recent years, principally radical prostatectomy [1]. The limitations of standard laparoscopic instrumentation and vision have driven the rapid expansion of robotic prostatectomy since the first robotic prostatectomy, performed by Binder in Germany in 2000 [2].

In renal surgery, robotics have promoted adaptations in surgical techniques which have enabled nephron-sparing approaches for complex tumours that might otherwise have required open or total nephrectomy and complex reconstruction for pyeloplasty [3]. Furthermore, in partial nephrectomy in particular, refinement of techniques permitted by robotic surgery have significantly enabled minimisation of warm ischaemia times [4], with multiple surgical adaptations to the procedure described, including sliding clip renorrhaphy [5]. Hilar microdissection, with the use of Firefly® vascular imaging, now enables completely off-clamp partial nephrectomy [6].

In radical cystectomy patients, robotic assistance has traditionally been used to excise the bladder and regional lymph nodes, with the urinary diversion being performed extracorporeally through a short periumbilical incision. In more recent years, several groups have accomplished a completely intracorporeal approach, with the benefits of a smaller incision, reduced pain, decreased bowel exposure and reduced complication rates reported [7]. Such complex bowel and ureteric reconstruction has been deemed impractical by pure laparoscopy and has led to increased complications [8].

Robotic surgery has thus extended within the urologic field to include kidney, bladder, reconstructive urologic surgery and renal transplantation. The improved ergonomics, three-dimensional view and fine motor control, have proven invaluable in deep pelvic work, particularly in obese patients. The superior 3D view has redefined our understanding of pelvic floor, neurovascular and fascial anatomy, resulting in improved functional outcomes for continence and sexual function [9]. The ease of instrument access throughout the pelvis has been facilitated more recently by side docking of the robot. In angulating the robot at approximately 45° to the lower torso, vaginal and perineal access has vastly improved [10].

As techniques are evolving with the new technology, the technology itself continues to evolve. A new contender is Intuitive Surgical's da Vinci® Xi System, which uses a more compact design, with thinner arms and longer instrument shafts, on an overhead boom. This enables greater range of movement, flexibility in port positioning and easier multiquadrant working without repositioning the robot. This creates opportunity for the pelvic surgeon in multiple scenarios, notably higher access to mobilise bowel for exenteration and intracorporeal urinary diversion and facilitating lymphadenectomy extending up to the para-aortic and inferior mesenteric areas.

Concomitant robotic nephrectomy is also a possibility, not an unforeseeable situation in cases, whereby a ureter is rendered unreconstructable following a major gynaecological resection or in cases where a gynaecological tumour or pathology has resulted in obstructive uropathy and a non-functioning kidney. Although the traditional management of significant ureteric loss is by open surgery with ileal interposition or autotransplantation, an increasing number of cases are being reported in the literature of completely intracorporeal robotic ileal interposition and are likely to become more widespread in the future with the developing techniques and technology [11, 12].

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Background: Anatomy, Tissue Handling, Stents and Drains

Ureteric Anatomy

The ureter is approximately 25–30 cm long and courses down the retroperitoneum just anterior to the psoas, commencing at the pelviureteric junction at the level of the second lumbar vertebra on the left, slightly lower on the right. Just below their origin, the gonadal vessels cross over the ureters, so-called the bridge over water [13]. In the pelvis, the ureters cross anteriorly to the iliac vessels, usually at the bifurcation of the common iliac artery, a useful landmark for their identification. The ureters then diverge laterally, out to the ischial spines, before coursing medially towards the base of the bladder. In the female, the pelvic ureter courses posterior to the ovary, forming a convex curve obliquely crossing under the uterine vessels in a sagittal direction, a few centimetres from the cervix of the uterus, reaching the base of (and deep to) the broad ligament of the uterus. The very distal ureter is in close association to the anterior vaginal fornix, more so on the left, before entering the bladder (Fig. 20.1). The close proximity to the ovarian vessels renders the ureters susceptible to damage particularly during oophorectomy or hysterectomy.

The ureter is encased in a loose *ureteric sheath*, lying just under the peritoneum to which it is adherent. Proximally, both the ureteric sheath and the adventitia are continuous with the corresponding layers of the renal pelvis. Distally, the sheath and adventitia join Waldeyer's sheath. In the female, the sheath is closely associated with the uterovaginal and vesicovaginal plexuses of veins within the parametrium, making the ureter more difficult to free during operations on the uterus. There it is susceptible to injury and devitalisation, as well as to subsequent fixation in fibrous tissue. After the destruction of the ureteric sheath, adherence of the ureter to adjacent structures may result in functional obstruction. The sheath supplements the adventitia to act as a barrier to periureteric neoplastic and inflammatory processes. In the proximal ureter, the arterial supply is delivered medially, from the renal artery, the aorta and the gonadal arteries. Distally, the most frequent sources are supplied laterally from the superior and inferior vesical arteries, but ureteric vessels also arise from internal iliac arteries, vessels that provide the richest supply to the lower portion of the ureter. The middle portion of the ureter between the lower pole of the kidney and the brim of the pelvis is the most poorly vascularised. The ureteric arteries branching from the uretero-subperitoneal vessels usually divide into long ascending and descending branches. These branches anastomose with descending branches from above and with the ascending branches from below. This vascular arrangement does not limit the sites of division of the ureter because the anastomoses within a sectioned ureter should prevent ischemia. On the other hand, interference with the arterial plexus jeopardises the viability of the end of the ureter, whether the damage occurs directly during surgery or as the effect of electrocoagulation or infection. It is worth being vigilant for congenital anomalies of the ureter; ureteric duplication in particular can be present in up to 1% of patients.

Female Bladder Anatomy

The urinary bladder, when empty, lies within the lesser pelvis, partially posterior and superior to the pubic bones, separated from these by the potential retropubic space of Retzius. The body of the bladder is highly distensible, surrounded by extraperitoneal fat; the neck is held firmly by lateral ligaments and the pubovesical ligaments of the pelvic fascia. The bladder is mostly inferior to the peritoneum, which

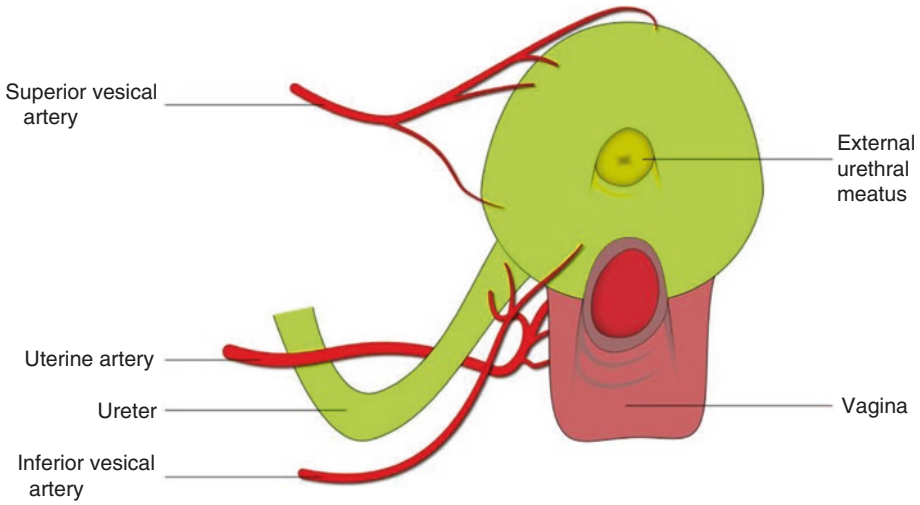

Fig. 20.1 Arterial supply of distal ureter

covers the superior wall of the bladder, uterus and rectum, forming the recto-uterine pouch of Douglas and vesico-uterine pouch more anteriorly.

The apex of the bladder points towards the pubic symphysis; the fundus (or base) of the bladder is directly related to the superior anterior wall of the vagina. The arterial supply to the bladder arises from branches of the internal iliac arteries, the superior vesical arteries supply the bladder anterosuperiorly and the vaginal arteries supply the bladder posteroinferiorly. Additional small branches arise from the obturator and inferior gluteal arteries. The vesical venous plexus mainly drains into the internal iliac veins. Lymphatic vessels from the superolateral bladder drain to the external iliac lymph nodes, lymphatic of the bladder base and neck drain to the internal iliac chains [14].

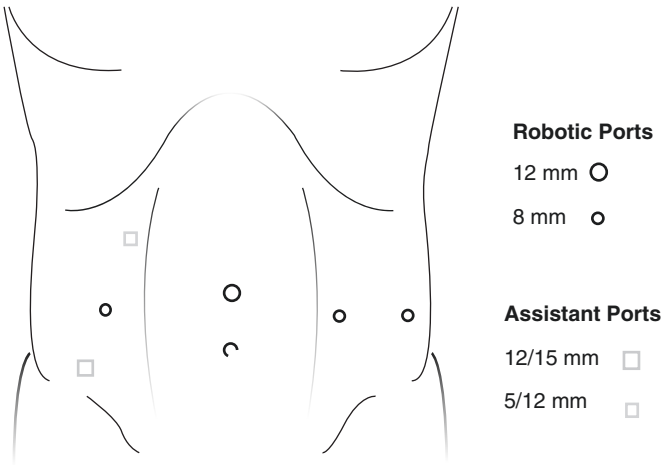

Fig. 20.2 Port placements for robot-assisted radical cystectomy

Robotic Instruments

Multiple instruments are available and undoubtedly vary according to surgeon preference [15]. For choice of tissue grasper, we advocate the use of the Cadiere™, which from our experience causes much less trauma than a ProGrasp™, for example, due to its much lower closure pressure. Although it does not grip the bladder quite as well, we have found it far safer for more generic use. The Graptor™ is safe for bowel mobilisation, unlike the ProGrasp™, but it is slightly longer and some might find it cumbersome for ureteric procedures or deep pelvic dissection. The choice of an instrument that is versatile is an important consideration in minimising expenditures. It is important to use as few instruments as possible to help reduce costs and has certainly been economically beneficial to multiple centres that have used this approach of instrument limitation [16].

Mobilising the Ureter

A repertoire of procedures necessitates the ureter to be resected or reimplanted, from strictures, trauma (often iatrogenic), fistulas and malignancy. Short ureteric defects can be managed by ureteroureterostomy (direct anastomosis) or ureteroneocystostomy (reimplantation into the bladder). Longer defects require more complex reconstruction, often involving a psoas hitch and Boari flap, or a combination of the above procedures.

The surgical technique of ureteric reconstruction will be covered later; firstly we discuss the fundamental principles of ureteric mobilisation.

All descriptions assume a right-handed surgeon using a four-port approach, which is suitable for most pelvic surgery, with robot arms 2 and 3 on the patient's left, and two assistant ports as shown in Fig. 20.2.

The most important messages in ureteric mobilisation are early identification of the normal ureter away from the site of pathology and avoiding direct handling of the ureter, due to its delicate structure and tenuous blood supply. For these reasons, understanding of the anatomical relations and blood supply of the different segments of the ureter is crucial.

The ideal anatomical position for identification of the ureter is as it crosses over the common iliac vessels/iliac bifurcation; this can be difficult in cases of aneurysmal or severely tortuous vessels.

Using a Cadiere™ in arm 3, the peritoneum is lifted and then incised with robotic scissors in arm 1, with traction on the other peritoneal cut edge by the assistant. Once the ureter is identified, hold it up using the Cadiere™ and then use Maryland bipolar forceps along with scissors to dissect the appropriate length of ureter. When mobilising the ureter, avoid grasping the ureter directly, which will crush the arterial plexus and render it ischaemic. Likewise an extremely judicious use of diathermy should be applied, with short bursts of bipolar cautery using the Maryland, mild venous oozing can usually be ignored; this helps to minimise ureteric ischaemia and thermal injury resulting in late perforation or stricture formation.

Use the surgical assistant to hold and retract the opposite peritoneal fold whilst dissecting out the ureter, mobilising it fully off the peritoneum. If it is challenging to identify at this level, then dissect proximally and medially towards the kidney. Previous pelvic surgery or radiation tends to pull the ureter medially, so start over the external iliac artery and move medially to the aorta. On the left be sure to mobilise the sigmoid colon quite high to allow its medial reflection. The left ureter usually lies in the groove at the root of the sigmoid mesocolon. At times in obese patients, this can be difficult. If necessary trace the gonadal vessels proximally to where they cross the ureter higher up. Once the ureter is identified, then follow it distally. Dissection of the ureter

should be as per its anatomical principles, and the fascial layers and the fat covering should not be stripped from the ureter, in order to preserve its blood supply and reduce the risk of devascularisation. Avoid circumferentially mobilising the ureter above the pelvic brim. Handling of the ureter with instruments should be kept to a minimum, if at all; a 10 cm 3/0 Vicryl stay suture may be used at the tip of a spatulated divided ureter for mobilisation. Alternatively, an effective trick to minimise ureteric handling involves passing a rubber sloop around the ureter, once the initial ureteric isolation has been achieved. A 10cm long sloop with a Hem-o-lok® clip (Weck Closure Systems, NC, USA) to hold the ends together can also aid in the traction-countertraction, whilst the dissection of the ureter is complete. A complete left ureteric mobilisation is shown in Video 20.1, with its division after clipping with a large Gold Hem-o-lok® clips. Note in Fig. 20.3 that the ureter is not gripped with the forceps. If performing planned ureteric division, a 15 cm 2/0 Vicryl suture can be tied to the clip used on the proximal end. This allows traction without directly handling the ureter. In cases where there is already a ureteric stent in situ to relieve obstructive uropathy, incise the ureter and retrieve the stent first, to avoid time consumed chasing the cut stent ends.

When performing an extended pelvic lymphadenectomy, the ureter may be protected from inadvertent injury by looping it behind the medial cut edge of peritoneum and using this as a retractor. This technique relies on long ureteric mobilisation.

Handling and Mobilising the Bladder

For robotic procedures on the bladder, the dissection of the bladder begins with its posterior release by an inverted U-shaped incision on the peritoneum of the pouch of Douglas. The ovarian vessels are controlled with Hem-o-lok® clips and divided. The posterior plane of dissection will depend on whether the uterus is present or is being preserved. If it is, then dissection will begin anterior to the fundus of the uterus, developing the plane between the posterior bladder wall and the anterior vagina, towards the urethra. This is commonly a fairly bloodless plane, though it may be obliterated by previous radiotherapy. Laterally the dissection is continued medial to the external iliac veins to carefully preserve the obturator nerves and expose the lateral pelvic wall. This delineates the lateral pedicles to the bladder and uterus. The obliterated umbilical ligament is a useful landmark to aid identification of the internal iliac artery from which it arises. Control over the pedicles of the bladder can be achieved either with Hem-o-lok® clips; a vessel sealer, e.g. LigaSure®; or a linear vascular stapler, such as Endopath™ ATW45 linear stapler (Ethicon Endosurgery, Livingston, UK). Video 20.2 demonstrates bladder mobilisation, after mobilisation of the sigmoid colon to expose the ureter. Anteriorly, the bladder is dropped by an inverted U incision to include the urachus. The endopelvic fascia is opened and the dorsal clitoral vein controlled by a stitch. For complete release of the bladder, the anterior dissection of the bladder should only be performed once the posterior and lateral release has been achieved.

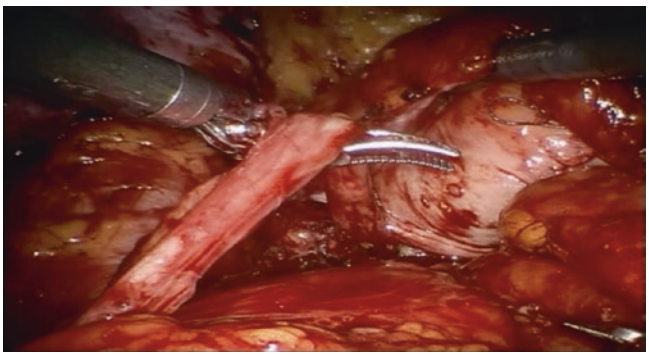

Fig. 20.3 Left ureteric mobilisation

Whilst preparing the bladder to perform either a Boari flap or a psoas hitch, the contralateral superior pedicle needs to be released in order to achieve an adequate tension-free ureteroneocystostomy anastomosis. It is rare to need posterior mobilisation in this instance.

Handling and Mobilising the Bowel

Small bowel is used for augmentation cystoplasty or for diversion procedures following a cystectomy performed for either benign or malignant reasons. Intracorporeal robotic procedures reduce the handling of the small bowel and thus may reduce the postoperative morbidity.

For most of the robotic urogynaecological procedures, the patient is in a steep 35° Trendelenburg position; for the procedures involving small bowel, such a steep position is often not required. It may also result in difficult bowel handling, as the small bowel loops will easily fall out of camera view. For these procedures, the steps can often be performed comfortably by keeping the patient at a Trendelenburg angle of approximately 10–15° head down, thus reducing the risk of compartment syndrome associated with procedures involving long operating times. Undocking of the robot is required for this position change.

For arm 3 of the robot, a 15mm laparoscopic port is inserted initially, and the 8mm robotic port is inserted through the laparoscopic port, which is then docked to the robotic arm (so-called port-in-port). The rest of the ports are as for other robotic pelvic procedures. For robotic procedures involving small bowel, a three-surgeon team often provides optimum efficiency, with the first surgeon on the

console and the remaining two assistants on either side of the patient.

The small bowel is best handled with a Cadiere™ or Graptor™. A ProGrasp™ must not be used as it will crush and injure the bowel. A 15 cm length of suture can be used to identify and measure the length of the ideal segment of ileum. The bowel and the mesentery are prepared using a vascular stapler (Endo GIA™, Covidien). The stapler is inserted through the 15 mm port after removing the robotic port. After the stapler has been used, the arm is redocked. The anastomosis of the ureter to the ileum is performed using an absorbable suture, e.g. 4/0 Vicryl in an interrupted or a continuous manner over an indwelling double J or single J stent. Interrupted sutures are considerably more time-consuming, though may be preferable if the ureter has been irradiated or there are concerns for compromised tissue healing.

Ureteric Stenting

The insertion of a ureteric stent pre-procedure should always be considered in cases where difficult anatomy, dissection or advanced pathology is expected or encountered. Careful pre-operative evaluation of cross-sectional imaging should identify most cases. A stent should be inserted via cystoscopy using a retrograde approach, at the start of the procedure, before commencing the robotic-assisted component. It may be practical for a urologist to do this as a separate procedure before, with retrograde imaging studies to assess the ureter. Alternatively it may be more appropriate for antegrade stents to be inserted percutaneously by a radiologist in cases of bulky pelvic pathology resulting in distorted anatomy at the bladder base.

If a stent is deemed necessary, aim for the stent insertion and definitive robotic procedure to be in close succession, to minimise ureteric inflammation and oedema, which may make handling/suturing more difficult. A further option is to use illuminated catheters (Cook® Medical), placed retrogradely at procedure commencement to aid intraoperative ureteric identification.

Intraoperative ureteric stenting is usually performed over a guidewire. A floppy-tipped or hydrophilic guidewire is preferable, to minimise trauma or even perforation of the ureter. The stent can then be railroaded over the guidewire, which is subsequently removed once the stent is felt to have advanced sufficiently. Radiological screening is not usually required and is impractical with the robot in situ. The choice of stent is dependent on the procedure and surgeon preference. Shorter stents may be used in shorter patients (22 or 24 cm, as opposed to the standard 26 cm), to minimise the length of stent within the bladder, as this can cause urinary frequency and discomfort. Usually double J stents are used,

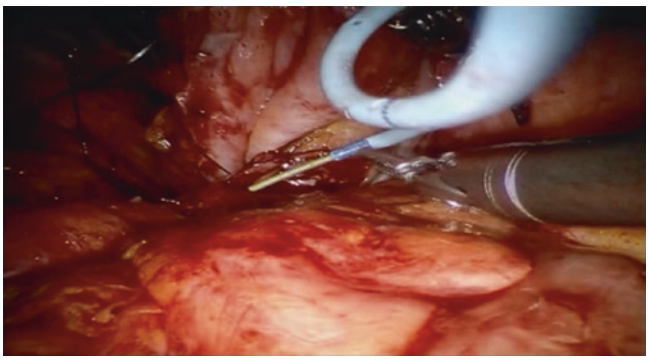

Fig. 20.4 Left ureteric stenting

with the suture cut-off. Some surgeons prefer infant feeding tubes or long Cook® Bander ureteric diversion stents which can be cut to the required length and are long enough to pass percutaneously from a neobladder. They are also available in different colours, a convenient aid for identifying the laterality. Stents are passed intra-abdominally via the 12 mm assistant port or percutaneously via a 2 mm stab incision and a large bore venous cannula. The stent should be passed up the ureter with 5 mm of guidewire protruding from its end to straighten its curl. Pass it hand over hand, observing its passage to assess for resistance which cannot be felt due to robotic loss of haptic feedback. Markers show how far it has advanced. It is common to see urine drain through the stent holes once the proximal end has reached the renal pelvis. The guidewire is then withdrawn by the assistant. It may be necessary to gently hold the stent to prevent the assistant displacing it. Do not grasp the stent too tightly, or the guidewire will also be held and it will not withdraw. Figure 20.4 and Video 20.3 show a stenting procedure of the left ureter.

If the distal end of the stent is to be passed into the distal ureter, rather than a large viscus such as the bladder or a bowel segment, it is necessary to pass the guidewire through one of the stent side holes to straighten the distal end, before placing it into the distal ureter. A non-suction 20Fr Robinson's tube drain is inserted and removed once output is minimal, along with a bladder catheter on free drainage. Suction drains should not be used as they will encourage prolonged urinary leakage and cutaneous/vaginal urinary fistula.

Specific Robotic Urological Procedures and Their Outcomes

Ureteric Reimplantation: Psoas Hitch and Boari Flap

The principles of ureteric reconstruction are no different from those of reconstructive urology in the rest of the urinary system. Generally, treatment for ureteric injury, stricture and

obstruction depends on the length of the defect, location, aetiology and time of diagnosis. The principles for obtaining successful outcomes for any ureteric reconstruction include prompt recognition of the injury, spatulation of the ureteric end, lack of tension, a watertight anastomosis with fine absorbable sutures, stenting and postoperative drainage.

The surgical intervention of choice is primarily determined by the length of the defect, from ureteroureterostomy or ureteroneocystostomy for short defects to psoas hitch and Boari flap for longer defects. The level of the injury must also be considered, in general:

Upper/middle ureter: direct ureteroureterostomy/transurete roureterostomy
Lower ureter: reimplantation/psoas hitch

The conventional laparoscopic approach has been well established in ureteric reconstruction, offering the benefits of quicker recovery, lower morbidity, less pain, less blood loss and better cosmesis [17–20]. These advantages have been superseded by the robot, with its three-dimensional visualisation, increased degree of freedom in movement and elimination of physiologic tremor, which is paramount in the dissection and suturing of such a fine anastomosis in a small or narrow pelvis.

After Yohannes et al. published the first case of robot-assisted laparoscopic ureter reimplantation for a distal stricture [21], several groups have since reported their series of robotic-assisted ureteric reimplantation, with and without psoas hitch or Boari flap. Most of these reported series, however, present a heterogeneous group of ureteric procedures [22–24]. More recently, Marien et al. report their series of 250 robotic-assisted upper urinary tract reconstruction, demonstrating favourable outcomes, with radiographic and symptomatic success rates from 85 to 100% [25]. Similarly, Gellhaus et al. demonstrate good outcomes following robotic repair of genitourinary injuries as a direct consequence of obstetric and gynaecological injury, with minimal complication and quick recovery using the robotic approach [26].

In 2016 Stolzenburg et al. described the robot-assisted Boari flap and ureteric reimplantation based on the open surgical technique of Übelhör [27, 28]. Our technique for robotic ureteric reimplantation is based on this transperitoneal approach, with all patients receiving prophylactic antibiotics at induction and intermittent pneumatic compression stockings (Flowtron™). The ureter is exposed with simultaneous division of the round ligament of the uterus. The ureter is most readily identified behind the branching of the obliterated umbilical artery from the internal iliac artery or alternatively at its crossing with the common iliac artery. The ureter is lifted up by a vessel loop to ease further preparation. Care must be taken to preserve the periureteric adventitial tissue with its inherent blood supply to the ureter. The ureter is mobilised towards the bladder as far as possible, transected and its distal stump ligated. In cases with a ureteric fistula or an iatrogenic obstruction, the ureter is transected just above that level.

A 15 cm 3/0 Vicryl stay suture is placed into the proximal ureteric end at the 6 o'clock position. Before commencing its mobilisation, the bladder is filled with 200–300 mL of saline through the Foley catheter to ease dissection. The peritoneum is dissected from the surface of the bladder. In patients with a long ureteric defect extending higher up, bladder mobilisation is extended, and both the median umbilical ligament (urachus) and the ipsilateral medial umbilical ligaments (and occasionally also the contralateral medial umbilical ligament) have to be divided using clips or a vessel-sealing device, e.g. LigaSure® (Covidien). The aim is to allow a tension-free fixation of the bladder to the psoas muscle at least 2–3 cm above the common iliac vessel.

For the psoas hitch procedure, the bladder is opened using a 4–5 cm oblique incision between two stay sutures. In patients with a ureteric defect extending higher up and being too wide to bridge by this technique, a Boari flap may be developed. With an open bladder, the ipsilateral most cranial aspect of the bladder is elevated to check if the raised flap easily reaches the intended point of fixation at the psoas muscle. The level of fixation at the psoas muscle is determined by the length of the proximal ureter plus additional length for creation of a submucosal tunnel. In cases where the bladder can only be brought to the psoas muscle with tension, the oblique bladder incision is extended to obtain a longer bladder flap. In the modified Übelhör's Boari technique, the ratio between length and width of the flap is 2:1, respectively [27].

For fixation of the bladder at the psoas muscle, two to three 15 cm 3/0 poly-p-dioxanone monofilament absorbable sutures (such as MonoPlus® or PDS®) are placed preferentially through the tendon of the psoas muscle above the common iliac artery and the femoral branch of the genitofemoral nerve. The sutures must encompass the whole detrusor muscle thickness, without mucosa. The sutures must not be tied at this stage of the operation. A neocystostomy is formed, and the ureter is sutured to the bladder mucosa using an absorbable interrupted suture, e.g. 4/0 Vicryl. This is shown in Fig. 20.5 and Video 20.4. Once the ureter has been reimplanted, then the sutures on the psoas are tied, with the surgical assistant and the third robotic arm providing assistance with adequate tension. A double J stent is inserted, and the bladder is closed with a 15 cm 2/0 Vicryl suture. A pelvic drain and urinary catheter are left in situ. The drain is removed when there is less than 150 mL output in a 24 h period. The catheter should be removed after a cystogram at 2 weeks. If there is evidence of a leak, it should be kept for a further 2 weeks. The stent can be removed after 6–8 weeks with a flexible cystoscope under local anaesthetic.

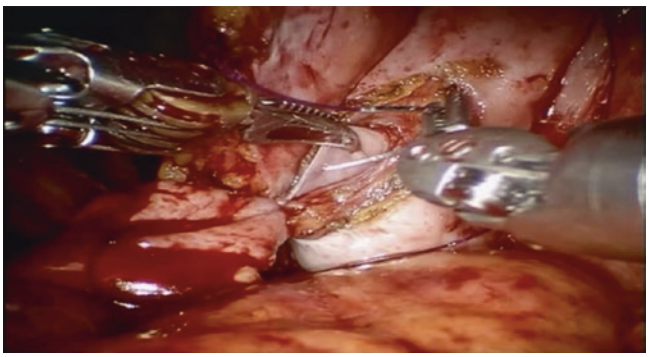

Fig. 20.5 Left ureteric reimplantation

In the experience of 11 cases, excellent results have been shown after a mean follow-up period of >12 months. The robot-assisted Boari flap ureteric reimplantation technique should be considered a safe and effective method of ureteric reimplantation for long distal ureteric strictures [27]. The Cleveland Clinic experience is the largest series comparing robotic ureteroneocystostomy to open surgery; the open procedures were associated with a shorter median operative time (200 vs. 279 min, $P = 0.0008$), whereas robotic procedure patients had a shorter hospital stay (median 3 vs. 5 days, $P = 0.0004$), less narcotic pain requirement ($P = 0.0001$) and less estimated blood loss ($P = <0.0002$). There was no significant difference in the rate of reoperation between groups [29].

Transureteroureterostomy

This repair involves bringing the injured ureter across the midline and anastomosing it end to side to the normal ureter. Although rarely used, it may be required in cases of middle or distal ureteric injury, whereby ureteroureterostomy or Boari flap/hitch is impossible due to a long segment of ureteric defect or a contracted or congenitally small bladder. The main reluctance in performing this technique is the difficulty in intubating this ureter in the future, in addition to potentially damaging a normal ureter and subjecting the patient to bilateral ureteric injury. Alternative options would be ileal interposition or renal mobilisation, and careful consideration must be made on a case-by-case basis for the most appropriate choice of repair. Although the standard approach would be an open repair, cases of robotic TUU repair have more recently been described [25, 30].

The colon is mobilised medially, and the affected ureter with its adventitia preserved is isolated. The ureter is divided just proximal to the level of obstruction or pathology. On the contralateral side, the colon is again mobilised medially, and the normal ureter is exposed: only minimal exposure is required sufficient to perform the end-to-side anastomosis. The injured ureter is tunnelled under the sigmoid colon mesentery, just inferior to the inferior mesenteric artery. It is important to mobilise the affected ureter laterally and make a wide mesenteric window to avoid tethering of the ureter. A 2 cm anteromedial ureterotomy is made in the normal ureter, using the scissor tip length as a size guide, and the end of the injured ureter is spatulated for the same length and anastomosed to the side of the normal ureter, using 4/0 Vicryl. A stent is routinely inserted across the anastomosis, bladder to injured side renal pelvis. If the calibre of the ureter permits, a second ureteric stent may be inserted into the normal side ureter. The principles of ureteric anastomosis should be followed as mentioned previously.

Cutaneous Ureterostomy

Rarely a cutaneous ureterostomy may be indicated. This avoids bowel mobilisation and anastomosis and may be preferable for urinary diversion in a single kidney or in selected thin, frail patients. It is a simple, low morbidity option but can be complicated by stomal stenosis and ureteric obstruction.

Bilateral ureterostomies can be performed to the same stoma, but ureteric length is usually prohibitive.

Robotic end ureterostomy has infrequently been described [31]. The site of the ureterostomy is often preoperatively marked, between umbilicus and xiphoid, preferably pararectal. The ureteric mobilisation is performed as previously described. A cruciate or Y-shaped skin incision is made, the subcutaneous fat is excised, and an incision is made in the rectus sheath. The spatulated ureter is gently pulled through by its stay suture and is sutured with the point of the cruciate skin flap drawn down to the spatulation, to prevent stomal stenosis. The ureter is then stented with a single-ended urinary diversion J stent and cut to length with 10 cm only protruding. If performing a bilateral ureterostomy, both ureters are pulled through the opening and are spatulated medially at the 3 and 9 o'clock positions. A suture is placed at the medial join of the two ureters. The thinnest part of the greater omentum is wrapped around both ureters and fixed subcutaneously. Interrupted absorbable sutures are made skin to ureter to fix the fish-mouthed ureters to the epidermis. Two stents are then inserted. There is some evidence to suggest long-term stenting for over 3 months does help to reduce rates of ureteric obstruction [32].

Partial Cystectomy

The indications for partial cystectomy are particularly relevant to the gynaecologist, where local invasion of a gynaecological tumour may necessitate removal of part of the bladder. Other indications include adenocarcinoma of the urachus, the

management of genitourinary sarcomas in adults and children or (rarely) a solitary transitional cell carcinoma in which radical cystectomy is otherwise contraindicated. Non-malignant indications for partial cystectomy include the management of colovesical or vesicovaginal fistulas and the management of localised endometriosis of the bladder.

The details of the surgical technique, including bladder mobilisation, are common to simple cystectomy. The superior pedicles are released bilaterally. Release of the remainder of the pedicles depends upon the location of the area of interest in the bladder. When partial cystectomy is performed for urachal carcinoma or adenocarcinoma at the dome of the bladder, the dome of the bladder is excised along with full length of the urachus. Insertion of the camera port approximately 5 cm above the umbilicus helps to excise the urachus.

Once the area of interest on the bladder has been isolated and demarcated with robotic scissors, the bladder wall is excised, and the defect is closed in two layers with a 15 cm 3/0 Vicryl suture. A wide margin should be taken in cases of suspected malignancy. The initial closure layer should be continuous and include the mucosa and detrusor, between two stay sutures held by the assistant and robotic arm 3 to ensure an equal and straight suture line. The second layer should include the outer serosa and extra-vesical fat. This may be interrupted or continuous. Methylene blue may be instilled into the catheter to test for leaks. Any visible leaks can be closed by further sutures. If the area to be excised is close to the trigone or the ureteric orifice, the placement of a pre-procedure stent or ureteric catheter can be considered. If the procedure is a robotic diverticulectomy, the bladder is filled with fluid through a urethral catheter to identify the diverticulum [33]. If the excision of the bladder wall also includes the ureteric orifice, then the ureter is reimplanted. With the bladder already open, using the robotic scissors and Maryland forceps, a neocystostomy is performed. The detached end of the ureter with a stay suture at its end is pulled through the neocystostomy. The wall of the ureter opposite to the robotic arm 1 is sutured first with interrupted 4/0 Vicryl sutures. A double J stent is inserted into the ureter over a guidewire. Following stent insertion, the remainder of the ureter is sutured to the bladder mucosa. A pelvic drain and an indwelling urethral catheter are left in situ during the postoperative period. The Foley catheter is left in place for 7–14 days and removed after a negative cystogram.

Cystectomy (Simple/Radical)

Simple cystectomy is defined as removal of the bladder without removal of adjacent structures or organs; in particular, the vagina is spared. The indications simple cystectomy include:

- Radiation cystitis after treatment of pelvic malignancies
- Interstitial cystitis
- Cyclophosphamide cystitis
- Severe incontinence
- Neurogenic bladder
- Severe urethral trauma
- Obstruction of the upper tracts

Initially, simple cystectomy was not routinely included during supravesical diversion for these indications because of the increased morbidity involved in bladder removal. However, complications from the retained bladder occur in up to 60% of patients undergoing supravesical diversion without simple cystectomy, and simple cystectomy as a secondary procedure has been reported in up to 20% [34, 35].

The patient is positioned in a steep Trendelenburg position and a six-port access is made. For simple cystectomy, the bladder is dissected posteriorly, and then the lateral pedicles are controlled to release the bladder. A plane is created between the bladder and the anterior vaginal wall up to the urethra. The bladder is then released anteriorly, and the specimen is bagged through the 15 mm laparoscopic port. Once the urinary diversion has been performed, the bladder can be extracted through a small transverse incision in the suprapubic area, or transvaginally. A drain is left in the pelvis dependent upon the urinary diversion.

The perioperative and early postoperative complications of partial cystectomy and simple cystectomy include haemorrhage and infection. In patients undergoing partial cystectomy, urinary extravasation can occur; in the longer term, patients may experience a reduced bladder capacity. Robotic partial cystectomy has been successfully performed for various indications [33, 36, 37]. Although most of the reported outcomes are from case reports and small series, results from a larger cohort of patients would help to depict more meaningful outcomes. However it is likely the functional outcomes will be similar to those associated with open surgery.

Once the cystectomy has been performed for benign or malignant reasons, the ureters are prepared depending upon the planned diversion procedure. If an ileal conduit is planned, then the ureter needs to be tunnelled under the sigmoid colon, whereas for a neobladder, the ureters can be anastomosed to the reservoir on their respective sides.

Early and Late Complications of Radical or Simple Cystectomy

Early Complications:

- Genitourinary anastomotic leak
- Gastrointestinal anastomotic leak
- Infection
- Wound complications
- Cardiopulmonary and thromboembolic complications

Late Complications:

- Urinary tract infection
- Gastrointestinal bowel obstruction
- Urethral stricture
- Stones
- Incontinence/retention
- Metabolic abnormalities
- Orthotopic bladder substitute to vaginal fistula (rare)
- Stoma retraction/parastomal hernia
- Deterioration in renal function

Ileal Conduit

A large Gold Hem-o-lok® is applied to the cut end of the left ureter. This Hem-o-lok® should have a 15 cm 2/0 Vicryl suture tied to it. The surgeon then creates space under the sigmoid colon through which the assistant should gently advance a laparoscopic needle holder to grasp the suture on the Hem-o-lok® and bring the left ureter under the sigmoid colon to the right side. The robot is undocked and patient table is repositioned to 10°–15° head down. The robot is redocked and the terminal ileum is identified.

A 20 cm length of intestine is isolated 20 cm from the ileo-caecal junction, using a suture for measurement and an Endo GIA™ stapler. It is useful to suture a 24 cm 2/0 Vicryl suture just proximal to the planned distal division. This can then be used to measure the conduit and mark the proximal division site with a clip or suture. It can also then be used as a stay on the distal end for manipulation and retraction through the assistant's 12 mm port. At the end of the procedure, it will be used to pull the stomal end through the abdominal wall. For the bowel division/stapling, some surgeons use a 60 mm intestinal stapler, though others prefer three 45 mm vascular reloads, using two reloads for the distal incision into the mesentery, to allow its passage through the abdominal wall at the stoma site [38]. The continuity of the small bowel is restored by excising the stapled ends of the bowel to be joined and stapling them together side to side and then transversely. The initial side-to-side anastomosis needs to be longer, so the transverse staple cut does not cause stenosis and obstruction of the anastomosis. A 60 and 40 mm intestinal reload is used for the side to side and a further 60 mm for the transverse staple line. A 10 cm 3/0 Vicryl suture is used to bolster the side-to-side anastomosis. Some surgeons also close the mesenteric defect. The ureters are then incised and spatulated 2 cm. The uretero-ileal anastomosis can be made using the Wallace technique, with a side-to-side ureteric anastomosis, followed by side-to-end uretero-ileal anastomosis, or each ureter may be individually anastomosed directly to small lateral incisions on the bowel as described by Bricker. The latter technique is preferable as it is more versatile and allows the anastomosis to be made wherever the ureter lies most comfortably. This is important if the ureters are short or the mesentery is fatty [39]. Single J 40 cm ureteric stents are then introduced into the ureters via the conduit before the suture lines are completed anteriorly using two 15 cm 4/0 Vicryl sutures. The distal end of the conduit is fashioned as a stoma by the surgical assistant at a previously marked site on the abdominal wall. Care must be taken not to dislodge the stents when pulling the stomal end through the abdominal wall.

Neobladder

There are a number of techniques described for the formation of a neobladder. The most popular open technique, described by Studer, has been modified for robotic use by Wiklund [40, 41]. Other variations include the pyramid technique, described by Tan in 2015 [42].

For the Wiklund neobladder, the robot is redocked with a table tilt of about 10°–15° [38]. A 55–60 cm of ileal loop is measured (15 cm from the ileo-caecal valve). The afferent limb of the neobladder, into which the uretero-ileal anastomosis is later performed, is positioned on the right-hand side of the pelvis and is not detubularised. The uretero-ileal anastomosis is performed before disconnecting the ileal segment, using the Van Velthoven technique [43].

Making the anastomosis between the urethra and the ileum should be the first step in the formation of an intracorporeal orthotopic neobladder. This is a critical step because the anastomosis can be made without tension, and the neobladder will be placed correctly in the small pelvis during the whole procedure [38, 44]. The position of the anastomosis is 20 cm from the distal aspect of the neobladder segment, which corresponds to the most dependent portion of the neobladder within the pelvis. A 0° robotic telescope is used for this step. The ileal segment is disconnected, and the intestinal anastomosis is performed, using four 60 mm reloads of the Endo GIA™ linear stapler through the left-sided 15 mm assistant port. The ileal loop is detubularised using the monopolar scissors. Robotic arm 3 and assistant provide countertraction. The staple line is excised from the cranial section of the afferent limb, and either oversewn with 3/0 PDS if a Bricker-type anastomosis is planned for the uretero-ileal anastomosis or when the Wallace technique is used, it will be the future site of the ureteric anastomosis so can be left open until that time [45].

The posterior and anterior wall of the neobladder is reconfigured using 3/0 PDS, Vicryl or V-loc, according to surgeon preference. The aim should be for a globular shape, and cross-folding is performed as described by Studer for open surgery in 1995 [40]. A small opening remains at the anterior

wall just below the afferent limb, which is where the ureteric stents will pass through the neobladder and into the ureters. The posterior ureteric plate is formed, using the suture of choice, in preparation for the Wallace-type uretero-ileal anastomosis. The afferent limb and ureters are lined up on the right side. The two 7 Fr ureteric stents are inserted via a suprapubic puncture using the Cook® Suprapubic Catheter trocar and access sheath. The stents are pulled through the small hole in the anterior wall of the neobladder pouch and are guided through and out of the afferent limb and up each ureter.

The Wallace uretero-ileal (neobladder afferent limb) anastomosis is performed using 4/0 suture. The 0° or 30° lens can be useful for this part of procedure. The small gap in the anterior neobladder wall, where the ureteral stents exit, is closed. A new 24 Fr catheter is placed into the neobladder, and leak testing is performed with 180 mL normal saline.

In the postoperative period, the neobladder is flushed with 60 mL normal saline every 8 hours; the drain is removed when the measured creatinine of the drain fluid excludes a leak. The urine must remain sterile. Any metabolic acidosis is corrected with sodium bicarbonate. Ureteric stents are removed on day 10. A cystogram is performed on day 20, and the urethral catheter is removed the same day if there is no leak. Voiding intervals are gradually increased from 2 to 4 hourly day and night [45]. The ratio between orthotopic and ileal conduit diversions in women is far lower than in male patients. Data on urinary function in female patients with neobladders is therefore limited; those performed robotically are even fewer. The postoperative functional outcomes are expected to be similar to an open or extracorporeal technique. A significant proportion of women do report to be fully continent after an orthotopic neobladder. Daytime incontinence (26–43%), night-time incontinence (29–55%), and retention (31%) have been reported [46, 47]. On unadjusted analysis, having daytime incontinence was associated with a concurrent or previous hysterectomy ($P = 0.031$), but not with age, disease stage, preoperative incontinence, year of surgery or sparing the vaginal wall. The severity of daytime incontinence was associated with preoperative incontinence only ($P = 0.02$). The presence and severity of night-time incontinence were associated with patient age only ($P = 0.013$, $P = 0.005$, respectively) [46]. Development of a neobladder-vaginal fistula has been reported [46].

Augmentation Cystoplasty

Augmentation cystoplasty (AC) has traditionally been used in the treatment of the low-capacity, poorly compliant or refractory overactive bladder. AC remains an option, with high patient satisfaction rates, in neurogenic and non-neurogenic bladder dysfunction when conservative management and pharmacological methods have been unsuccessful. More recently, the use of intravesical Botox® has led to diminution of the need for surgical AC in this group. AC does, however, retain a role in the management of infective and inflammatory bladder disorders which lead to a low-capacity and poorly compliant bladder, including post-radiotherapy cystitis, cystitis following intravesical or systemic chemotherapy, schistosomiasis, tuberculosis and interstitial cystitis [48].

Firstly, a 6 cm incision is made from the front to the trigone of the bladder along the sagittal plane, and four points of the bladder are retracted with stay sutures to open it. A 15 cm of ileal segment is identified, 15–20 cm proximal to the ileo-caecal junction, similar to an ileal conduit. The preparation of the mesentery of the ileal segment and the ileoileal anastomosis is performed using vascular stapler as described earlier. The ileal segment is incised vertically along the antimesenteric border. A U-shaped ileal pouch is formed by consecutive sutures of the medial and lateral borders of the incised segment. The ileum and the bladder are connected with continuous or simple sutures by using 3/0 absorbable suture. A suprapubic cystostomy is formed by using an 18 Fr Foley catheter, and a drainage tube is retained at the end of the operation. An anastomotic leak test is performed prior to closure. A cystogram is done on day 10–14 to plan for removal of the catheter [49]. All patients should be taught clean intermittent self-catheterisation to deal with any degree of retention and prevent subsequent bladder rupture.

Vesicovaginal Fistula Repair

Repair of a vesicovaginal fistula (VVF) is complicated by the challenge of locating the defect in the bladder and the technical difficulty in oversewing the bladder, which often must be done on the underside of the bladder, between the vaginal and bladder walls. To combat these challenges, a robotic approach promises improved visualisation, whilst preserving the manual dexterity characteristic of open surgery. It is believed that, in order to improve chances of successful surgical repair, the fistula should be approached either immediately (within 1–2 weeks of the insult) or delayed by 8–12 or more weeks after the causative surgery [50]. VVF can rarely involve the ureters; indeed any ureteric involvement must be excluded. Hence, the workup of the VVF should begin with a thorough cystoscopic evaluation of the bladder, with retrograde pyelography to evaluate the integrity of the ureters bilaterally. During this procedure, the location of the fistulous tract should be meticulously mapped. Care should be taken to document the location and extent of the fistula, as well as to identify the presence of multiple or separate tracts. If these tracts are present, they also need to be catalogued.

Cystoscopy is performed, and the two ureters are catheterised using single J ureteric catheters of different colours

for each side. A simple ureteric catheter of a colour different to those used for the ureters is pulled cystoscopically through the fistula into the vagina and retrieved outside through the vaginal introitus. After ureteric catheter placement, an indwelling urinary catheter is inserted in the bladder. The ports are inserted and the patient is then placed in a steep Trendelenburg position [51].

Using a combination of sharp and blunt dissection with Maryland fenestrated bipolar forceps and monopolar curved scissors, further adhesiolysis is performed to expose the anterior surface of the uterus (if it is present) and the superior aspect of the bladder. Small bowel loops and/or the sigmoid colon are usually required to be carefully dissected off the underlying bladder. The adhesiolysis is extended until the rectovaginal (Douglas) pouch is completely free of any tissue content. Before the cystostomy, the bladder is filled with 180 mL saline through the transurethral Foley catheter to facilitate anatomical identification of the bladder. Before the incision is carried vertically downwards, the ureteric or Foley catheter that runs along the fistulous tract is manipulated by the bedside assistant and laparoscopically identified from the movement of the bladder wall. Thus, a gentle drawing on the ureteric catheter, which passed through the VVF, is usually helpful for the location of the approximate site of the fistula as seen laparoscopically, allowing the creation of a minimal cystostomy just above the adherent and fistulous area [51].

In direct proximity to the VVF, the posterior bladder wall is incised vertically with the monopolar robotic scissors. Then the cystostomy is continued in the direction of the catheter that defines the fistula, completely opening the posterior bladder wall. If the fistulous tract is relatively small and laparoscopically visible through the cystostomy, the vaginally placed ureteric catheter, which was used as a marker for the fistula, is cut and removed. Margins of resection of the fistulous tract are marked in the form of a 'tennis racket' by scoring the bladder mucosa with the monopolar robotic scissors [51]. Loss of pneumoperitoneum is avoided by clamping the Foley catheter at the external site and packing the vagina with a wet sponge. After performing a generous excision of the fistulous tract, a meticulous dissection follows to separate the vagina from the bladder using robotic scissors and gentle countertraction with the robotic Maryland grasper. Beginning with the closure of the vagina, the suture line is placed mostly transversely using 3/0 monofilament synthetic absorbable suture as a running, locking, watertight suture.

The patient is placed in an almost horizontal position by undocking and redocking the robot, and the omentum is then pulled to interpose between the vagina and the bladder. After the transversely placed vaginal suturing, the bladder is closed in a vertical manner to minimise the contact surface of suture lines. Bladder closure is initiated at the apex of the incision at the most distal part of cystostomy near to the ureteric orifices. On finishing bladder closure, watertightness is confirmed by filling the bladder with saline.

Sundaram et al. reported the technique of VVF repair and the results of such repairs in five patients [52]. The proposed sequence of steps was similar to the open transabdominal repair of the fistula including excision of the fistula, closure of the bladder and vagina and omental interposition. The mean operating time was 233 min (range 150–333 min) with an estimated blood loss of 70 mL and mean length of hospital stay of 5 days (range 4–7 days). All reported cases were completely dry at 6 months follow-up (100% cure rate).

Agrawal et al. reported on their case series of ten patients, with a median length of stay of 1 day (range, 1–5 days). There were no intraoperative complications and only low-grade postoperative complications. All patients were cured and were without VVF recurrence at a median follow-up close to 2 years [53].

Robotic transvesical vesicovaginal fistula repair is a safe, effective, minimally invasive technique with excellent cure rates. It is anticipated that an increasing number of fistula repairs will be undertaken with robot-assisted approach in the future, offering more patients who need VVF repair the advantages of minimally invasive surgery.

Conclusion

We have discussed the general principles of mobilisation of the ureter, bladder and bowel, with a particular emphasis on ureteric injury and reconstruction. The main principles include avoidance of ureteric injury with early identification of the ureter in pelvic surgery and minimisation of ureteric handling to avoid devascularisation. When ureteric injuries do occur, small incisions may be repaired primarily over a stent. Early recognition is crucial. The type of repair is dependent on the site and length of the defect, but the key principles in anastomosis must be followed in all, in particular; a clean cut, watertight anastomosis, protected with a stent.

Meticulous preoperative assessment is vital; patient factors and radiological findings should be considered within the multidisciplinary team when planning for surgery. This approach can often anticipate urological injuries or requirement for resection and reconstruction of the urinary tract. Postoperatively, a non-suction drain is removed once output is minimal; renal function should be monitored postoperatively with serum creatinine and serial imaging. The timing of stent removal will be dependent on the indication, the procedure performed and the clinical progression, but is commonly at 2–3 months postoperatively. For bladder repairs, a Foley catheter is inserted for at least 7 days postoperatively, and a cystogram is normally performed prior to removal.

We have outlined the surgical techniques of ureteric reimplantation/anastomosis, simple and partial cystectomy,

urinary diversion, augmentation cystoplasty and VVF repair and reported the current outcomes of these robotic techniques to date. The benefits of robotic surgery in this field of surgery cannot be underestimated. The nature of the procedures, with intricate anastomoses whilst working in a small pelvis, really do reap the full benefits of robotic technology, with its three-dimensional visualisation, ergonomic positioning and elimination of tremor and operator fatigue. The main limitations are primarily the expense, although this can be modified with restricting instrument usage. Case series do demonstrate favourable outcomes though more robust evidence from randomised trials is lacking. The widespread use of the robotic approach to the pelvis by both gynaecologists and urologists is generating extensive experience, and progressive refinement in techniques is only likely to increase its use in more challenging and varied scenarios.

References

1. Murphy D, Challacombe B, Khan MS, Dasgupta P. Robotic technology in urology. Postgrad Med J. 2006;82(973):743–7. https://doi.org/10.1136/pgmj.2006.048140.
2. Binder J, Kramer W. Robotically-assisted laparoscopic radical prostatectomy. BJU Int. 2001;87(4):408–10.
3. Khosla A, Wagner AA. Robotic surgery of the kidney, bladder, and prostate. Surg Clin North Am. 2016;96(3):615–36. https://doi.org/10.1016/j.suc.2016.02.015.
4. Rogers CG, Singh A, Blatt AM, et al. Robotic partial nephrectomy for complex renal tumors: surgical technique. Eur Urol. 2008;53(3):514–23.
5. Benway BM, Wang AJ, Cabello JM, Bhayani SB. Robotic partial nephrectomy with sliding-clip renorrhaphy: technique and outcomes. Eur Urol. 2009;55(3):592–9.
6. Kaczmarek BF, Tanagho YS, Hillyer SP, et al. Off-clamp robot-assisted partial nephrectomy preserves renal function: a multi-institutional propensity score analysis. Eur Urol. 2013;64(6):988–93.
7. 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.
8. Abraham JB, Young JL, Box GN, et al. Comparative analysis of laparoscopic and robot-assisted radical cystectomy with ileal conduit urinary diversion. J Endourol. 2007;21(12):1473–80. https://doi.org/10.1089/end.2007.0095.
9. Walz J, Epstein J, Ganzer R, 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. https://doi.org/10.1016/j.eururo.2016.01.026.
10. Einarsson JI, Hibner M, Advincula AP. Side docking: an alternative docking method for gynecologic robotic surgery. Rev Obstet Gynecol. 2011;4(3–4):123–5.
11. Brandao LF, Autorino R, Zargar H, et al. Robotic ileal ureter: a completely intracorporeal technique. Urology. 2014;83(4):951–4. https://doi.org/10.1016/j.urology.2013.11.035.
12. Sameer C, Charles M, Raj S, et al. Initial series of four-arm robotic completely intracorporeal ileal ureter. J Endourol. 2016;30(4):395–9.
13. Frober R. Surgery illustrated: surgical atlas, surgical anatomy of the ureter. BJU Int. 2007;100(4):949–65.
14. Moore KL, Dalley AF. Clinically oriented anatomy. 5th ed. Philadelphia: Lippincott Williams and Wilkins; 2006.
15. Intuitive Surgical 2014. EndoWrist/Single-Site Instrument and Accessory Catalog. http://wwwintuitivesurgicalcom/products/871145_Instrument_Accessory_%20Catalogpdf. Accessed 3 Sept 2016.
16. Ramirez D, Ganesan V, Nelson RJ, Haber GP. Reducing costs for robotic radical prostatectomy: three-instrument technique. Urology. 2016;95:213–5. https://doi.org/10.1016/j.urology.2016.03.067.
17. Challacombe B, Dasgupta P. Reconstruction of the lower urinary tract by laparoscopic and robotic surgery. Curr Opin Urol. 2007;17:390–5.
18. Stolzenburg JU, Katsakiori PF, Liatsikos EN. Role of laparoscopy for reconstructive urology. Curr Opin Urol. 2006;16:413–8.
19. Rassweiler J, Gozen AS, Teber D, et al. Ureteral reimplantation for management of ureteral strictures: a retrospective analysis of laparoscopic and open techniques. Eur Urol. 2007;51:512–23.
20. Gozen AS, Cresswell J, Canda AE, et al. Laparoscopic ureteral reimplantation: prospective evaluation of medium term results and current developments. World J Urol. 2010;28(2):221–6.
21. Yohannes P, Chiou RK, Pelinkovic D. Pure robot-assisted laparoscopic ureteral reimplantation for ureteral stricture disease: case report. J Endourol. 2003;17:891–3.
22. Hemal AK, Nayyar R, Gupta NP, Dorairajan LN. Experience with robot assisted laparoscopic surgery for upper and lower benign and malignant ureteral pathologies. Urology. 2010;76:1387–93.
23. Patil NN, Mottrie A, Sundaram B, Patel VR. Robotic-assisted laparoscopic ureteral reimplantation with psoas hitch: a multi-institutional, multinational evaluation. Urology. 2008;72:47–50.
24. Phillips EA, Wang DS. Current status of robot-assisted laparoscopic ureteral reimplantation and reconstruction. Curr Urol Rep. 2012;13:190–4.
25. Marien T, Bjurlin MA, Wynia B, et al. Outcomes of robotic-assisted laparoscopic upper urinary tract reconstruction: 250 consecutive patients. BJU Int. 2015;116(4):604–11.
26. Gellhaus PT, Bhandari A, Monn MF, et al. Robotic management of genitourinary injuries from obstetric and gynaecological operations: a multi-institutional report of outcomes. BJU Int. 2014;115(3):430–6.
27. Stolzenburg JU, Rai BP, Do M, et al. Robotic assisted technique for Boari flap ureteral reimplantation (RA-BFUR): replicating the techniques of open surgery in robotics. BJU Int. 2016;118(3):482–4. https://doi.org/10.1111/bju.13502.
28. Stein R, Rubenwolf P, Ziesel C, et al. Psoas hitch and Boari flap ureteroneocystostomy. BJU Int. 2013;112(1):137–55.
29. Isac W, Kaouk J, Altunrende F, et al. Robot-assisted ureteroneocystostomy: technique and comparative outcomes. J Endourol. 2013;27:318–23.
30. Zee RS, Anthony Herdon CD, Smith-Harrison LI, Corbett ST. V10-05 robotic-assisted laparoscopic transureteroureterostomy. J Urol. 2014;191(4):e907–8.
31. Ma LL, Bi H, Hou XF, et al. Laparoendoscopic single-site radical cystectomy and urinary diversion: initial experience in china using a homemade single-port device. J Endourol. 2012;26(4):355–9. https://doi.org/10.1089/end.2011.0300.
32. Rodríguez AR, Lockhart A, King J, et al. Cutaneous ureterostomy technique for adults and effects of ureteral stenting: an alternative to the ileal conduit. J Urol. 2011;186(5):1939–43.
33. Elands S, Vasdev N, Tay A, Adshead JM. Robot-assisted laparoscopic bladder diverticulectomy and ureteral re-implantation for a diverticulum containing high grade transitional cell carcinoma. Curr Urol. 2015;8(2):104–8.
34. Eigner EB, Freiha FS. The fate of the remaining bladder following supravesical diversion. J Urol. 1990;144(1):31–3.

35. LaFontaine P, Petros JA. Simple and partial cystectomy. In: Glenn's urologic surgery. 5th ed. Philadelphia: Lippincott-Raven; 1998. p. 181–6.
36. Le Carpentier M, Merlot B, Bot Robin V, et al. Partial cystectomy for bladder endometriosis: robotic assisted laparoscopy versus standard laparoscopy. Gynecol Obstet Fertil. 2016;44(6):315–21.
37. Nap AW, Wijnberger L, Wijburg C. Robot-assisted partial cystectomy for bladder endometriosis. J Robot Surg. 2014;8(4):393–6.
38. Wiklund NP, Poulakis V. Robotic neobladder. BJU Int. 2011;107(9):1514–37.
39. Kouba E, Sands M, Lentz A, et al. A comparison of the Bricker versus Wallace ureteroileal anastomosis in patients undergoing urinary diversion for bladder cancer. J Urol. 2007;178(3):945–8.
40. Studer UE, Turner WH. The ileal orthotopic bladder. Urology. 1995;45:185–9.
41. Collins JW, Hosseini A, Sooriakumaran P, et al. Tips and tricks for intracorporeal robot-assisted urinary diversion. Curr Urol Rep. 2014;15(11):457. https://doi.org/10.1007/s11934-014-0457-7.
42. Tan WS, Sridhar A, Goldstraw M, et al. Robot-assisted intracorporeal pyramid neobladder. BJU Int. 2015;116(5):771–9. https://doi.org/10.1111/bju.13189.
43. Van Velthoven RF, Ahlering TE, Peltier A, et al. Technique for laparoscopic running urethrovesical anastomosis: the single knot method. Urology. 2003;61:699–702.
44. Hosseini A, Adding C, Nilsson A, et al. Robotic cystectomy: surgical technique. BJU Int. 2011;108(6):962–8.
45. Haddad RL, Richard P, Bladou F. Canada's first robotic-assisted totally intracorporeal orthotopic ileal neobladder. Can Urol Assoc J. 2013;7(7–8):E537–42.
46. Anderson CB, Cookson MS, Chang SS, et al. Voiding function in women with orthotopic neobladder urinary diversion. J Urol. 2012;188(1):200–4.
47. Rouanne M, Legrand G, Neuzillet Y, et al. Long-term women-reported quality of life after radical cystectomy and orthotopic ileal neobladder reconstruction. Ann Surg Oncol. 2014;21(4):1398–404.
48. Veeratterapillay R, Thorpe AC, Harding C. Augmentation cystoplasty: contemporary indications, techniques and complications. Indian J Urol. 2013;29(4):322–7.
49. Kang IS, Lee JW, Seo IY. Robot-assisted laparoscopic augmentation ileocystoplasty: a case report. Int Neurourol J. 2010;14(1):61–4.
50. Lee R, Symmonds R, Williams T. Current status of genitourinary fistula. Obstet Gynecol. 1988;72(3):313–9.
51. Sotelo R, Moros V, Clavijo R, Poulakis V. Robotic repair of vesicovaginal fistula (VVF). BJU Int. 2012;109(9):1416–34.
52. Sundaram BM, Kalidasan G, Hemal AK. Robotic repair of vesicovaginal fistula: a case series of 5 patients. Urology. 2006;65(5):970–3.
53. Agrawal V, Kucherov V, Bendana E, et al. Robot-assisted laparoscopic repair of vesicovaginal fistula: a single-center experience. Urology. 2015;86(2):276–81.

Robotic Gastrointestinal (GI) Procedures in Gynecology

21

John T. Kidwell and Nitin Mishra

Introduction

Robotic gynecological procedures are becoming more common in tertiary and quaternary referral centers [1]. Multidisciplinary approaches to extensive endometriosis or advanced gynecological malignancies are now commonplace. The GI surgeon may be consulted electively for en bloc resection of bowel or assistance with adhesiolysis and exposure of the pelvis. Nonelective consultation may result from injury to the surrounding gastrointestinal tract (colon or small bowel) during complex gynecology surgery. The anatomical proximity of the small bowel and colon with respect to the female pelvic organs renders this unavoidable. In the setting of robotic gynecology surgery, intestinal encounters may be observed in the background of tumor involvement in gynecologic malignancies, implants in deep infiltrating endometriosis, or inadvertent intestinal injury. The role of the GI surgeon may involve segmental resection of the colon or small intestine with anastomosis, colostomy or ileostomy formation, and primary repair of bowel injuries.

Background

Since FDA approval of the da Vinci surgical system for use in gynecology surgery in 2005, the growth of robotic procedures has increased exponentially [2]. Only 4 years after its clearance for gynecologic applications, 24% of US gynecologist oncologists reported using robotic-assisted surgery, with 66% indicating that they planned to increase their use of the technology in the next year [2]. In addition, robotic technology is utilized in non-oncologic settings. Currently, the most common robotic procedures in gynecology surgery consist of robotic hysterectomy, myomectomy, removal of endometriotic implants, repair of pelvic organ prolapse with sacrocolpopexy, and complex procedures for gynecologic malignancy. In this chapter we will discuss certain gastrointestinal procedures that may facilitate success and safety in execution of the above mentioned procedures.

Presentation

The GI surgeon may be called into a case by the gynecologist after injury to bowel (most commonly rectum, rectosigmoid) or as an elective consultation for a combined case where close proximity to bowel or frank involvement of bowel is anticipated. The most common role of the GI surgeon is to assist with rectal or rectosigmoid resections where the port placement is akin to low anterior resection (LAR). Sometimes right-sided resections are performed where the port placement and technique are similar to a right hemicolectomy. These two robotic configurations (LAR and right hemicolectomy) encompass the majority of surgical interventions done by the GI surgeon in conjunction with the gynecological team. In instances of intervention needed at the level of the transverse colon, the authors prefer a laparoscopic approach. However, with the Xi system, it is easy to approach the transverse colon pathologies robotically as well.

Technical Details

The GI surgeon, thus, needs to have the skills to be able to operate using the port placement used by his/her gynecological colleague and the judgment to recognize when the port placement needs to be changed or the operation converted to an open/laparoscopic one. The authors will describe below their technique for approaching pelvic/left-sided and right-sided pathology, respectively. For both approaches the port placements for the Si and the Xi system as well as patient positioning shall be described. The choice of instruments and surgical steps is not influenced by the system used.

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Pelvic/Left-Sided Procedures

Si System

- Port placement (see Fig. 21.1): Hasson trocar entry at the supraumbilical position is used to obtain pneumoperitoneum and then use two 8 mm robotic ports on the left side and one 12 mm robotic port in the right lower quadrant for stapling. A 5 mm laparoscopic port is used by the assistant. As a general rule, all robotic ports should be 8–10 cm apart, and the camera should be 15–20 cm away from the target organ.
- Preferred robot docking: Over patient's left hip.
- Optional robot docking: Between legs (this is commonly the position used by the gynecologists). Disadvantage is limited access to anus.
- Patient positioning (see Picture 21.1): Patient is supine in a modified lithotomy position with legs in low profile stirrups. Pad pressure points and bony prominences; secure body position with 3 in. silk tape wrapped around the lower chest over an OR towel. This should be snug but not constricting. Steep "tilt tests" are performed to make sure patient is secure when extreme Trendelenburg and left side up positions are used. During this test the anesthesiologist is asked to check for changes in airway pressures as well as to assess the patient's ability to tolerate extreme positioning. Patient is tilted left side up in a Trendelenburg position (25° is usual for most average patients). The OR table should be brought down "as low as it goes." Positioning must be completed prior to docking the robot. If splenic flexure takedown is planned, then less Trendelenburg is preferred. The use of the "Trumpf" table, which can be synchronized with the robot, facilitates patient position changes during flexure mobilization without undocking (Picture 21.2).

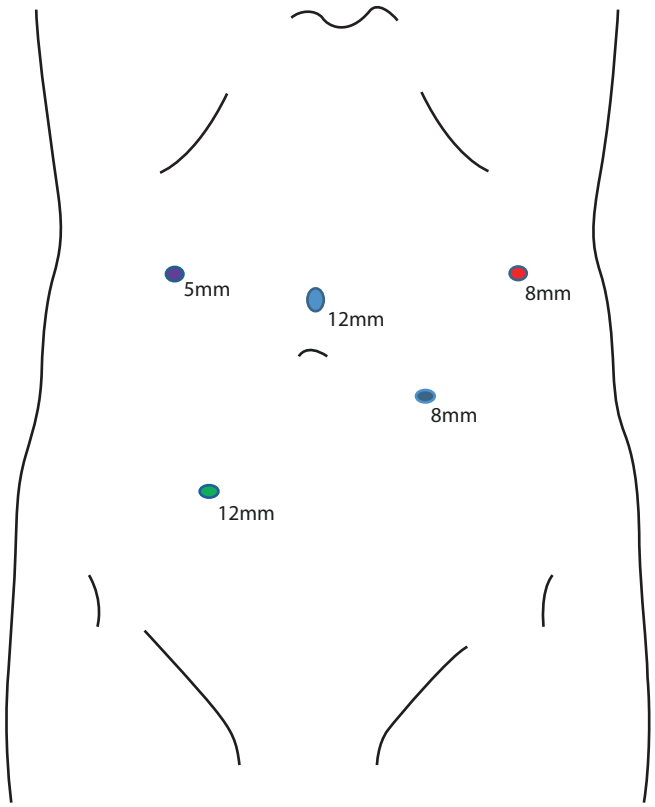
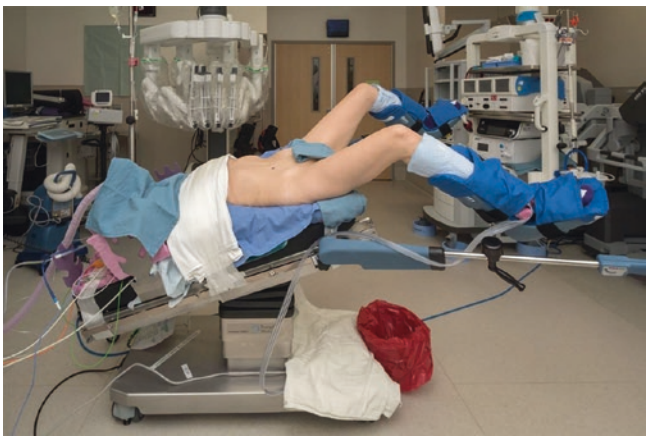


Fig. 21.1 Port placement for LAR, Si system (source: da Vinci LAR procedure card)

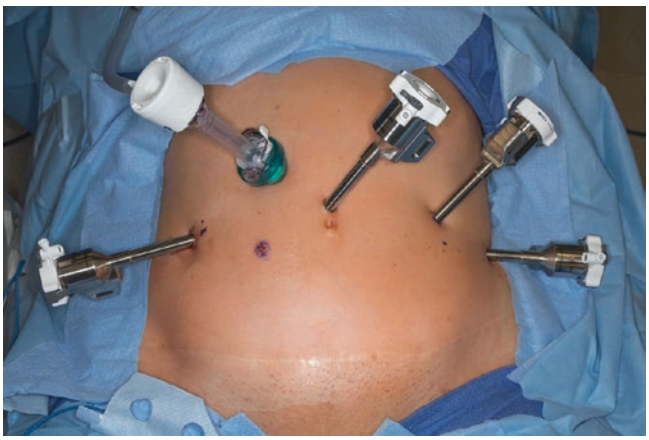


Picture 21.1 Patient positioning for LAR. (Courtesy Dr. Nitin Mishra, Mayo Clinic, AZ)

Picture 21.2 Robotic consul demonstrating patient tilt (24° Trendelenburg and 11° "left up") with a 30° camera

Xi System

- The Xi system has made advances which make docking easier and also adds flexibility in positioning of the robotic cart. The system has the ability to rotate at the level of the robotic "boom," thus making it possible to work in all abdominal quadrants with the same port configuration. Performing a total proctocolectomy is feasible with the use of this system without the need for multiple re-docking.
- Port placement (see Picture 21.3): Four ports are placed in a straight line perpendicular to a line drawn along the axis of the target organ, i.e., for a LAR or any pelvic case, four ports are placed along a transverse line at the level of the umbilicus.



Picture 21.3 Port placement for LAR, Xi System. (Courtesy Dr. Nitin Mishra, Mayo Clinic, AZ)

This, however, makes it difficult to use these ports for conventional laparoscopy as they are all in one straight line. The author's preference is to use a balloon Hasson trocar entry at the assistant port site to obtain pneumoperitoneum and then use three 8 mm robotic ports and one 12 mm robotic port in the right lower quadrant for stapling.

- Preferred robot docking: Over patient's left side.
- Optional robot docking: Between legs (this is commonly the position used by the gynecologists).
- Patient positioning: Same as Si system above.

Instruments

- Right arm: Monopolar scissors/vessel-sealing device/robotic stapler
- Left arm: Fenestrated bipolar grasper
- Third arm: Cardiere
- Midline port: Camera (30 degree)

Assistant: Alternates between suction and bowel grasper.

Key Operative Steps for Low Anterior Resection/Sigmoid Colectomy

1. Abdominal cavity exploration. Visualization of entire abdomen including the liver.
2. Exposure of pelvis and sigmoid mesocolon. This is achieved by positioning the patient in steep Trendelenburg (25° or more) and left side up position (10° or more). The small intestine loops are gently retracted out of the pelvis. If there are adhesions, then sharp adhesiolysis is performed. Sometimes a redundant cecum may obscure the view by flopping down into the pelvis and may need to be mobilized and retracted away for exposure of the pelvis. In difficult cases (morbidly obese, multiple prior surgeries, prior radiation, etc.), it helps to introduce a surgical gauze or sterile vaginal packing (cut to desirable length) to help retract the small intestine out of the pelvis.
3. Dissection and ligation of inferior mesenteric artery (IMA) proximal to the origin of the superior hemorrhoidal artery. The author's preference is the vessel-sealing device. Alternatively, vascular clips may be used. Ligation of the IMA close to its origin is optimal for maximum length in order to achieve a tension-free anastomosis.
4. Medial to lateral mobilization of sigmoid and left colon.
5. Retrorectal dissection in the TME plane.
6. Rectal division.
7. Splenic flexure mobilization (if indicated). When the splenic flexure needs to be mobilized, the authors prefer to divide the inferior mesenteric vein close to the duodenojejunal flexure. This helps in maximizing the length of the colon and aids in tension-free anastomosis.
8. Specimen extraction. The sites commonly used are the site for diverting loop ileostomy, Pfannenstiel incision, periumbilical incision, and transvaginal extraction. The choice of the site depends on the procedure, need for extraction of concomitant specimen, bulk of the specimen, patient body habitus, and surgeon preference.
9. Colorectal anastomosis using a circular stapling devise. When making the anastomosis, the surgeon must ensure adequate blood supply, proper orientation, and lack of tension. Additionally, the small intestinal loops must be retracted medially so that they are not trapped under the left colon.
10. Loop ileostomy creation (if indicated). It is very important to maintain proper orientation when maturing the loop ileostomy. It is a good practice to mark the afferent and efferent limb in order to avoid maturing the wrong limb (i.e., brooking the efferent limb instead of the afferent limb of the ileal loop). Such an error leads to difficult pouching and excoriation of peristomal skin and the need for revision of the stoma.

Right-Sided Procedures

Si System

- Port placement (see Fig. 21.2): There are four arms to the Si robot which correspond the ports 1–3 in addition to the camera. An assistant LLQ port is also placed.
- Preferred robot docking: Over patient's right side.
- Patient positioning: Supine, both arms tucked, tilt test, and padding as described for left-sided procedures above. Patient is tilted right side up (10° or more) in a Trendelenburg position (25° is usual for most average patients). The OR table should be brought down "as low as it goes." Positioning must be completed prior to docking the robot.

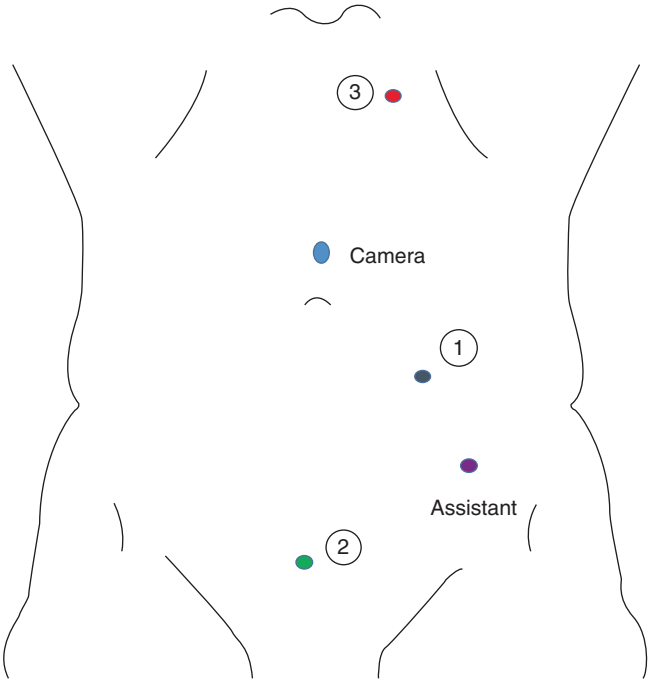


Fig. 21.2 Port placement for right colectomy, Si system (Source: Journal of Surgical Oncology 2015; 112:315–320)

Xi System

- Port placement (see Fig. 21.3): Four ports are placed in an oblique line drawn along the left of the patient's midline. Port 2 is the camera port.
- Preferred robot docking: Over patient's right side.
- Patient positioning: Same as Si system above.

Instruments

- Right arm: Monopolar scissors/vessel-sealing device/robotic stapler
- Left arm: Fenestrated bipolar grasper
- Third arm: Cardiere
- Midline port: Camera (30°)

Assistant: Alternates between suction and bowel grasper.

Key Operative Steps for Right Colectomy

1. Abdominal cavity exploration. Visualization of entire abdomen including the liver.
2. Exposure of the right colon and ileocolic pedicle. This is done by reflecting the omentum above the transverse colon and the small intestine medially. The cecum is retracted anteriorly and laterally to tent up the ileocolic pedicle.
3. Medial to lateral dissection and delineation of ileocolic pedicle. It is important to prevent trauma to the duodenum.
4. Ileocolic pedicle division and completion of medial to lateral dissection with division of right branch of middle colic artery.
5. Lateral to medial dissection with takedown of hepatic flexure.
6. Anastomosis. This can be extracorporeal or intracorporeal depending on surgeon preference. If an extraction incision is needed for another reason (abdominal hysterectomy, etc.), then there is no inherent advantage of doing an intracorporeal anastomosis.

Intraoperative Injury to Intestines

Small Intestine and Colon

The principles of management of intraoperative injuries remain the same whether the procedure is performed robotic, laparoscopic, or open. Robotic surgery makes it easier to manage as sewing robotically is easier than laparoscopic suturing. Most small bowel and colon injuries are amenable to primary repair. A single-layer repair for small bowel and double-layer repair for colon are the author's preference. If the injury is large (greater than 50% of bowel circumference) or there is devitalization of tissue (thermal injury) or involvement of the mesentery or mesocolon then a segmental resection is preferred. This can be performed in a hand sewn or stapled fashion depending on the location of trauma and surgeon preference. Multiple injuries in a short segment of bowel may also warrant a segmental resection.

Rectum

Most high rectal injuries can be repaired primarily without the need for diversion. Most low rectal injuries (below peritoneal reflection) can also be repaired primarily however; fecal diversion is performed for low injuries in most cases by the authors. Segmental resection, with or without diversion, may be needed for large injuries (greater than 50% of bowel circumference) or if there is devitalization of tissue (thermal injury) or vascular compromise. Omentoplasty after repair of rectal injury or segmental resection is routinely performed to prevent future complications like a rectovaginal fistula. The authors do not perform distal rectal washout or presacral drainage for low rectal trauma.

Results

There have been randomized controlled trials, multiple non-randomized comparisons, and systematic reviews comparing laparoscopic and robotic colectomies [9]. Pappou et al. have summarized these nicely in their 2015 review pub-

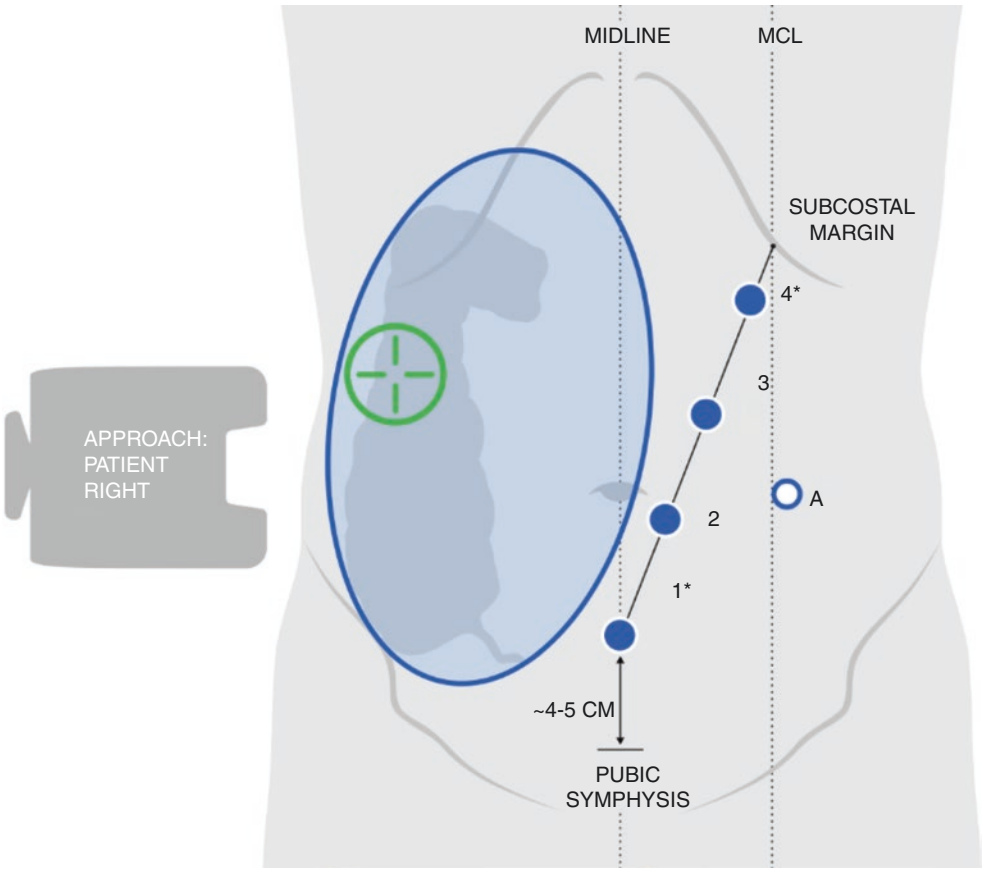


Fig. 21.3 Port placement for right colectomy, Xi system (Source: da Vinci Xi procedure card)

lished in *Journal of Surgical Oncology*. The two tables (Tables 21.1 and 21.2) from their paper are being reproduced here (with permission).

A well-formed systematic review of robotic colorectal surgery by Starvos et al. identifies pertinent results of common robotic colectomies [3]. In this article, 440 anterior resections were reviewed and had a mean operative time of 199 min. Only a 0.4% conversion rate was reported, and the length of hospital stay was between 5 and 6 days. The most common complications included anastomotic failure (<1%), prolonged ileus (2%), intra-abdominal bleeding (2%), and pneumonia (1%). Ileocolic resections in 210 patients were found to have an average procedure time of 167 min, a conversion to laparoscopic rate of 1.1%, and a mean length of stay between 5 and 6 days. The most common complications included prolonged ileus (3%), intra-abdominal bleeding (1.5%), and pneumonia (1%). With regard to stoma formation, the results are largely determined by the type of stoma created. Many randomized and nonrandomized studies have been carried out to shed light on the tolerance and complications of different stoma types [4–7]. Ileostomies are more prone to cause skin irritation around the stoma (34%). They are also more commonly associated with obstruction (23%), prolapse (11%), and fistula formation (12%) when compared to colostomies. The most common complications of colostomy formation include skin irritation (14%) and parastomal hernia (11%). Many advocate that the construction and reversal of ileostomies prove less arduous when compared to that of colostomies, yet this must be balanced with the higher rate of postoperative complications seen with ileostomies. In the end, both techniques are comparable in the quality of life, ability to decompress distal bowel, and ability to achieve fecal diversion. Notably, the majority of stoma complications may be addressed successfully nonoperatively via appropriate wound-ostomy care. There is a paucity of data concerning the outcomes of robotic primary suture repair of traumatic bowel injury. Though iatrogenic bowel injury in gynecologic robotic surgery is usually secondary to trocar placement, it may also occur during adhesiolysis or electrosurgery [8]. Though there is little evidence, one may expect equivalent or improved results of robotic primary repair when compared to laparoscopic primary repair because of the enhanced visualization, ergonomics, and degrees of wrist motion seen in robotic surgery [10].

Table 21.1 Summary of selected studies comparing robotic-assisted to laparoscopic right colectomy

Author (year)	Country	Study type	Group	Patients	OR time, mean (SD), min	EBL, mean (SD), mL	Anastomosis type (number of patients)	Conversions, (rate, %)	Retrieved LN, mean (SD)	Complications (%)	LOS mean (SD), days	Total cost, mean, (SD), US $
Rawlings et al.	United States	R	RRH	17	**218.9 (44.6)**	40.0 (24.9)	**IC EC**	0	**NR**	1 (5.8%)	5.2 (5.8)	9255 (5075)
			LRH	15	**169.2 (37.5)**	66.3 (50.7)		2 (13.3%)	**NR**	2 (13.3%)	5.5 (3.4)	8073 (2805)
deSouza et al.	United States	PCS	RRH	40	**158.9 (36.7)**	50 (NR)	EC EC	1 (2.5%)	17 (NR)	8 (20%)	5 (NR)	**15,192 (NR)**
			LRH	135	**118.1 (38.1)**	50 (NR)		1 (0.7%)	16 (NR)	28 (20.7%)	5 (NR)	**12,361 (NR)**
Deutsch et al.	United States	R	RRH	79	219.2 (39.2)	**76.4 (48.9)**	EC EC	2 (2.5%)	21.1 (NR)	**6 (7.5%)**	4.3 (2.5)	NR
			LRH	92	214.4 (63.2)	**123.2 (89.7)**		0	18.7 (NR)	**21 (22.8%)**	6.3 (6.4)	NR
Park et al.	Korea	RCT	RRH	35	**195 (41)**	35.8 (26.3)	**IC (30)**	0	29.9 (14.7)	6 (17.1%)	7.9 (4.1)	**12,235**
			LRH	35	**130 (43)**	56.8 (31.3)	**EC (5)**	0	30.8 (13.3)	7 (20%)	8.3 (4.2)	**(1908)**
							IC (7)					**10,320**
							EC (28)					**(1608)**
Lujan et al.	United States	PCS	RRH	22	**258.3 (40.9)**	**60.8 (71.3)**	**IC EC**	0	22.5 (6.2)	7 (31.8%)	3.92 (2.7)	NR
			LRH	25	**158.6 (38.1)**	**70.2 (52.9)**		0	18.3 (10.3)	7 (28%)	3.63 (2.4)	NR
Morpurgo et al.	Italy	PCS	LRH-RICA	48	**266 (41)**	NR	**IC EC**	NR	26 (13)	**8 (16.6%)**	**7.5 (2.0)**	NR
			LRH-ECA	48	**223 (51)**	NR		NR	25 (13)	**18 (37.5%)**	**9.0 (3.2)**	NR
Casillas et al.	United States	PCS	RRH	54	**143 (NR)**	63 (NR)	EC EC	2 (4%)	28 (NR)	**9 (17%)**	6.2 (NR)	NR
			LRH	110	**79 (NR)**	57 (NR)		12 (11%)	24 (NR)	**39 (25%)**	5.5 (NR)	NR
Trastulli et al.	Italy	R	RRH	102	**287.4 (76.4)**	30 (NR)	IC EC EC	4 (3.9%)	20.3 (7.7)	23 (22.5%)	**4 (NR)**	NR
			LRH-ICA	40	**204.3 (51.9)**	10 (NR)		6 (15%)	19 (10.1)	8 (20%)	5.5 (NR)	NR
			LRH-ECA	94	**208 (61)**	45 (NR)		8 (8.5%)	19.5 (7.7)	21 (22.3%)	**7 (NR)**	NR

OR operating room, *EBL* estimated blood loss, *LN* lymph nodes, *LOS* length of stay, *R* retrospective, *PCS* prospective case-control study, *RCT* randomized controlled trial, *RRH* robotic right hemicolectomy, *LRH* laparoscopic right hemicolectomy, *LRH-RICA* laparoscopic right hemicolectomy with robotic intracorporeal anastomosis, *LRH-ICA* laparoscopic right hemicolectomy with intracorporeal anastomosis, *LRH-ECA* laparoscopic right hemicolectomy with extracorporeal anastomosis, *IC* intracorporeal, *EC* extracorporeal, *NR* not recorded

Table 21.2 Summary of selected studies comparing robotic-assisted to laparoscopic left colectomy

Author (year)	Country	Study type	Group	Patients	OR time, mean (SD), min	EBL, mean (SD), mL	Conversions, (rate, %)	Retrieved LN, mean (SD)	Complications, (rate, %)	LOS, mean (SD), d	Total cost, mean, (SD), US $
Delaney et al.	United States	PCS	RSC	3	**200 (NR)**	167 (NR)	1 (33%)	NR	1 (33%)	2.7 (NR)	3321 (NR)
			LSC	3	**140 (NR)**	75 (NR)	0	NR		3.7 (NR)	3553 (NR)
Rawlings et al.	United States	R	RSC	13	225.2 (37.1)	90.4 (60)	2 (15.3%)	NR	5 (38.4%)	6 (7.3)	12,335 (12,162)
			LSC	12	199.4 (44.5)	65.4 (52.1)	0	NR	2 (16.6%)	6.6 (8.3)	10,697 (11,719)
Woeste et al.	Germany	R	RSC	4	**236.7 (5.8)**	60 (17.3)	1 (25%)	NR	1 (25%)	NR	NR
			LSC	32	**172.4 (38)**	58.9 (55.5)	3 (13%)	NR	5 (21.7%)	NR	NR
Shin	Korea	R	RLH	7	337 (138)	106 (80)	0	16.9 (6.6)	NS	9.1 (1.7)	NR
			LLH	12	265 (71)	167 (62)	0	16.2 (4.7)	NS	8.9 (2.1)	NR
Casillas et al.	United States	PCS	RLH	68	**188 (NR)**	89 (NR)	4 (5.8%)	20 (NR)	8 (11.7%)	3.6 (NR)	NR
			LLH	82	**109 (NR)**	110 (NR)	9 (10.9)	17 (NR)	17 (20.7%)	6.5 (NR)	NR

Items in bold are statistically significant, $P < 0.05$

OR operating room, *EBL* estimated blood loss, *LN* lymph nodes, *LOS* length of stay, *R* retrospective, *PCS* prospective case-control study, *RCT* randomized controlled trial, *RSC* robotic sigmoid colectomy, *LSC* laparoscopic sigmoid colectomy, *RLH* robotic left hemicolectomy, *LLH* laparoscopic left hemicolectomy, *NS* nonsignificant, *NR* not recorded

Conclusion

In modern surgical practice, multidisciplinary care is routine. With modern anesthesia and excellent postoperative critical care, the complexity of procedures being performed is increasing with more re-operative procedures and advanced malignancy surgeries being performed. Almost all of these procedures deal with at least the manipulation of bowel, and some inherently require bowel resection, anastomosis, diversion, and/or injury repair. In order to ensure the best outcomes, it is important that the gynecologic surgeon be able to implement such intestinal procedures in the correct settings (either independently or in conjunction with the GI surgeon). These principles, used correctly, may facilitate complete oncologic resections, lower recurrence of gynecologic disease, and decreased morbidity/mortality for iatrogenic bowel injuries.

References

1. Yim GW, Kim YT. Robotic surgery in gynecologic cancer. Curr Opin Obstet Gynecol. 2012;24(1):14–23.
2. Bouquet de Joliniere J, et al. Robotic surgery in gynecology. Front Surg. 2016;3:26.
3. Antoniou SA, et al. Robot-assisted laparoscopic surgery of the colon and rectum. Surg Endosc. 2012;26(1):1–11.
4. Leong AP, Londono-Schimmer EE, Phillips RK. Life-table analysis of stomal complications following ileostomy. Br J Surg. 1994;81(5):727–9.
5. Londono-Schimmer EE, Leong AP, Phillips RK. Life table analysis of stomal complications following colostomy. Dis Colon Rectum. 1994;37(9):916–20.
6. Park JJ, et al. Stoma complications: the Cook County Hospital experience. Dis Colon Rectum. 1999;42(12):1575–80.
7. Porter JA, et al. Complications of colostomies. Dis Colon Rectum. 1989;32(4):299–303.
8. Picerno, T., et al., Bowel injury in robotic gynecologic surgery: risk factors and management options. A systematic review. Am J Obstet Gynecol, 2017 216(1):10-26.
9. Park JS, et al. Randomized clinical trial of robot-assisted versus standard laparoscopic right colectomy. Br J Surg. 2012;99:1219–26.
10. Pappou EP, Weiser MR. Robotic colonic resection. J Surg Oncol. 2015;112(3):315–20. https://doi.org/10.1002/jso.23953. Review. PubMed PMID: 26179217.

Robotic-Assisted Total Pelvic Exenteration

22

Peter C. Lim and Elizabeth Y. Kang

Introduction

Total pelvic exenteration is an ultra-radical procedure which involves removal of pelvic organ content and reconstruction of urinary system, gastrointestinal, and pelvic floor. Brunschwig in 1948 was the first to describe the procedure [1]. This ultra-radical surgery typically requires a large incision in an operative field that is small and deep. In addition, the tissues are commonly distorted, obliterated, or fibrotic either from previous surgical dissection and/or radiation. Thus, the development of surgical planes can be challenging. Consequently, this procedure is associated with long operative time, high morbidity, prolonged hospitalization, and mortality. Minimally invasive surgery offers several advantages over open surgery including shorter hospitalization, faster recoveries, less blood loss, better cosmesis, and fewer complications. In order to decrease morbidity and prolonged hospitalization, a minimally invasive approach might be an alternative to laparotomy for pelvic exenteration.

Pomel described the first laparoscopic total pelvic exenteration in 2003 [2]. The difficulty of performing laparoscopic pelvic exenteration is the learning curve can be challenging as the surgeon must navigate through an altered, narrow, deep, fibrotic, obliterated operative field. Traditional laparoscopy relies on hand movements that are counterintuitive, require a skilled coordinated surgical assistant, and the instruments have limited range of motion thus often requiring ergonomically challenging positions. This can lead to surgeon's fatigue and frustration.

The introduction of robotic surgery in the field of gynecologic surgery has afforded this complex procedure to be achievable. Lim reported in 2009 the first robotic-assisted total intracorporeal pelvic exenteration with urinary diversion for treatment of recurrent cervical cancer [3]. The potential major advantage for the robotic surgical platform was the ×40 magnification camera vision system (Intuitive, Sunnyvale) that provided a stable three-dimensional image of the operative field. In addition, the small EndoWristed instruments (Intuitive, Sunnyvale) allow seven degrees of freedom which mimic natural hand and wrist motions intuitively much like open surgery, thus facilitating the surgical dissection deep down into the confines of the narrow pelvic floor.

The intent of this chapter is to describe the techniques and the different types of robotic pelvic exenteration along with the associated urinary, bowel, and pelvic floor reconstruction that can be performed. In addition, the learning curve required to adopt this procedure, the indication for the procedure, the techniques, the complications, and the surgical outcomes associated with this procedure will be discussed.

Learning Curve

Robotic pelvic exenteration procedure requires removal of either bladder, uterus, and/or colon and rectum depending upon the disease and the viscera that is involved. The surgical procedural steps that are required to perform pelvic exenteration are very similar to the performing robotic radical hysterectomy such that one must develop the avascular space of paravesicle space, pararectal, retropubic, and retrorectal spaces along with development of parametria in order to detached the intended organ structure: uterus and adnexal content, bladder, colon, rectum, vagina, and/or vulva. Thus, it is critical that one must familiarize themselves with these operative spaces prior to performing the robotic pelvic exenteration, particularly in the absence of haptic feedback that is heavily relied upon during the procedure.

It is unclear how many robotic surgical cases are required to achieve efficiency prior to performing this complex difficult procedure. However retrospective cohort have reported

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between 25 and 50 cases are required to achieve proficiency in the early learning curve for both benign and malignant hysterectomies [4–6]. Furthermore, it is important to recognize that there was a different learning curve for each part of robotic surgical procedure such as port placement, docking, hysterectomy, cuff closure, and lymph node dissection. It is the authors' recommendation that multiple robotic hysterectomies and radical hysterectomies be performed to develop and maintain skills such as multiple clutching, tracking, and articulating instruments to become efficient. Performing robotic radical hysterectomy is an essential and necessary prelude to performing robotic pelvic exenteration as the technical steps for robotic hysterectomy procedure are the same as pelvic exenteration. Figure 22.1 demonstrates the author's experience of the number of robotic procedures that was performed in the first year of the adoption. The first robotic pelvic exenteration was attempted after having performed 135 robotic procedures. The number of pelvic exenterations performed then increased over time. Due to the absence of haptic feedback, it is essential to perform multiple robotic procedures as it affords development of neuromuscular memory and visual acuity prior to attempting a robotic pelvic exenteration procedure. Thus, the recommendation prior to proceeding with more advanced procedures is to perform somewhere between 100 and 150 robotic hysterectomies for malignant disease and 20 robotic radical hysterectomies.

Patient Selection

Pelvic exenteration is primarily performed as a last resort for lifesaving measure. Patients who are candidates for pelvic exenterations should be no different than open pelvic exenterations. It should be limited to central pelvic recurrent gynecological diseases such as cervical, vaginal, and vulval who have failed primary surgical resection and/or radiotherapy or chemotherapy. Patients who have underlying pulmonary conditions, such as sleep apnea, chronic obstructive pulmonary disease, restrictive lung disease, cardiac conditions, cerebral vascular disease, and ocular conditions (such as glaucoma), should be appropriately evaluated by the respective specialist prior to undergoing robotic surgery due to the potential intraoperative complications that are associated with prolonged steep Trendelenburg position that is required with robotic surgery [7].

Robotic Pelvic Exenteration Technique

Magrina described three different types of pelvic exenteration based on the removal of pelvic content relative to the pelvic floor levator muscle: Type I supralevator, Type II infralevator, and Type III pelvic exenteration with total vulvectomy [8]. All three types of pelvic exenteration as described can be performed robotically. However, robotic pelvic exenteration can be performed either a non-hybrid or hybrid approach depending upon the reconstructive procedure planned. A non-hybrid approach is defined as the entire procedure performed via minimally invasive technique without the requirement of an abdominal incision. The entire robotic-assisted pelvic exenteration along with the ileal conduit neobladder reconstruction is performed intracorporeally, and the specimen is removed via the perineum rendering the patient without any abdominal incision with the exception of port incision scar (Fig. 22.2). The hybrid approach is combining the minimally invasive robotic-assisted approach for completion of the pelvic exenteration in conjunction with an abdominal incision for completion of urinary neobladder

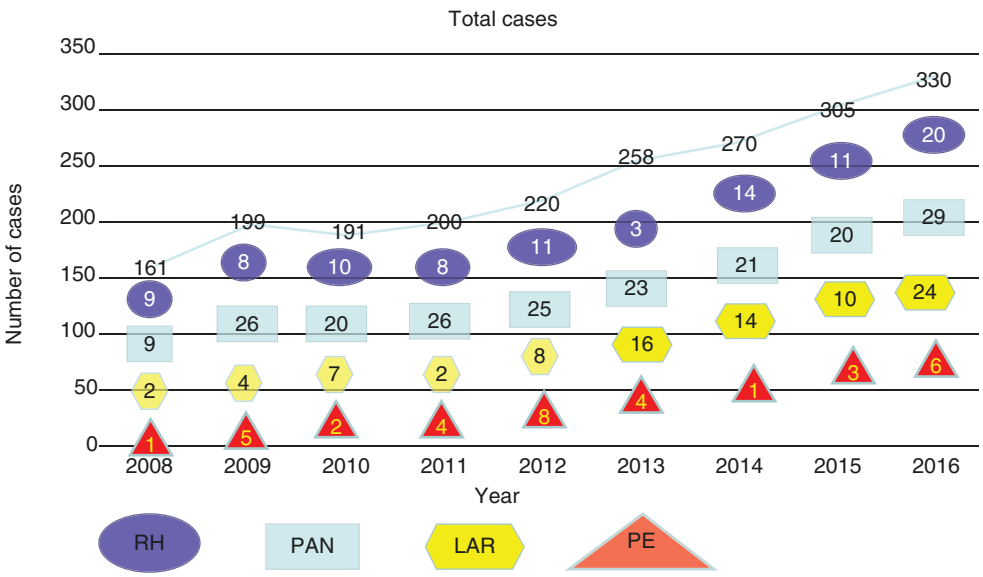

Fig. 22.1 Learning curve and adoption of complex robotic surgery over time. *RH* radical hysterectomy, *PAN* para-aortic node dissection, *LAR* low anterior, *PE* pelvic exenteration. The *inset number* represents the total number of cases performed with respect to the year

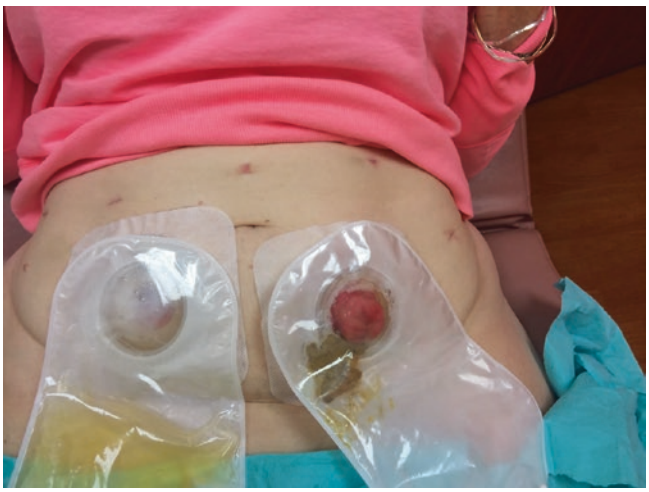

Fig. 22.2 A well-healed robotic port scars from a non-hybrid robotic-assisted total pelvic exenteration with an ileal conduit and colostomy stoma

reconstruction along with harvesting of rectus abdominus muscle flap for a neovagina pelvic floor reconstruction (Fig. 22.3a, b).

Robotic pelvic exenteration procedure is broken down to three phases, the pelvic exenteration which is performed via robotic-assisted approach, the perineal phase in which incision is made on the perineum to remove the specimen and possible pelvic floor reconstruction, and lastly the reconstructive phase in which neobladder is reconstructed or colostomy is performed depending on the type of pelvic exenteration being performed. Robotic pelvic exenteration procedure is broken down to three phases, the pelvic exenteration which is performed via robotic assisted approach, the perineal phase in which incision is made on the perineum to remove the specimen and possible pelvic floor reconstruction, and lastly the reconstructive phase in which neobladder is reconstructed or colostomy is performed depending on the type of pelvic exenteration being performed.

Positioning is critical in robotic surgery because it must provide access to the surgical field and must accommodate the robotic camera and working arms. Positioning starts with placement in the dorsal lithotomy position with the legs in Allen Yellowfins stirrups (Allen Medical Systems, Acton, Massachusetts), as with conventional laparoscopy. One must ensure adequate padding at all pressure points and avoidance of extreme flexion, extension, and abduction of extremity positions to minimize potential neuromuscular injuries. A standard motorized operating-room table featuring a maximum tilt is used to achieve steep Trendelenburg, typically 25–28°. To prevent a patient in steep Trendelenburg from shifting while on the operating table, a layer of eggcrate foam on top of the bed is securely taped to the surgical bed. For morbidly obese patients, we recommend Trenguard™ foam shoulder pad brace, (Model #56100 D.A. Surgical, Newbury, Ohio) which is anchored to the operating table. It is important that the pad rest on the shoulder and not at the pressure points. In addition, well-padded arm sleds made of rigid plastic material are designed to cradle the arm and extend under the mattress to protect and stabilize the arms particularly in morbidly obese patients (Fig. 22.4).

Particular consideration should be taken for protection of the patient's face—particularly the eyes, which are at risk of injury during robotic surgery. The risk of fascial and ocular trauma becomes accentuated when the robotic ports are placed superior to the umbilicus when the robotic camera comes in contact with the face. There are no standard recommendations for the best way to protect a patient's face and eyes. Placement of Mayo stands or a foam face mask has been suggested. We prefer the foam face mask mainly because Mayo stands often clash with the robotic arms (Fig. 22.5).

It is also important to keep in mind that corneal abrasion is the most common ocular complication because of failure of the eyelids to completely close, which result in corneal drying during the surgical procedure [9]. To minimize this potential complication, it is recommended that patient's eyelids are shut after induction of general anesthesia.

The combination of dorsolithotomy position in conjunction with steep Trendelenburg may subject a patient to certain perioperative risks and complications, such as laryngeal edema, fascial swelling, increased intracranial pressure, and increased intraocular pressure. Thus it is crucial for the surgeon, the bedside assistants, and the anesthesiologist to understand the degree of limitations of patient positioning as it can lead to potential complications.

After the patient is properly positioned, proper port placement is imperative not only to minimize potential complications, but it will dictate the success of the procedure. We recommend an upper abdominal port placement typically 8–10 cm above the umbilicus. We recommend utilizing all three robotic arms with the "third arm" providing static counter traction and exposing operative field. The ports are aligned in straight line, and the assistant port is placed inferiorly in the left lower quadrant 2 cm ipsilateral to port #2 at the level of anterior superior iliac spine. Placement of the assistant port in left lower quadrant has several advantages: it allows the surgeon to visualize the upper abdomen during placement of instruments through the robotic ports thereby minimizing internal organ injury; it allows the surgeon to tract and assist in removal of suture with needles to prevent a lost needle; and it minimizes "chopsticking" with the robotic arms at the time of pelvic dissection. In addition, in the event that robotic ports are displaced when pneumoperitoneum is lost during surgery, placing the robotic scope via assistant port in the Xi model allows diagnosis of any robotic port problems without having to redock the robotic camera. Robotic system is docked lateral to the right to allow vaginal access for the perineal phase (Fig. 22.6a, b).

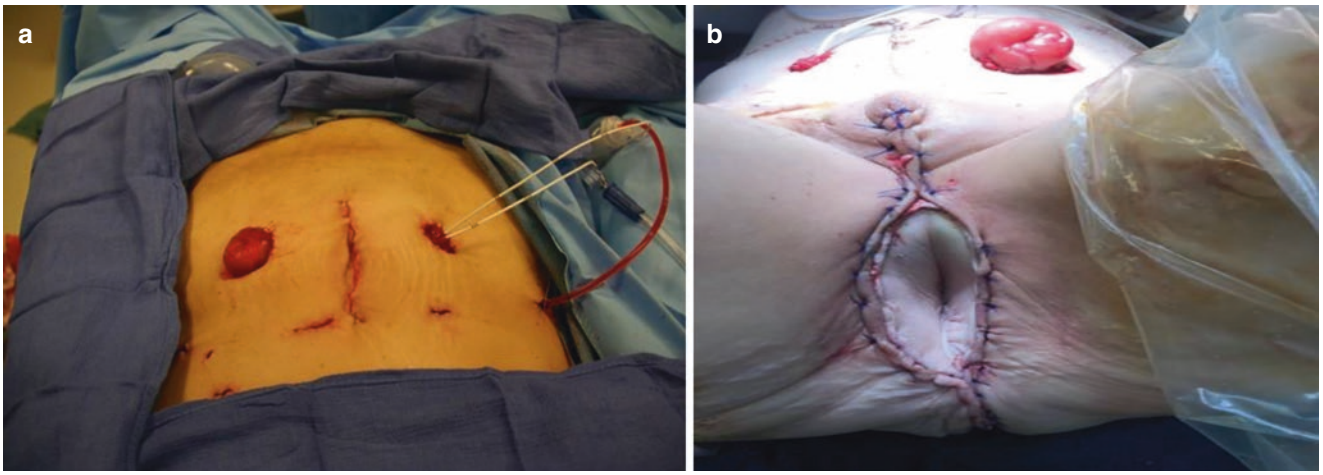

Fig. 22.3 (**a**) A Hybrid approach demonstrating robotic port scars and midline incision with ileal conduit and colostomy stoma. (**b**) A hybrid approach following a robotic-assisted Type III total pelvic exenteration with rectus abdominus myocutaneous neovagina reconstruction and an ileal conduit and colostomy stoma

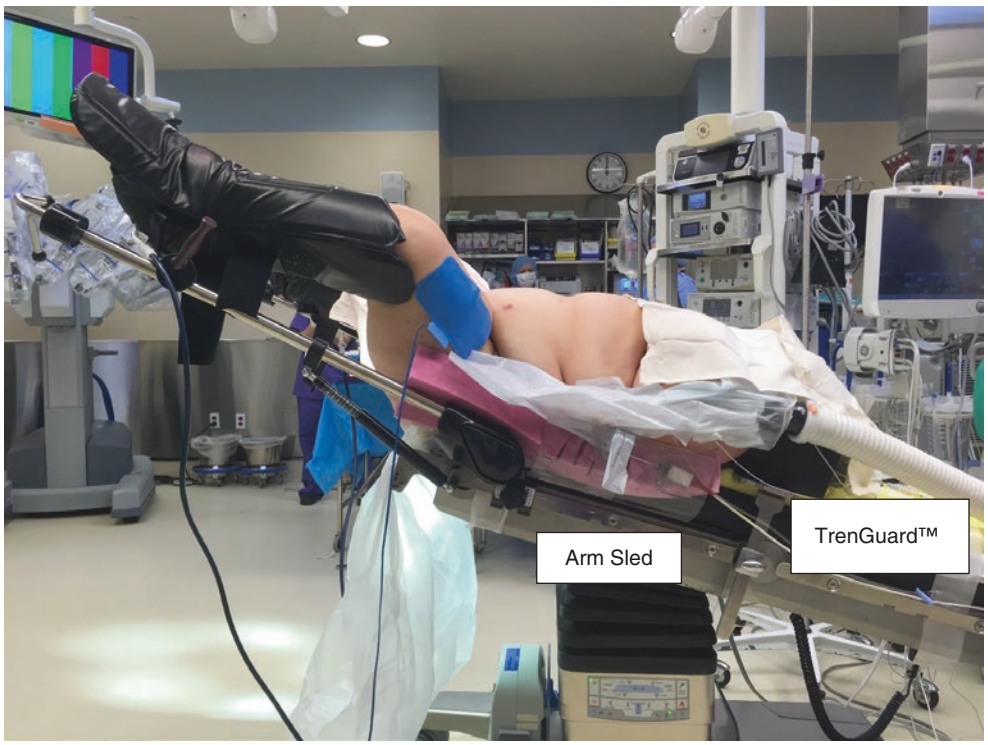

Fig. 22.4 Patient in dorsolithotomy steep Trendelenburg position with legs in Allen Stirrups with adequate padding. An eggcrate foam on top of the bed is securely taped to the surgical bed. In addition, an arm sled is placed around the padded arm to prevent slippage of the arm and also a padded shoulder brace (TrenGuard™) is anchored to the surgical bed

Instrumentations

A 30-degree down scope is placed in the midline port, while a spatula or robotic unipolar scissors (Intuitive, Sunnyvale) is placed in the surgeons dominant working port; thus, for a right-handed surgeon, this will typically be placed in the right inner port, while for a left handed dominant surgeon it will be placed in the left port. The bipolar Maryland grasper or fenestrated bipolar grasper will be placed in the non-dominant working port contralateral to spatula or robotic scissors port. The "third arm" robotic port is placed in the right or left outer port (depending upon surgeon's preference), and a ProGrasp grasper (Intuitive, Sunnyvale) is placed for traction and exposure. We also recommend robotic Endo GIA stapler (Intuitive, Sunnyvale) and Vessel Sealer (Intuitive, Sunnyvale) to be placed in the dominant working port to divide the bowel and the mesentery of the bowel, cardinal ligaments, and pelvic ligaments, respectively. Robotically driven Hem-o-lock clips (Intuitive, Sunnyvale) are employed to secure the anterior hypogastric vasculature.

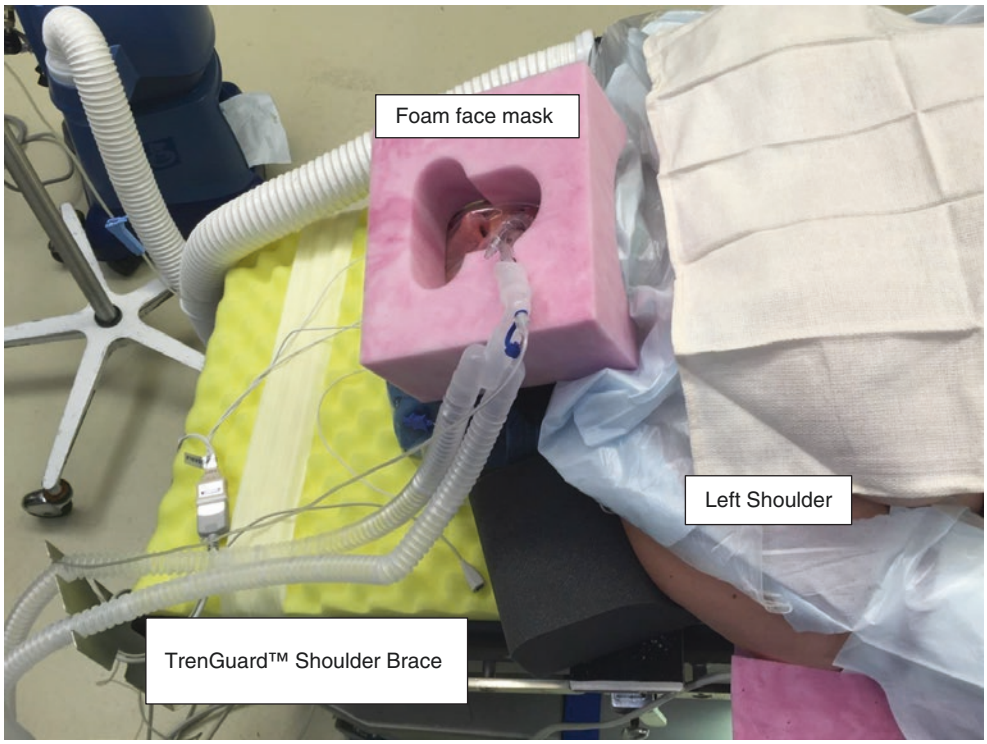

Fig. 22.5 Aerial view of the foam padded should brace (TrenGuard™) is anchored to the table along with a foam padded face mask to protect the face

Robotic diamond forceps (Intuitive, Sunnyvale) and Potts scissors (Intuitive, Sunnyvale) are employed to perform ureteroileal anastomosis.

Robotic Total Pelvic Exenteration Technique

Table 22.1 outlines the critical steps of the robotic total pelvic exenteration. After appropriate port placement and intraperitoneal assessment to rule out metastatic disease, robotic-assisted pelvic exenteration is undertaken Video 22.1. The right and left round ligament is divided using monopolar robotic scissors or spatula. The anterior and posterior leaves of the broad ligaments are incised followed by the development of paravesicle and pararectal spaces. In robotic surgery it is critical to rely on visual acuity as it lacks haptic feedback. Thus, it is important to rely on anatomical landmarks when developing the paravesicle and pararectal spaces. After the anterior and posterior broad ligaments are incised, identify the external iliac vessel laterally and the ureter medially. Once the external iliac artery is identified, it is important to skeletonize the anterior division of the hypogastric artery. This in turn will lead to the identification of the superior vesical artery which is the first branch of the anterior hypogastric artery which will serve as an anatomical landmark for the paravesicle space. We recommend developing the pararectal space first by identifying the external iliac artery laterally and then identifying the ureter medially, posteriorly the sacrum, and anteriorly the cardinal ligament complex. Once the ureter is identified medially, using careful meticulous dissection with the spatula or the scissors, the ureter is pushed medially to develop the pararectal space. After the pararectal space is developed, the superior vesical artery is identified and pushed medially to develop the paravesicle space. The paravesicle space is bounded medially by the superior vesical artery, laterally by the external iliac vessels, anteriorly by the pubic bone, and posteriorly by the parametria. It should be noted that development of these spaces can be challenging as these spaces maybe obliterated consequent to previous surgical dissection and radiation exposure resulting in bleeding. Thus, it is recommended an endopeanut be used for this portion of the procedure as it will minimize trauma to and keep the operative field clear (Fig. 22.7).

After development of the pararectal and paravesicle spaces, the anterior division of the hypogastric vessels and the cardinal ligament complex is developed. It is important to skeletonize and identify the branches of the anterior hypogastric artery and its vein, the superior and deep uterine artery, and laterally the obturator artery and vein. These vessels are skeletonized and Hem-o-lock clip is applied to ensure hemostasis. It is our experience again these vasculatures might be fused or fibrotic due to previous radiotherapy exposure, thus precluding from individual skeletonization and ligation with Hem-o-lock clips. In the event that the individual branches of the anterior hypogastric vessels cannot be skeletonized, it is recommended that the anterior division of the internal iliac vessel is secured with Hem-o-lock clips and a vessel sealer is employed to divide the cardinal ligament

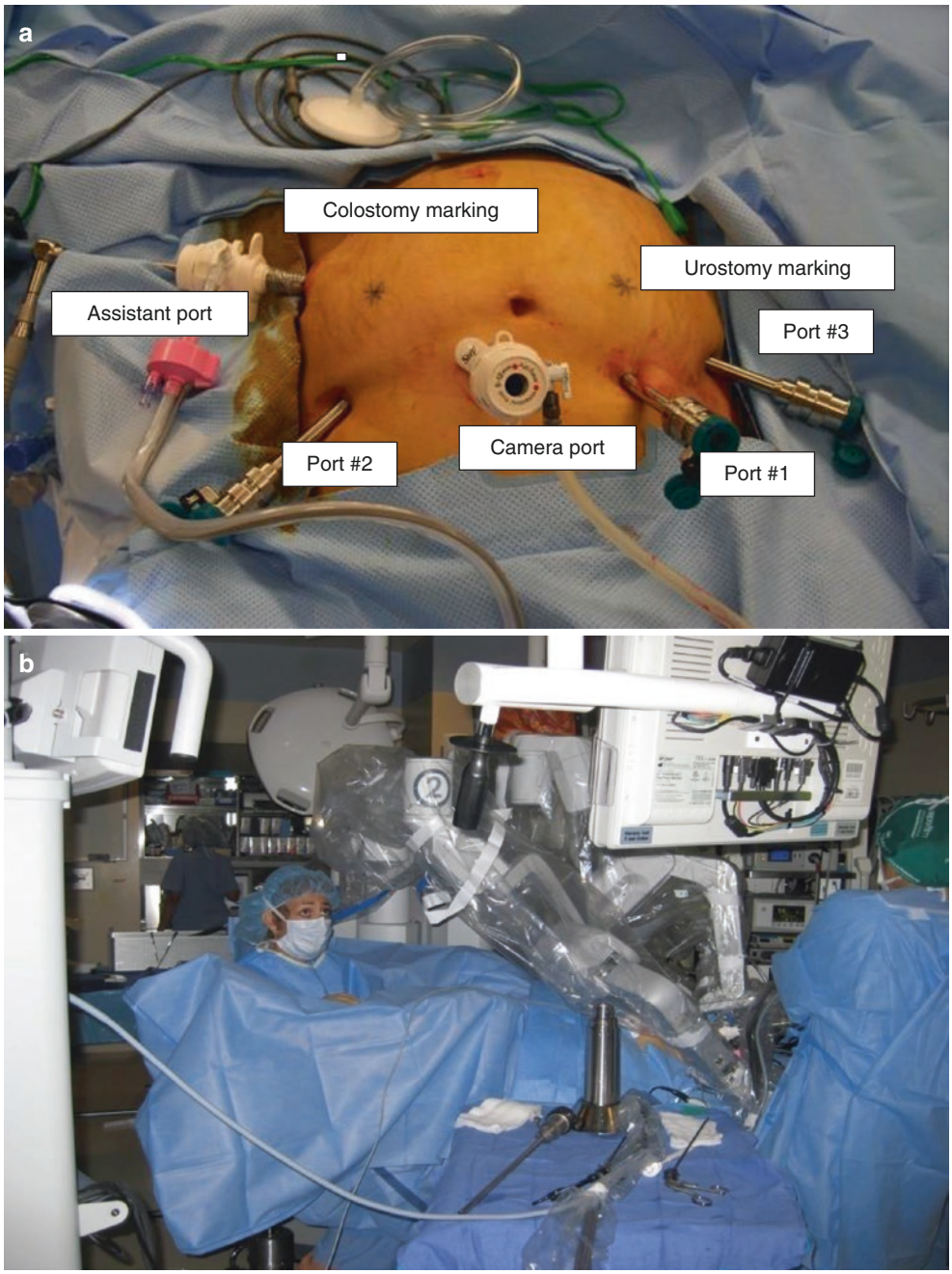

Fig. 22.6 (**a**) Abdominal pelvic port placement for S or Si utilizing all three arms. Camera port (CP) is placed midline at the umbilicus, port #1 is placed 8 cm right lateral to the camera port, while port #3 is placed 8 cm lateral to port #1 in the right upper quadrant. Port #2 is placed 8 cm left lateral to the camera port (CP). The assistant port is placed in the left lower quadrant, 2 cm lateral port #2, at the level of the anterior superior iliac spine. Stoma site is marked for creation of urostomy and colostomy. (**b**) Abdominal port placement with right hip docking allowing the assistant to sit between the patient's legs at the perineum to allow vaginal access

complex along with the accompanying vasculature down to the level of the levator muscle. The ureters are then identified proximal to the ureteric tunnel, Hem-o-lock clips are applied, and the ureters are divided.

When performing a robotic-assisted total pelvic exenteration procedure, it is critical that posterior exenteration is performed after securing the parametria and ligation of the hypogastric vessels and prior to performing the anterior exenterative portion of the procedure. It is our experience that when anterior exenterative procedure is preceded by the posterior exenterative procedure, the detached bladder often will obstruct the operative field of the posterior exenteration.

Thus, attention is turn toward the sigmoid colon in preparation for posterior exenteration Video 22.2. The sigmoid colon is suspended ventrally, and a mesenteric window is created. The divided ureter should be identified at the level of the pelvic brim. Robotic controlled Endo GIA stapler is delivered through inner right port to divide the colon. The divided sigmoid colon is suspended ventrally with the third arm providing static countertraction, and the mesenteric blood supply is exposed and skeletonized and divided with the vessel sealer instrument after it is exchanged out with the stapler. The superior hemorrhoidal vessels are isolated, ligated, and divided. The sigmoid mesenteric blood supply is

Table 22.1 Steps to robotic pelvic exenteration

1. Development of paravesicle space
2. Development of pararectal space
3. Ligation of the anterior division of hypogastric vessels (Hemoclips)
4. Division of cardinal ligament to the level of levator muscle
5. Robotic anterior or total pelvic exenteration
– Development of space of Retzius (RTPE or RAPE)
– Identify dorsal clitoral vein and ligation of the vessel
– Identifying and division of pubovesical ligament
– Division of urethra
6. Robotic posterior or total pelvic exenteration
– Creation of mesenteric window to allow division of the colon
– The proximal colon is divided
– Development of retrorectal space
– Division of mesentery of sigmoid colon to the level of levator muscle
– Identifying and division of anal coccygeal ligament
7. Completion of perineal phase

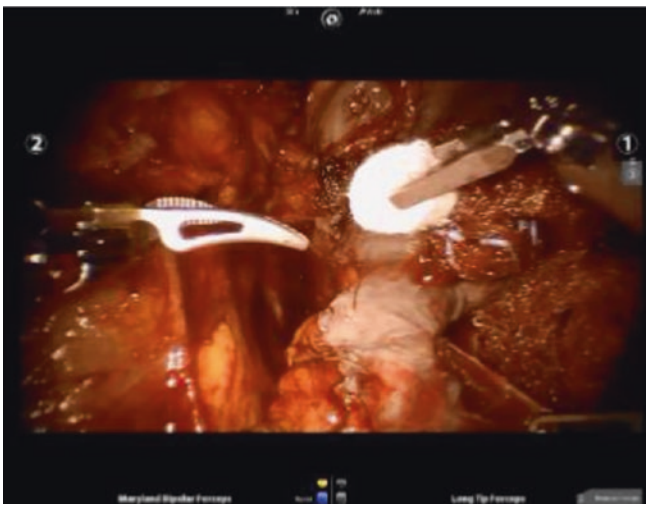

Fig. 22.7 Endopeanut is demonstrated in preparation for dissection

further divided to the level of sacral hollow with the vessel sealer. The dissection is then carried out laterally to identify the puborectalis ligament or the rectal pillar, and the anococcygeal ligament is identified and divided down to the level of the levator muscle.

If Type I supralevator is the intended procedure then, a robotic stapler is then introduced via the right inner port and the rectum is then divided. If, however, Type II infralevator or Type III total pelvic exenteration is the intended procedure, then the remainder of the procedure is completed via perineal phase.

However, prior to the perineal phase, if the intended procedure is to also remove the bladder, the anterior exenteration portion of the procedure must be undertaken. In preparation for anterior exenteration, the obliterated superior vesicle artery is identified, and a peritoneal incision is made medial to the obliterated artery. The incision is extended to the contralateral side. This allows access and develops the retropubic space known as space of Retzius. Once the space of Retzius is developed, the dissection is then carried out laterally to identify the pubovesical ligament. This ligament is isolated and divided with a vessel sealer since often incorporates a vascular pedicle down to the level of the levator muscle. After the pubovesical ligament is divided, the dorsal clitoral vein is identified, which is typically 1 cm inferior to the retropubic arch and superior to the urethra. Due to absence of haptic feedback with robotic surgery, we recommend to mobilize the Foley catheter back and forth in order to identify the dorsal clitoral vein. Location of the urethra will help facilitate the dorsal clitoral vein which is 1 cm superior to the urethra under the pubic arch. The dorsal clitoral vein is skeletonized, ligated, and divided followed by division of the urethra.

We recommend the perineal phase. After the robotic-assisted pelvic exenteration procedure is completed and depending upon the intended type of exenteration procedure, for Type II or Type III exenteration procedure, a perineal phase is required. Once the specimen is free, a vulvar incision is made to remove the specimen. The major advantage of robotic-assisted pelvic exenteration procedure is all the ligaments are identified intracorporeally and divided via robotic-assisted approach; thus, it does not require to be divided during the perineal phase.

During the perineal phase after the removal of the specimen, if neovagina pelvic floor reconstruction is desired, the perineal wound is left open until the rectus abdominus myocutaneous muscle flap is harvested via a hybrid approach. An abdominal incision is made to harvest the rectus abdominus muscle flap for the creation of a neovagina and pelvic floor reconstruction [10]. If however, pelvic floor reconstruction or neovagina are not desired, the perineal wound is closed and attention is turn toward the urinary reconstruction phase.

Robotic-Assisted Urinary Reconstruction

For robotic anterior pelvic exenteration or total pelvic exenteration, a neobladder procedure is required. Although there are many different neobladder reconstructive procedures such as an incontinent ileal or sigmoid urinary conduit and continent ileocolic urinary diversion, we prefer the ileal conduit as the procedure of choice if total intracorporeal robotic approach is desired. If however a continent urinary diversion is desired, we recommend a hybrid approach where the pelvic exenteration phase is completed robotically followed by completion of ileocolic continent urinary reconstruction via a small midline incision.

Table 22.2 outlines the major key steps in performing a total intracorporeal robotic-assisted ileal conduit. After

completion of the perineal phase, the robotic system is redocked. This portion of the procedure does not require the 25–28° steep Trendelenburg position as it would for the pelvic exenteration portion of the procedure. We typically recommend 10–15°.

We begin by harvesting the ileum for the conduit. Typically this segment should be about 15 cm long; however, it should be noted the length of the conduit that is harvested is dictated by the abdominal wall thickness. Thus, it is important to adjust for the abdominal wall thickness. We recommend a minimum of 10 cm segment of the ileum to be intraperitoneal. Thus, if the abdominal wall thickness is 10 cm, a total of 20 cm of ileum should be harvested. The distal ileum is elevated with the third arm while the assistant grasps the proximal portion of the ileum. A mesenteric window is created in the distal end of the ileum 15 cm from the ileocecal valve, then the desire length of conduit is measured, and a proximal mesenteric window is created. Once the ileal segment is measured, robotic Endo GIA is delivered through the dominant hand port to divide its proximal and distal ends.

Table 22.2 Steps to total intracorporeal ileal conduit

• Harvesting of the ileal loop segment (10–15 cm) depending upon the abdominal wall thickness
• Create mesenteric window proximal and distal segment of the bowel 15 cm proximal from ileocecal junction
• Divide the ileum with Endo GIA stapler
• Orient the conduit. The divided staple line of the afferent limb of the ileal conduit is oversewn with 2-0 Vicryl suture to isolate the staple line to minimize stone formation in the conduit
• Secure and sew the afferent limb bud end of the ileal loop to the sacrum
• Create an ileotomy for (the ureteroileostomy anastomosis) approximately 2–3 cm from the base of the ileal loop
• Mobilize the ureters from the pelvic cavity
• Spatulate the ureters
• Stay suture to be placed at 12 O'clock (4-0 Vicryl with RB needle)
• Intubate the ureteral stent
– Eight French approximately (20 cm) feeding tube catheter to be placed retrograde from the ureteroileostomy site through the segment of the ileum and then intubate the ureteral end into the ureter
– Place the guide wire from the assistant port into the feeding tube catheter
– Remove the feeding tube
– Place a single J ureteral stent through the guide wire
– The guide wire is then remove
– Secure the stent to the ileal loop to minimize the stent from displacing
• Complete the closure of the ureteroileostomy
• Reanstamosis of the small bowel
• Mature the urostomy

The conduit is then oriented such that the proximal divided segment is the butt end or the afferent limb while the distal divided segment is oriented as the efferent limb which will be matured as stoma. It is important to not compromise the blood supply of the conduit when the conduit is oriented. The next step is to suture the stapled butt end with 2-0 Vicryl suture to bury the staples to minimize stone formation. Then the butt end is sewn onto the sacrum with 2-0 Prolene suture to stabilize the conduit in preparation for ureteroileal anastomosis. The stapled line of the efferent limb is removed with monopolar scissors in preparation for the ureteroileal anastomosis. The divided pelvic ureters are mobilized from the pelvic cavity in preparation for the anastomosis. I recommend performing the left ureter anastomosis first. It is brought under the inferior mesenteric artery without tension or angulation. An 8 mm elliptical ileostomy is created about 3 cm distal to the butt end. The dilated, ligated ureter is cut with robotic-driven Potts scissors and spatulated. A 4-0 Vicryl suture on an RB-1 needle is used to place a stay suture to maneuver the ureter. I then recommend suturing the posterior aspect of the ureter to the ileostomy with robotic-driven diamond forceps. After sewing the posterior wall, the stent is introduced.

Stenting of the ureter robotically can be challenging and tricky. I do not recommend directly inserting a guide wire as it will coil in the ileal conduit. It is imperative that an eight French feeding tube or Red Robinson catheter approximately 20 cm in length is first placed in the antegrade fashion into the ileal conduit and into the ureter. This catheter can be delivered via the assistant port. Once the catheter is placed in position, a guide wire is then intubated into the catheter to allow the guide wire to be threaded into the ureter and renal pelvis. After the guide wire is placed, the catheter is then removed, and a single ureteral catheter is then placed via guide wire followed by the removal of the guide wire. After the ureteral stent is inserted, the anterior aspect of the ureter is sutured to the ileostomy. It is important to secure the stent to the ileal conduit. I recommend placing a 3-0 chromic suture including the stent and the full thickness of the ileum. The right ureteroileal anastomosis is then performed in the same fashion. After completion of the ureteral anastomosis, a functional side-to-side anastomosis in an antimesenteric fashion with a robotic-driven Endo GIA is performed to reconnect the divided ileal ends Video 22.3.

A stoma site is then created in the right anterior abdominal wall in the usual fashion.

Bowel Reconstruction and Anastomosis

For robotic posterior pelvic exenteration, the bowel reconstruction is dependent upon whether an infra- or supralevator exenteration is performed. Generally, if infralevator posterior pelvic exenteration is performed, an end colostomy is required. If, however, supralevator posterior pelvic exenteration is undertaken a low colorectal anastomosis can be performed as part of the bowel reconstruction. Either of these procedures can be accomplished via total robotic approach intracorporeally.

If total intracorporeal colorectal anastomosis is desired, I recommend mobilizing the descending colon to allow for a tension-free anastomosis.

An end-to-end anastomosis with an EEA stapler (Covidien, Minneapolis) is performed as follows. First, the third arm with the ProGrasp is used to suspend the proximal descending colon. The staple line is excised. A 2-0 Prolene suture on a GI needle is used to perform a purse string suture. After appropriate selection of the EEA size, I typically like to use the largest diameter stapler to minimize stricture, the anvil is delivered through the vagina. The anvil is inserted in the open descending colon and purse string suture tied. The EEA is then delivered through the rectal stump, and the colorectal anastomosis is performed Video 22.4.

Pelvic Floor Reconstruction

Regardless of the type of pelvic exenteration, I recommend at the minimum an omental J plasty to lay on the dissected raw surface of the pelvic floor to minimize adhesions and prevent bowel obstruction. In some selected cases, omental J plasty is sufficient to support the pelvic floor; however, if the pelvic exenteration procedure has rendered the pelvic floor with a large defect, we recommend either of gracilis myocutaneous muscle graft or rectus abdominus muscle flap to prevent a perineal hernia (Fig. 22.8). Pederson described a robotic intraperitoneal harvest of the rectus abdominus muscle flap in ten patients however I have not had any experience with this procedure [11]. In our institution, if pelvic floor reconstruction is desired, I perform a hybrid approach of robotic-assisted pelvic exenteration with an abdominal incision for a rectus abdominus myocutaneous muscle (RAM) flap, which I prefer, or gracilis myocutaneous muscle flap.

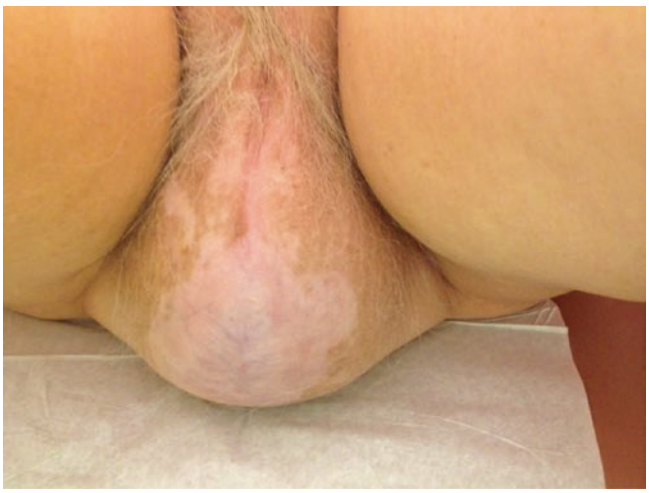

Fig. 22.8 Perineal hernia following a robotic-assisted total pelvic exenteration without pelvic floor reconstruction

Discussion

In 1948, Brunschwig reported the first total pelvic exenteration procedure for treatment of advanced and recurrent cervical cancer, and at that time it had an operative mortality rate of 23% [1]. Over the past several decades with the improvements in critical care, antibiotics, thromboembolism prophylaxis, improved surgical techniques, and better instrumentations such as stapling device, the operative mortality has decreased to 3–5%. Even through the improvement of operative mortality, this procedure is associated with major operative complication rate of 30–44% [12–15] and reoperation rate of 25–43% [16, 17]. Complications associated with this procedure are significant blood loss requiring blood transfusion, pelvic and wound infection, and urinary diversion and reconstructive techniques [18, 19]. Consequently, patients who undergo this procedure not only have prolonged hospitalization, but they have a prolonged recovery.

Pelvic exenteration procedure is one of the most difficult and technically challenging procedures that is performed in treatment of gynecological cancers. Thus, this procedure is often associated with prolong operative time, and it is associated with intraoperative and postoperative morbidity resulting in prolong hospitalization and recuperation period. Laparoscopy has been suggested to minimize morbidity for pelvic exenteration. However, due to the rigid instrumentations, the ability to negotiate in a narrow confine pelvis can be quite challenging. In addition, reconstruction of the urinary system, particularly the ureteral anastomosis, can be technically challenging. The daVinci© Surgical system plat-

form allows the surgeon to circumvent some of the technical challenges of traditional laparoscopy.

There is paucity of data for surgical outcomes associated with robotic-assisted pelvic exenteration. In 2009, Lim reported the first feasibility case of robotic intracorporeal total pelvic exenteration, including urinary reconstruction and end colostomy, without pelvic floor reconstruction on a patient with recurrent cervical cancer [3]. This was followed by Davis et al. in 2010 who reported on two patients undergoing robotic-assisted anterior pelvic exenteration for persistent or recurrent cervical cancer [20]. Puntambekar in 2014 reported on ten cases of robotic anterior pelvic exenteration with favorable operative and short-term clinical outcomes [21].

We observed a significant decrease in blood loss for the robotic as compared to the open approach for pelvic exenteration [22]. This could be an explanation for the lower admission rate to ICU for the robotic patients. There were no differences in complications, length of hospital stay, or hospital readmission among both groups.

Summary

The adoption of robotic surgery for the treatment of gynecologic malignancies has dramatically increased over the last decade. The role of robotic-assisted simple and radical hysterectomy with pelvic lymphadenectomy for the endometrial and cervical cancer is established. However, the role of robotic-assisted pelvic exenteration with reconstructive procedure is still in its infancy stage. Open pelvic exenteration procedure itself is a difficult and challenging surgery with significant morbidity. Although this procedure is clearly feasible via a robotic approach, it requires a long learning curve, and its benefits are not clear yet. As surgeons gain more experience and adopt this technology to perform this difficult procedure, we will better understand whether there is a clear and defined role for robotic-assisted pelvic exenteration.

References

1. Brunschwig A. Complete excision of pelvic viscera for advanced carcinoma; a one-stage abdominoperineal operation with end colostomy and bilateral ureteral implantation into the colon above the colostomy. Cancer. 1984;1(2):177–83.
2. Pomel C, Rouzier R, Pocad M, et al. Laparoscopic total pelvic exenteration for cervical cancer relapse. Gynecol Oncol. 2003;91:616–8.
3. Lim PC. Robotic assisted total pelvic exenteration: a case report. Gynecol Oncol. 2009;115(2):310–1.
4. Lim PC, Kang E, Park DH. A comparative detail analysis of the learning curve and surgical outcome for robotic hysterectomy with lymphadenectomy versus laparoscopic hysterectomy with lymphadenectomy in treatment of endometrial cancer: a case-matched controlled study of the first one hundred twenty two patients. Gynecol Oncol. 2011;120(3):413–8. https://doi.org/10.1016/j.ygyno.2010.11.034.
5. Seamon LG, Fowler JM, Richadson DL, et al. A detailed analysis of the learning curve: robotic hysterectomy and pelvic-aortic lymphadenectomy for endometrial cancer. Gynecol Oncol. 2009;114(2):162–7. https://doi.org/10.1016/j.ygyno.2009.04.017.
6. Lim PC, Kang E, Park DH. Learning curve and surgical outcome for robotic-assisted hysterectomy with lymphadenectomy: case-matched controlled comparison with laparoscopy and laparotomy for treatment of endometrial cancer. J Minim Invasive Gynecol. 2010;17(6):739–48. https://doi.org/10.1016/j.jmig.2010.07.008.
7. Lim PC, Kang EK. How to prepare the patient for robotic surgery: before and during the operation. Best Pract Res Clin Obstet Gynaecolo. 2017. pii: S1521-6934(17)30066-4. doi:https://doi.org/10.1016/j.bpobgyn.2017.04.008
8. Magrina JF, Stanhope CR, Weaver AL. Pelvic exenterations: supralevator, infralevator, and with vulvectomy. Gynecol Oncol. 1997;64(1):130–5.
9. Chalmers D, Cusano A, Haddock P, et al. Are preexisting retinal and central nervous system-related comorbidities risk factors for complications following robotic-assisted laparoscopic prostatectomy? Int Braz J Urol. 2015;41(4):661–8. https://doi.org/10.1590/S1677-5538.IBJU.2014.0464.
10. Morrow CP, Curtin JP. Gynecologic cancer surgery. 1st ed. New York: Churchill Livingstone; 1996. p. 534–77.
11. Pedersen J, Song DH, Selber JC. Robotic, intraperitoneal harvest of the rectus abdominis muscle. Plast Reconstr Surg. 2014;134(5):1057–63. https://doi.org/10.1097/PRS.0000000000000586.
12. Rutledge FN, Smith JP, Wharton JT, et al. Pelvic exenteration: analysis of 296 patients. Am J Obstet Gynecol. 1977;129(8):8811–92.
13. Morley GW, Hopkins MP, Lindenauer SM, et al. Pelvic exenteration, University of Michigan: 100 patients at 5 years. Obstet Gynecol. 1989;74(6):934–43.
14. Goldberg GL, Sukumvanich P, Einstein MH, et al. Total pelvic exenteration: the Albert Einstein College of Medicine/Montefiore Medical Center experience (1987 to 2003). Gynecol Oncol. 2006;101(2):261–8.
15. Ramamurthy R, Durainpandian A. Morbidity and outcome of pelvic exenteration in locally advanced pelvic malignancies. Indian J Surg Oncol. 2012;3(3):231–5. https://doi.org/10.1007/s13193-012-0129-3.
16. Maggino A, Roviglione G, Landoni F, et al. Pelvic exenteration: ten-year experience at the European Institute of Oncology in Milan. Gynecol Oncol. 2009;114(1):64–8. https://doi.org/10.1016/j.ygyno.2009.03.029.
17. Jäger L, Nilsson PJ, Rådestad AF. Pelvic exenteration for recurrent gynecologic malignancy: a study of 28 consecutive patients at a single institution. Int J Gynecol Cancer. 2013;23(4):755–62. https://doi.org/10.1097/IGC.0b013e318287a874.
18. Petruzziello A, Kondo W, Hatschback SB, et al. Surgical results of pelvic exenteration in the treatment of gynecologic cancer. World J Surg Oncol. 2014;12:279. https://doi.org/10.1186/1477-7819-12-279.
19. Moreno-Palacios E, Diestro MD, De Santiago J, et al. Pelvic exenteration in gynecologic cancer: La Paz University Hospital experience. Int J Gynecol Cancer. 2015;25(6):1109–13. https://doi.org/10.1097/IGC0000000000000435.
20. Davis MA, Adams S, Eun D, et al. Robotic-assisted laparoscopic exenteration in recurrent cervical cancer robotics improved the surgical experience for 2 women with recurrent cervical cancer. Am J Obstet Gynecol. 2010;202(6):663.e1. https://doi.org/10.1016/j.ajog.2010.04.004.
21. Puntambekar S, Lawande A, Desai R, et al. Initial experience of robotic anterior pelvic exenteration at a single institute. Int J Gynaecol Obstet. 2014;126(1):41–4. https://doi.org/10.1016/j.ijgo.2013.12.015.
22. Lim PC, Kang EY (2011) Early experience of robotic pelvic exenteration compared to pelvic exenteration for treatment of gynecological malignancy. In: 17th International meeting of the European Society of Gynecological Oncology, 11–14 September 2011.

Robot-Assisted Laparoscopic Fertility-Sparing Radical Trachelectomy

23

Jan Persson and Celine Lönnerfors

Introduction

Cervical cancer is primarily a disease afflicting young women; one third of whom are under the age of 40 at the time of diagnosis. This, in conjunction with delayed conception, has led to an increased need to provide curative but fertility-sparing treatment options.

Radical vaginal trachelectomy in women with early-stage cervical cancer was first described by Daniel Dargent in 1994 [1]. The procedure included radical removal of the cervix, upper vagina and paracervical tissue vaginally, and the regional lymph nodes by laparoscopy. A cerclage was placed in the remaining cervix to decrease the rate of pregnancy loss and premature birth.

A trachelectomy can also be performed abdominally either as an open procedure or by laparoscopy [2–7]. The latter approach has not gained any popularity, probably due to its complexity [3, 8–10]. More than 1200 cases of fertility-sparing radical trachelectomy have been published [11–19]. Selection criteria include stage IAI (with lymphovascular space invasion), IA2, and IBI cervical cancers with a tumor size of <2 cm. A more restrictive policy is advocated in case of high-risk histology such as clear cell or neuroendocrine cancers. Given these criteria, the procedure is considered as safe as a radical hysterectomy with a recurrence rate of less than 6% and a mortality rate of less than 3% [11–13, 15, 18, 20, 21]. Neoadjuvant chemotherapy to reduce tumor size and expanding the patient population available for fertility preservation in patients with stage IBI tumors >2 cm have been described, but the concept is not generally accepted [4, 22, 23].

As a rule, only well-informed women with a wish for preserved fertility and no previous history of infertility are candidates for a fertility-sparing trachelectomy. The tumor should be possible to resect with sufficient margins. In addition, the remaining cervix must be of adequate length which might disqualify women in whom a large cone biopsy has been performed. If applying the aforementioned criteria, around 45% of women younger than 40 years in whom curative surgery is deemed possible are potential candidates for fertility-sparing surgery [22].

Generally, women are delaying conception. Consequently, the proportion of candidates for radical trachelectomy will most likely increase with time. Surprisingly, only 43% of women attempt to conceive following a trachelectomy [22]. A pregnancy rate of up to 80% is reported among those with an active wish to conceive [11, 17, 22, 24–27]. There are no studies evaluating the risk of premature birth related to the remaining cervical length, but it is generally believed that the remaining cervix should be at least 10 mm to minimize the risk. One study found an association between a cervix <10 mm and the inability to conceive post-surgery [11]. The placement of a permanent cervical cerclage may partly counteract the risk associated with a short cervix but may be a hindrance in case of a late first- or second-trimester miscarriage. Optimal positioning of the cerclage is important as a too distal placement may cause erosion to the vagina and also be less biomechanically effective. If a foreign body reaction occurs, a removal of the cerclage is usually necessary. Using a multifilament suture for the cerclage might increase the risk of this unwanted inflammatory response [11]. The association between the development of a cervical stenosis and the use of a cervical cerclage is unclear.

Due to the importance of radical resection and keeping an adequate remaining cervix, it is crucial that the surgical approach is reproducible, allowing for an exact resection level and an optimal placement of the cervical cerclage.

As most candidates for a radical trachelectomy are nulliparous, vaginal access may be restricted and a vaginal approach may be difficult to perform in a standardized manner. In addition, due to the rarity of the procedure and the limited number of other procedures performed in the same dissection plane managed vaginally, procedure-specific proficiency will be low. Moreover, the parametrial resection performed vaginally

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tends to be more distal and has the potential of an increased risk of nerve injury, whereas with an abdominal approach, the upper lymphatic parametria following the uterine arteries can be removed with more precision without transecting the uterine arteries. Also, isolated upper parametrial lymph node metastases have been described [11]. It is also less likely that the lower paracervical/paravaginal tissue will be tumor involved in smaller cervical cancers as this would require a continuous tumor growth.

Robotic surgery offers improved dexterity, movement downgrading, tremor elimination, a stable three-dimensional view steered by the surgeon, and a comfortable working position, features that may help the surgeon overcome some of the surgical difficulties associated with traditional laparoscopy [16]. Robot-assisted laparoscopic trachelectomy was first described in 2008 and has been shown to be safe, accurate, and reproducible [11, 28]. Robotic radical trachelectomy and other advanced robotic oncological procedures share similar surgical steps thereby reducing the learning curve for this infrequent procedure [28–31]. Approximately 100 cases of robot-assisted trachelectomies have been published, of those, 78 patients by two authors [11, 32] and the remainder are case reports or small series. The oncological outcome following robotic trachelectomy seems similar to alternative approaches. Studies on fecundity are scarce although Johansen et al. reported a fertility rate of 81% in 48 women with an active wish to conceive [11].

Patient Selection and Preoperative Assessment

It is important to provide adequate patient information including necessary preoperative examinations, the risk of abandoning the procedure in case of lymph node metastases or inadequate surgical margins, and if so alternative treatment options including ovarian transposition or preservation measures as well as possible postoperative complications, fertility rates, and obstetric outcome prior to undertaking surgery.

All patients eligible for fertility-sparing surgery must conform to universal selection criteria to achieve an optimal oncological and fertility outcome. In women with a wish to preserve fertility, a large cone biopsy should be avoided in lieu of a smaller biopsy for diagnostic purposes. The clinical tumor stage should be between IA1 (with lymphovascular space involvement) and IB1 (tumor size <2 cm) with limited endocervical involvement and no deep stromal invasion. Women with high-risk histology tumors such as clear cell or neuroendocrine cancers are not primarily candidates for fertility-sparing surgery. Neither are women with previous evidence of infertility.

Recommended preoperative examinations include a colposcopy to evaluate the distal tumor margins and signs of vaginal dysplasia, a secondary review of the histopathological sample by a pathologist with subspecialty expertise in gynecologic pathology, and evaluation of the cervical length with high-resolution vaginal ultrasonography to ensure the possibility of adequate surgical margins and ideally a remaining cervix of at least 10 mm after a completed trachelectomy. In addition, a pelvic MRI and a CT scan of the thorax and abdomen should be performed, the former in order to evaluate the tumor diameter, the degree of stromal invasion, and the possibility to achieve adequate surgical margins and the latter to rule out disseminated disease.

Intraoperative Assessment

The procedure can be performed in two separate sessions: an initial lymphadenectomy followed by a trachelectomy if the lymph nodes are negative at final histology. This is not ideal, neither for the patient nor from a logistics perspective.

Less than one in ten of women who conform to the aforementioned selection criteria have lymph node metastases. Sentinel lymph node biopsy is used to determine the pathological status of the first lymph node receiving lymphatic drainage from the primary tumor. Even though the sentinel node technique has a high sensitivity and low false-negative detection rate in tumors smaller than 2 cm, it is still unclear whether it is safe to restrict the lymphadenectomy to sentinel node biopsy only [33]. The sentinel node concept allows for abandonment of the fertility-sparing approach if the lymph nodes are positive at frozen section. The ovaries should be transposed out of the radiation field in women with lymph node metastases. The ovaries and IP-ligaments should be sufficiently mobilized, the retroperitoneum tunneled without disturbing its integrity, and the ovaries attached to the paracolic gutter and clearly marked with metallic clips. Alternatively, ovarian tissue from one ovary may be preserved for later reimplantation. The possibility of ovarian stimulation for preoperative harvesting of oocytes may be considered although this will add waiting time up-front surgery, i.e., times for the stimulation cycle and for the ovaries to return to normal size.

The transection level of the cervix is crucial where a balance must be struck between an adequate remaining cervical length to minimize the risk of premature birth and tumor removal with adequate surgical margins to ensure a safe oncological outcome without the need for adjuvant treatment. The trachelectomy specimen, and in some cases even a separate proximal disc of the remaining cervix, is evaluated initially at frozen section and thereafter an elaborate final histological examination.

The presence and extent of possible factors that may impair fertility, i.e., endometriosis, tubal pathology, and

pelvic adhesions, should be assessed intraoperatively to optimize postoperative fertility guidance including instigation of assisted reproductive measures when necessary.

Surgical Technique

All models of the da Vinci robots can be used, but we recommend a system adapted to the near-infrared fluorescent technique (Firefly) with indocyanine green as the tracer for sentinel node detection. Ports should be placed for standard pelvic surgery as recommended for the respective systems. The Si robot may be docked centrally or side docked at the surgeons' discretion, whereas the Xi robot is usually docked 90° from the side. Suitable robotic instruments are a monopolar scissor, a bipolar forceps, an atraumatic grasper, and a needle holder. For the assistant one, 10–12 mm trocar is needed for suction/irrigation, for insertion of needles, sponges, and loops, and for the retrieval of lymph nodes. We recommend the use of a nodal retrieval bag. For identification of the vaginal fornices, a fornix presenter without an intracervical part is placed at the onset of surgery following intracervical injection of indocyanine green.

The operation may be divided into four steps:

1. Detection and removal of the sentinel lymph nodes including the upper vascular parametrial tissue
2. Radical trachelectomy including the dissection and lateralization of the pelvic hypogastric nerve fibers
3. Reconstructive part including readaptation of the vagina to the remaining cervix and placement of a permanent cerclage
4. Pelvic lymphadenectomy

To avoid time loss while awaiting the pathology report on the two separate frozen sections (sentinel lymph nodes and trachelectomy specimen), it is important to perform the different steps in the correct order. The sentinel nodes and the separate upper parametria are removed first, then if the sentinel nodes and parametria are cancer-free, the radical trachelectomy is performed, and finally awaiting the frozen section result on the trachelectomy specimen, the remaining lymphadenectomy is carried out.

Detection and Removal of the Sentinel Lymph Nodes Including the Upper Vascular Parametria

Prior to docking the robot, a total of 1 mL indocyanine green (diluted to 2.5 mg/mL in sterile water) is injected slowly submucosally in all four quadrants of the cervix (2, 4, 8, and 10 o'clock). The presacral, pararectal, and the paravesical spaces are carefully developed. To avoid spillage of dye and to enable detection of individual lymph vessels, it is important to leave the upper paracervical/parametrial tissue and lymph vessels intact during this dissection (Fig. 23.1). The sentinel nodes and the vascular upper paracervical tissue are removed separately and sent for a frozen section along with any macroscopically suspect nodes (Fig. 23.2). When the avascular planes are developed, the course of the ureter is visualized from the pelvic brim to a level distal to the uterine arteries. The dissection and mobilization of the ureters enable the removal of the upper paracervical tissue without disrupting the uterine arteries, allow for visualization of the descending uterine arteries, and further facilitate nerve-sparing dissection of the lower paracervical tissue (Fig. 23.3). If there is no uptake of indocyanine green, a full pelvic lymphadenectomy has to be performed at the respective pelvic sidewall. Local treatment protocol and the histology and size of the cervical cancer decide whether removal of the sentinel nodes only should be considered safe or if a full lymphadenectomy is always performed.

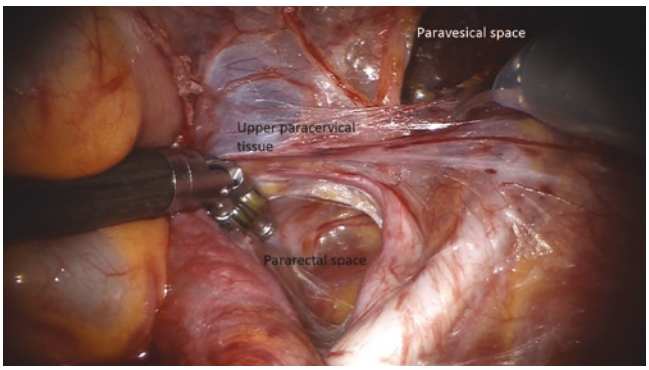

Fig. 23.1 The upper paracervical tissue is kept intact by opening the avascular paravesical and pararectal spaces. Lymphatic vessels and a sentinel lymph node appear *green* with the use of the near-infrared fluorescent technique and indocyanine green injected into the cervix

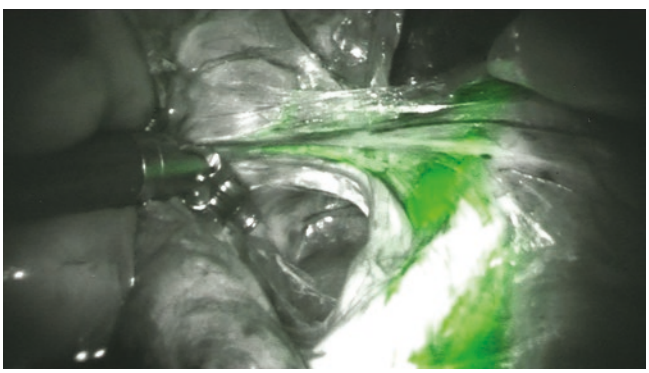

Fig. 23.2 The upper paracervical tissue is kept intact by opening the avascular paravesical and pararectal spaces. Lymphatic vessels and a sentinel lymph node appear *green* with the use of the near-infrared fluorescent technique and indocyanine green injected into the cervix

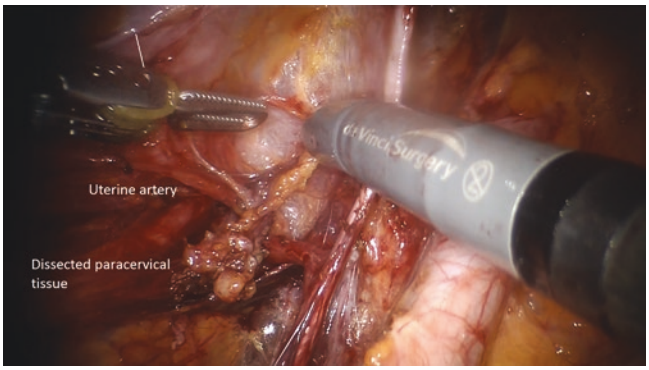

Fig. 23.3 The upper paracervical tissue is removed separately sparing the uterine artery

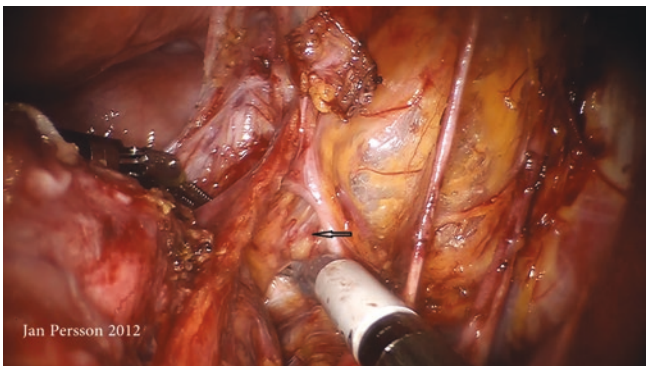

Fig. 23.5 The Okabayashi space is opened to separate the medial fibrous and lateral nervous parts of the sacrouterine ligament. *Black arrow* shows the hypogastric nerve fibers

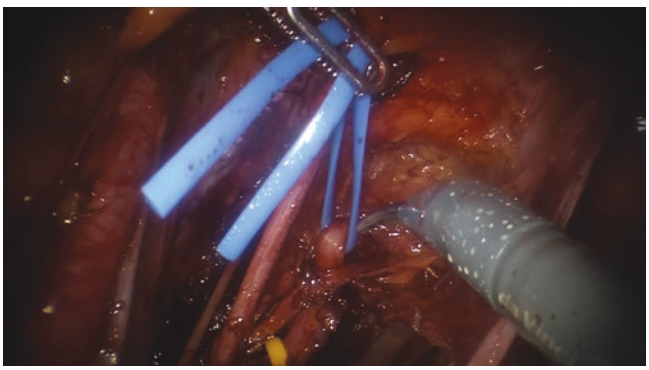

Fig. 23.4 Vessel loop placed around the ureter distal of the uterine artery

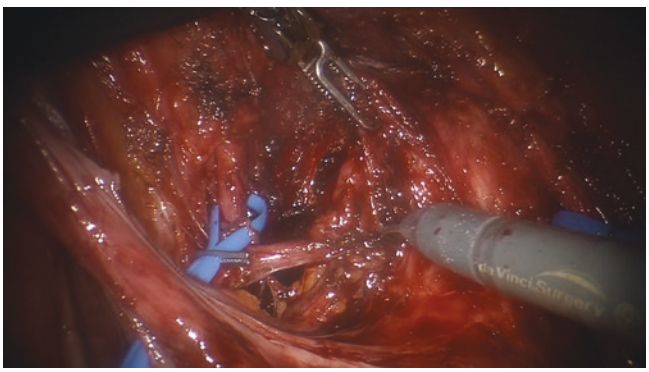

Fig. 23.6 Dissection of lower paracervical tissue (*left side*)

Radical Trachelectomy

Awaiting the frozen section, the trachelectomy is performed. A vessel loop is placed around the ureter distal of the uterine artery to facilitate later dissection of the lower paracervical tissue and bladder pillar (Fig. 23.4). The posterior dissection starts with further development of the pararectal space to identify the hypogastric nerves. The medial broad ligament is then opened, and by developing the Okabayashi space, the lateral nervous part of the sacrouterine ligament is separated from the medial fibrous part (Fig. 23.5). A second vessel loop is then placed around both the ureter and the nervous part of the ligament for retraction and identification of the hypogastric nerve fibers during further dissection to facilitate a nerve-sparing procedure. The rectovaginal space is opened to facilitate the division of the fibrous parts of the sacrouterine ligaments at the desired level. Then the anterior peritoneum is opened (leaving the round ligaments intact), and a strict midline dissection of the bladder is performed to separate the bladder pillars for later dissection. Before the final lateral dissection, and for control of bleeding, the descending uterine arteries are identified, ligated with two

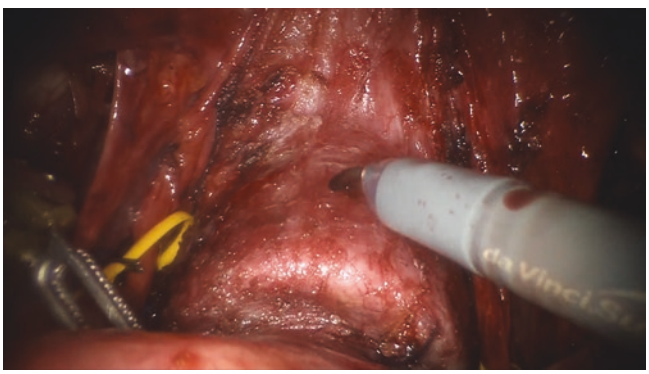

Fig. 23.7 The vaginal tube helps in identification of the vaginal fornices and estimation of an appropriate length of the vagina

sutures, and transected between the sutures. The further dissection of the lower paracervical tissue and the bladder pillars is facilitated by the placed vessel loops (Fig. 23.6). Distal dissection of the vagina to a level approximately 1.5 cm caudal to the desired length of the vaginal cuff is recommended to permit adequate mobilization of the vaginal tissue for sufficient reattachment to the cervix (Fig. 23.7). The vagina is divided at the desired level prior

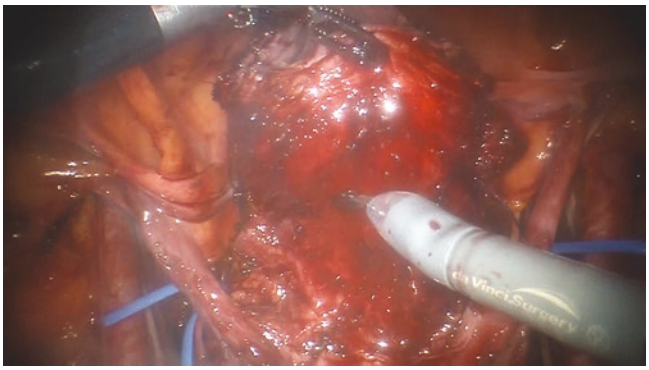

Fig. 23.8 The level of cervical transection is deduced with the help of the uterine contour after the vagina is opened

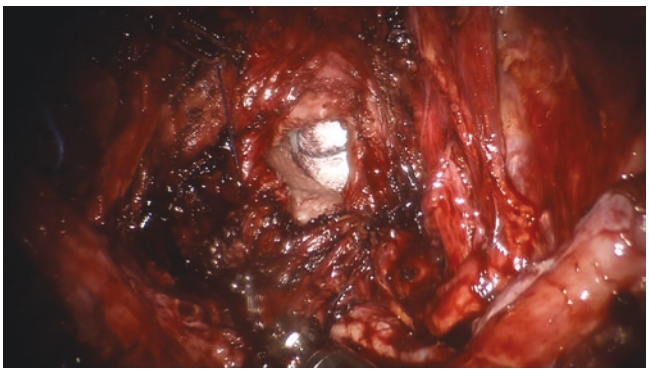

Fig. 23.9 The vagina is sutured to the remaining cervix starting at the lateral corners to ensure an even distribution of vagina anteriorly and posteriorly

to transecting the cervix. This enables a simultaneous abdominal and vaginal visualization thereby aiding the division of the cervix at the appropriate level. With the preoperative vaginal ultrasonography and tumor localization in mind, a careful planning of the cervical transection level is important. The outer contour of the uterus as well as the level of the main uterine artery branches is helpful when defining the level of the proximal uterine isthmus (Fig. 23.8). The whole trachelectomy specimen is sent for a frozen section to ensure negative margins. It is recommended to clearly mark the proximal and distal edges of the specimen, i.e., with ink, to simplify its orientation for the pathologist.

Reconstruction of the Vagina and Placement of Cerclage

The vagina is reattached to the remaining cervix with resorbable mattress sutures to cover most of the cut cervix but still leaving the new external orifice free. The first sutures should be placed at the lateral corners of the vagina to ensure an even distribution of the larger vaginal circumference to the smaller cervix (Fig. 23.9). A non-resorbable monofilament cerclage (i.e, 0-Prolene) is placed at the level of the inner os. The cerclage is placed medial of the uterine arteries. The tension of the cerclage suture is decided visually with the aid of a posterior sliding locking knot gradually tightened to achieve a slight induration of the tissue (Fig. 23.10). No intracervical device is necessary to secure patency of the cervical canal. A final check of the readapted uterus should be done.

Pelvic Lymphadenectomy

The remaining lymphadenectomy is performed while awaiting frozen section results of the trachelectomy specimen. The presacral and common iliac nodes are removed bilaterally via the previously opened presacral space while taking care to spare the hypogastric nerve. The nerve is easily identified at the level of the aortic bifurcation as well as medial to the internal iliac artery. Elevating the sigmoid using the fourth robotic arm facilitates removal of the left common iliac nodes. Tilting the right IP-ligament and the peritoneum accommodates the removal of the right common iliac nodes while visualizing the ureter and the genitofemoral nerve to avoid injury. The obturator nodes can be accessed medially or by dissection lateral to the external iliac artery and vein.

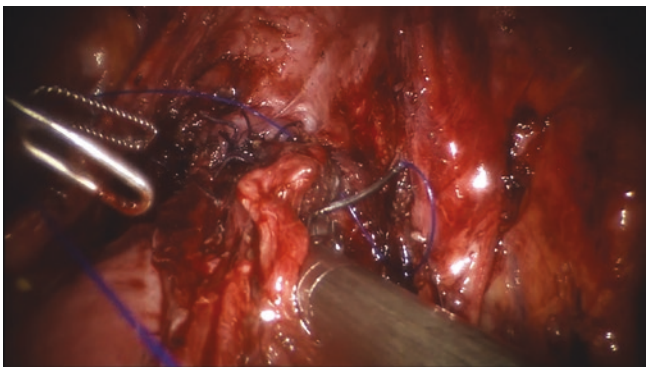

Fig. 23.10 A permanent monofilament suture is placed medial of the vessels at the level of the upper uterine isthmus

Metastatic Disease or Insufficient Margins

In case of metastatic nodes found at the frozen section, the procedure should be aborted in favor of a radical hysterectomy, the lymphadenectomy should be expanded to include the lower para-aortic area, and ooforopexia with or without preservation of ovarian tissue should be performed.

If the proximal margins are insufficient, the cervical length may, in selected cases, be sufficient to allow for removal of an additional part. If the margins are tumor involved, a conversion to a radical hysterectomy is recommended, simply by releasing the vaginal/cervical sutures, coagulating the uterine arteries, transecting the round ligaments, and dividing the ovarian ligaments. The fallopian tubes should be removed.

Postoperative Care and Follow-Up

Postoperative Symptoms and Complications

The overall rate of intraoperative and postoperative complications is low [11]. Morbidity is mostly due to the lymphadenectomy, i.e., distal lymphedema or lymphocytes. Early onset of moderate abdominal swelling or a proximal lymphedema is usually self-limiting [34–39].

Urinary retention following removal of an indwelling catheter post-surgery is rare, but a post-void residual measurement should be performed. Aberrant vaginal bleedings in particular the first 6–12 months due to exteriorization of intracervical mucosa are common. In addition, cervical stenosis and rejection/exteriorization of the cervical cerclage have been described postoperatively. A cervical stenosis may be an impediment to the retrieval of intracervical cells for a Pap smear, may cause problems when assisted reproductive measures are necessary, and in severe cases might cause hematometra or secondary endometriosis. In women with a permanent cerclage, late first- or second-trimester miscarriages might necessitate removal or cutting of the cerclage or a hysterotomy to enable complete evacuation of the fetus and placenta. Alternatively, cutting of the cerclage can be performed via a posterior culdotomy or laparoscopy, and the cerclage may later be replaced laparoscopically. In general, the use of an IUD as a form of contraceptive should be avoided due to a potentially increased risk for ascending infections. Cerclage rejection seems to be associated with multifilament sutures and a too distal placement [11]. One study indicates that robotic trachelectomy allows for cerclage placement closer to the inner cervical os when compared with vaginal trachelectomy [28]. A more optimal cerclage position might theoretically reduce the rate of erosion and the rate of preterm delivery [29].

Postoperative Follow-Up

A meticulous post-surgery follow-up including maintaining a high level of suspicion for recurrent disease is important. Follow-up protocols usually advocate clinical controls every 3 or 4 months in the first 2 years, then at 6-month intervals until 5 years post-surgery followed by individualized controls; returning to the screening program is usually sufficient. The lack of intracervical cells might lead to an inadequate Pap smear, and the presence of endometrial cells might make the interpretation more difficult for the cytologist. A HPV test should be performed. Information regarding a previous trachelectomy should be included in the request form. A colposcopy and guided biopsies or cervical curettage should be performed in case of aberrant bleeding and/or a pathological Pap smear. A vaginal ultrasonography should be performed to evaluate the length of the remaining cervix and the placement of the cerclage and to rule out retention of menstrual blood in the uterus as a sign of a cervical stenosis. MRI or PET-CT investigations should be performed if clinically indicated.

Some patients request a post-trachelectomy hysterectomy after finalizing childbirth. This may be performed after proper counseling but will further shorten the vagina. As a post-trachelectomy hysterectomy may be complex, the operation should be performed by an experienced gynecological oncologist and include a thorough inspection of the whole pelvis.

Fertility Following Trachelectomy

No commonly used criteria for timing of pregnancy after surgery exist. It is advisable to await a negative Pap smear at the first follow-up 3 months post-surgery. It is unclear whether antibiotic prophylaxis during pregnancy reduces the risk of prematurity. Oral metronidazole from gestational week 16 to 22, abstaining from sexual intercourse, and in case of a strenuous work situation sick leave from week 22 + 0 throughout the pregnancy are suggested measures that might decrease the risk of prematurity [11]. All patients should have a planned cesarean delivery. In case of premature contractions or premature rupture of membranes, an immediate evaluation is recommended.

Conclusion

A robotic fertility-sparing trachelectomy is considered as safe as a radical hysterectomy in women with early-stage cervical cancer. The importance of a meticulous preoperative evaluation, surgical expertise, and a meticulous reproducible surgical technique is important to optimize patient outcome.

References

1. Dargent D, Burn JL, Roy M, Remi I. Pregnancies following radical trachelectomy for invasive cervical cancer. Gynecol Oncol. 1994;52:105. (Abstract).
2. Ebisawa K, Takano M, Fukuda M, Fujiwara K, Hada T, Ota Y, et al. Obstetric outcomes of patients undergoing total laparoscopic radi-

cal trachelectomy for early stage cervical cancer. Gynecol Oncol. 2013;131:83–6.
3. Kim JH, Park JY, Kim DY, Kim YM, Kim YT, Nam JH. Fertility-sparing laparoscopic radical trachelectomy for young women with early stage cervical cancer. BJOG. 2010;117:340–7.
4. Pareja R, Rendon GJ, Sanz-Lomana CM, Monzon O, Ramirez PT. Surgical, oncological, and obstetrical outcomes after abdominal radical trachelectomy—a systematic literature review. Gynecol Oncol. 2013;131:77–82.
5. Park JY, Joo WD, Chang SJ, Kim DY, Kim JH, Kim YM, et al. Long-term outcomes after fertility-sparing laparoscopic radical trachelectomy in young women with early-stage cervical cancer: an Asan Gynecologic Cancer Group (AGCG) study. J Surg Oncol. 2014;110:252–7.
6. Park JY, Kim DY, Suh DS, Kim JH, Kim YM, Kim YT, et al. Reproductive outcomes after laparoscopic radical trachelectomy for early-stage cervical cancer. J Gynecol Oncol. 2014;25:9–13.
7. van Gent MD, van den Haak LW, Gaarenstroom KN, Peters AA, van Poelgeest MI, Trimbos JB, et al. Nerve-sparing radical abdominal trachelectomy versus nerve-sparing radical hysterectomy in early-stage (FIGO IA2-IB) cervical cancer: a comparative study on feasibility and outcome. Int J Gynecol Cancer. 2014;24:735–43.
8. Abu-Rustum NR, Sonoda Y, Black D, Levine DA, Chi DS, Barakat RR. Fertility-sparing radical abdominal trachelectomy for cervical carcinoma: technique and review of the literature. Gynecol Oncol. 2006;103:807–13.
9. Ungár L, Smith JR, Pálfalvi L, Del Priore G. Abdominal radical trachelectomy during pregnancy to preserve pregnancy and fertility. Obstet Gynecol. 2006;108:811–4.
10. Martin A, Torrent A. Laparoscopic nerve-sparing radical trachelectomy: surgical technique and outcome. J Minim Invasive Gynecol. 2010;17:37–41.
11. Johansen G, Lönnerfors C, Falconer H, Persson J. Reproductive and oncologic outcome following robotic-assisted laparoscopic radical trachelectomy for early stage cervical cancer. Gynecol Oncol. 2016;141(1):160–5.
12. Rob L, Skapa P, Robova H. Fertility-sparing surgery in patients with cervical cancer. Lancet Oncol. 2011;12:192–200.
13. Gizzo S, Ancona E, Saccardi C, Patrelli TS, Berretta R, Anis O, et al. Radical trachelectomy: the first step of fertility preservation in young women with cervical cancer (review). Oncol Rep. 2013;30:2545–54.
14. Plante M, Gregoire J, Renaud MC, Roy M. The vaginal radical trachelectomy: an update of a series of 125 cases and 106 pregnancies. Gynecol Oncol. 2011;121:290–7.
15. Martinez A, Poilblanc M, Ferron G, De Cuypere M, Jouve E, Querleu D. Fertility-preserving surgical procedures, techniques. Best Pract Res Clin Obstet Gynaecol. 2012;26:407–24.
16. Persson J, Kannisto P, Bossmar T. Robot-assisted abdominal laparoscopic radical trachelectomy. Gynecol Oncol. 2008;111:564–7.
17. Shepherd JH, Milliken DA. Conservative surgery for carcinoma of the cervix. Clin Oncol (R Coll Radiol). 2008;20:395–400.
18. Lanowska M, Mangler M, Spek A, Grittner U, Hasenbein K, Chiantera V, et al. Radical vaginal trachelectomy (RVT) combined with laparoscopic lymphadenectomy: prospective study of 225 patients with early-stage cervical cancer. Int J Gynecol Cancer. 2011;21:1458–64.
19. Gien LT, Covens A. Fertility-sparing options for early stage cervical cancer. Gynecol Oncol. 2010;117(2):350–7.
20. Xu L, Sun FQ, Wang ZH. Radical trachelectomy versus radical hysterectomy for the treatment of early cervical cancer: a systematic review. Acta Obstet Gynecol Scand. 2011;90(11):1200–9.
21. Schneider A, Erdemoglu E, Chiantera V, Reed N, Morice P, Rodolakis A, et al. Clinical recommendation radical trachelectomy for fertility preservation in patients with early-stage cervical cancer. Int J Gynecol Cancer. 2012;22:659–66.
22. Ramirez PT, Schmeler KM, Soliman PT, Frumovitz M. Fertility preservation in patients with early cervical cancer: radical trachelectomy. Gynecol Oncol. 2008;110:25–8.
23. Yan H, Liu Z, Fu X, Li Y, Che H, Mo R, Song L. Long-term outcomes of radial vaginal trachelectomy and laparoscopic pelvic lymphadenectomy after neoadjuvant chemotherapy for the IB1 cervical cancer: a series of 60 cases. Int J Surg. 2016;29:38–42.
24. Dargent D, Martin X, Sacchetoni A, Mathevet P. Laparoscopic vaginal radical trachelectomy: a treatment to preserve the fertility of cervical carcinoma patients. Cancer. 2000;88:1877–82.
25. Jolley JA, Battista L, Wing DA. Management of pregnancy after radical trachelectomy: case reports and systematic review of the literature. Am J Perinatol. 2007;24:531–9.
26. Kim CH, Abu-Rustum NR, Chi DS, Gardner GJ, Leitao MM Jr, Carter J, Barakat RR, Sonoda Y. Reproductive outcomes of patients undergoing radical trachelectomy for early-stage cervical cancer. Gynecol Oncol. 2012;125(3):585–8.
27. Boss EA, van Golde RJ, Beerendonk CC, Massuger LF. Pregnancy after radical trachelectomy: a real option? Gynecol Oncol. 2005;99:152–6.
28. Persson J, Imboden S, Reynisson P, Andersson B, Borgfeldt C, Bossmar T. Reproducibility and accuracy of robot-assisted laparoscopic fertility sparing radical trachelectomy. Gynecol Oncol. 2012;127(3):484–8. Epub 2012 Aug 28.
29. Nick AM, Frumovitz MM, Soliman PT, Schmeler KM, Ramirez PT. Fertility sparing surgery for treatment of early-stage cervical cancer: open vs. robotic radical trachelectomy. Gynecol Oncol. 2012;124:276–80.
30. Al-Niaimi AN, Einstein MH, Perry L, Hartenbach EM, Kushner DM. Uterine artery sparing robotic radical trachelectomy (AS-RRT) for early cancer of the cervix. Int J Gynaecol Obstet. 2011;112:76–80.
31. Ramirez PT, Schmeler KM, Malpica A, Soliman PT. Safety and feasibility of robotic radical trachelectomy in patients with early-stage cervical cancer. Gynecol Oncol. 2010;116:512–5.
32. Vieira MA, Rendon GJ, Munsell M, Echeverri L, Frumovitz M, Schmeler KM, et al. Radical trachelectomy in early-stage cervical cancer: a comparison of laparotomy and minimally invasive surgery. Gynecol Oncol. 2015;138:585–9.
33. Carter BJ. Women's experiences of lymphedema. Oncol Nurs Forum. 1997;24:875–82.
34. Zikan M, Fischerova D, Pikakova I, Slama J, Weinberger V, Dusek L, et al. A prospective study examining the incidence of asymptomatic and symptomatic lymphoceles following lymphadenectomy in patients with gynecological cancer. Gynecol Oncol. 2015;137:291–8.
35. Abu-Rustum NR, Barakat RR. Observation on the role of circumflex iliac node resection and etiology of lower extremity lymphedema following pelvic lymphadenectomy for gynecologic malignancy. Gynecol Oncol. 2007;106:4–5.
36. Biglia N, Librino A, Ottino MC, Panuccio E, Daniele A, Chahin A. Lower limb lymphedema and neurological complications after lymphadenectomy for gynecological cancer. Int J Gynecol Cancer. 2015;25:521–5.
37. Hareyama H, Ito K, Hada K, Uchida A, Hayakashi Y, Hirayama E, et al. Reduction/prevention of lower extremity lymphedema after pelvic and para-aortic lymphadenectomy for patients with gynecologic malignancies. Ann Surg Oncol. 2012;19:268–73.
38. Biglia N, Zanfagnin V, Daniele A, Robba E, Bounous V. Lower body lymphedema in patients with gynecologic cancer. Anticancer Res. 2017;37:4005–15.
39. Mendivil AA, Rettenmaier MA, Abaid LN, Brown JV III, Micha JP, Lopez KL, et al. Lower-extremity lymphedema following management for endometrial and cervical cancer. Surg Oncol. 2016;25:200–4.

Research and Evidence-Based Robotic Practice

24

Rasiah Bharathan and Esther Moss

Introduction

The journey from the introduction of new technology to its establishment in everyday clinical practice can be a long and tortuous one. In the case of robotics, there are other factors that have resulted in additional barriers to its implication, in particular the financial cost and surgeon training. The increasing demand for evidence-based healthcare creates further challenges in embedding new technology, particularly into surgical practice, due to the inherent difficulties in conducting clinical trials. This can therefore result in a 'chicken and egg' scenario with institutions reluctant to buy into robotics without proven benefit; however, unless centres are performing robotic surgery and are recruiting to trials, then it will not be possible to gather the required evidence to support its use.

Potential Pitfalls of Clinical Research in Robotics

The gold standard for research evidence is the randomised, controlled trial (level 1). Case-control studies or cohort studies command a lower level of influence (level 2) and case series even lower (level 3) (Table 24.1) [1]. The rationale for grading evidence is so that weight can be given to studies that will contain the least impact from bias and reflect the true effect from the new technology. Conducting multicentre surgical trials is fraught with difficulty, and with robotics the challenges can be even greater.

Selection Bias

Selection bias with regard to the patient population is a particular issue in nonrandomised studies [2]. Surgically complex patients, such as those with high body mass index or previous abdominopelvic surgery, may be selected to have robotic surgery in preference to open/laparoscopic surgery. This has resulted in many studies, comparing open or laparoscopy with robotic surgery, where the baseline characteristics of the groups differ. This undermines the assessment of the intervention.

Performance Bias

Performance bias is the other criticism that is often level against surgical trials [3]. This could either be due to surgical training, with many comparative studies including cases within the learning curve for robotics, raising the issue of bias when compared against other more established techniques, such as laparoscopy. Operating time, length of hospital stay and number of outpatient clinic visits may all be influenced since often it will not be just the surgeon that is inexperienced in this new technology but also the surgical and nursing teams. Performance bias with regard to the surgeon is another major issue in studies. In many centres,

Table 24.1 Classification of research evidence

Level	Evidence
1	Meta-analyses, systematic reviews of randomised controlled trials Randomised controlled trial
2	Case-control studies Cohort studies
3	Case series, case reports
4	Expert opinion

Adapted from 'Development of RCOG green-top guidelines'. Royal College of Obstetricians and Gynaecologists, 2015 (RCOG) [1]

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robotics is only conducted by a proportion of surgeons, and therefore comparing their outcomes directly with that of their peers/colleagues who do not perform robotics or do not have the same case mix can lead to differences that could be attributed to the surgeon and not the surgical platform.

Chronology Bias

Many of the reports in the literature compare a robotic case series with a historical cohort of open/laparoscopic cases. This can lead to chronology bias since clinical practice in continually changing [3].

Confounding

Confounding is another bias that can arise when conducting randomised controlled trials. Many robotic surgeons/centres do not perform a similar volume of cases open/laparoscopically and therefore in theory may not perform surgery to the same standard across all three modalities (open/robotic/laparoscopic). An alternative study design would be to have surgeons/centres only recruiting to their primary surgical route with randomisation by centre rather than by patient. Although this would result in patients having surgeons who are experts in their chosen modality, it would give rise to additional bias due to comparison of the processes within the different centres.

External Validity of Robotic Trials

External validity is the application of significant associations identified in studies to the general healthcare setting [4]. It is the 'next step' following clinical trials, and its importance is often not focused upon, although it is particularly relevant when looking at the impact of trials in robotics.

In particular, one of the main criticisms of surgical studies is that their populations do not reflect the general population, and therefore their reported benefits and outcomes cannot be extrapolated to different settings [5]. Patients who require surgery by their very nature will have a clinical indication, whether a malignancy or benign disease such as endometriosis. With increasingly elderly, obese and co-morbid populations across all aspects of healthcare, the clinical benefits in such 'real-world' populations are unlikely to ever reach that of a selected trial population and must be borne in mind when setting up a robotics programme.

Another issue with external validity is concerning health economics research. Many studies have focused upon or included analysis on the financial aspects of introducing robotic technology, often comparing costs with open and straight-stick laparoscopy. Although studies of this nature are important in the justification and delivery of robotic surgery, the diverse healthcare structures in different countries, between state/private providers and variations in remuneration of costs, mean that extrapolating from one system to another is either not possible or very inaccurate.

Research in Robotics Training

Many studies have been conducted investigating training in robotic surgery and comparing it with straight-stick laparoscopy. It has been repeatedly shown that the learning curve for robotics is shorter and steeper than for laparoscopy with a smaller number of cases required in order to acquire proficiency; however a significantly greater number of cases are needed to become an expert [6]. A confounding factor in many of the studies examining the learning curve is that the subjects were experienced surgeons, often with extensive laparoscopic experience, and therefore it could be argued that the training requirement of this population is not the same as surgeons in training. A truer comparison of the difference between acquiring robotic and laparoscopic skills is therefore with trainee surgeons who have no previous experience of either modality. The focus of many of the studies therefore involves trainees being randomised to different training interventions and their progress monitored over time, with the time to perform tasks and the number of errors calculated. This is discussed at greater length in Chap. 3. Due to difficulty in performing tasks objectively, simulation has been used in a large proportion of the training studies, as well as enabling a larger number of subjects to be included. Although this does bring standardisation to the complexity of the tasks, it does mean that the real-world applicability of the skills has to be questioned. Despite this, simulator training has been consistently shown in randomised trials to improve surgeon performance [7].

Research in Surgical Ergonomics

There has been much interest in ergonomics of robotic surgery since it is perceived that the surgical position creates significantly less pressure on the surgeon, and therefore may result in a lower rate of Work-related Musculoskeletal Symptoms (WMS). The focus of many of the studies has been to compare muscle activity and range of movement with laparoscopy. Objective analysis of surgeon movements using standard-simulated tasks has shown a difference between robotic and laparoscopic surgery with greater movements required laparoscopically, especially in simulated obesity [8], a factor commonly reported to be associated with WMS in surgeons. However, as previously mentioned, there is diffi-

culty in objectively measuring such parameters in a clinical setting, and when added to the differences between individual surgeons, in particular height and arm span, it makes real-world validation of findings fraught with difficulty.

Many studies have used non-validated questionnaires to determine the self-reported levels of pain and injury [9–11]. Visual analog scales [12] and the Borg scale [13], which rates perceived exertion [14], have been used; however, they are still subjective in nature. Various techniques have been trialled with an attempt to capture surgeon movements including video recording [12, 13, 15, 16], reflective markers and motion capture [17], force plates [18] and electromyography (EMG) [19]. More sophisticated techniques have been developed, for example, the tetherless virtual instrument ergonomics workstation [20] and a 9-axis inertial measurement unit [21], with the aim of capturing multimodal feedback on surgeon muscular activity and even stress levels, but these are complex to analyse, and the data they produce can be difficult to interpret.

Research in the Economics of Robotic Surgery

The global healthcare expenditure is increasing with population growth and older patient cohort, and the technological developments enable ever more complex interventions. In managing healthcare budgets, it is vital that all stakeholders have a shared goal. This is important in achieving a value-based healthcare system [22]. The financial cost is often held up as the main barrier for the permeation of surgical robotic technology, especially within state-funded healthcare systems or lower resource countries. Much work has been performed in an attempt to address this aspect of robotic surgery and discussed at length in Chap. 2.

In the context of robotic surgery, the capital and maintenance cost of the technology is expected to change rapidly in the short to medium term for a variety of reasons. These include the expiration of the patents held by Intuitive Surgical, miniaturisations of instruments, technological competition, increasing presence of virtual reality in our society and the 'cooperate-like' organisation of health service.

Cost-Effectiveness Studies

It is widely recognised that when clinicians are involved in healthcare leadership, effective changes can be delivered more efficiently; therefore, it is important that surgeons have a good understanding of health economics, particularly in relation to high-value interventions. The methods for conducting and reporting cost-effectiveness analysis in healthcare have been evolving with the most recent iteration being CHEERS guidelines [23]. The various stakeholders, such as clinicians, policymakers, commissioners and government officials, will be interested in divergent data; however, a holistic cost-effectiveness analysis is important in providing a consistent approach to procurement.

In terms of systematic comparisons, even the most rigorous methodology cannot account for the ever-changing dynamics around the world in terms of the economic status, technological evolutions and cultural/behavioural changes. The balance of economic arguments will change rapidly as the conditions evolve. For instance, the general economic principles, which normally guide resource allocation in a market place, rely on users being adequately informed about the market choices [24]. In healthcare, the epicentre of information usually resides with the medical practitioner. Therefore, health economic evaluation which uses transparent clinical information and patient-reported outcomes will add an extra dimension. In this regard, quality of life and quality-adjusted life years have become the norm in economic evaluations. There are significant ethical and moral issues in constructing economic evaluations in healthcare, but these are beyond the remit of this chapter.

Table 24.2 Description of approaches in health economic evaluations [24]

Term	Definition
Cost analysis	Value of the resources required to deliver the intervention and the resource consequences
Benefit analysis	Defining the changes in the clinical (QOL) or economic (QALY) parameters
Incremental cost-effectiveness ratio (ICER)	A ratio of differences in mean expected costs to differences in mean expected outcomes between alternative interventions—provides an index of the cost to yield a unit of benefit
Incremental cost-utility ratio (ICUR)	A ratio of differences in mean expected costs to differences in mean expected outcomes between alternative interventions—outcome is specifically defined as QALY
Cost-effectiveness analysis (CEA)	An analysis to compare both costs and outcomes—outcomes are the natural metrics employed in clinical studies
Cost-utility analysis (CUA)	A type of CEA—outcome is expressed as QALY
Cost benefit analysis (CBA)	An analysis to compare resource requirement and outcomes, where both are expressed in monetary terms—application of CBA is limited by ethical issues
Cost-consequence analysis (CCA)	A form of CBA, but the costs and the benefits are not factored within the same analysis. The costs are reported in monetary terms, and the benefits are reported in the natural metrics of clinical study
Cost-minimisation analysis (CMA)	Cost analysis of alternative interventions, all of which have the same clinical benefits (e.g. two drugs which have the same clinical efficacy)

QOL quality of life, *QALY* quality-adjusted life years

'Health economics' per se is a broad discipline encompassing economic, societal and healthcare domains. Within this 'economic evaluation' is the most relevant component for the frontline professional. There are several techniques for analysing economic evaluations, and these are defined in Table 24.2.

We provide a systematic narrative review of the current evidence regarding cost-effectiveness; this is not intended as an exhaustive review of the literature. Initially, the methodology of the studies is appraised, and this is followed by a discussion of the outcomes. We summarise 22 studies which have addressed health economic evaluations in gynaecologic robotic surgery which compared open surgery (LPT), standard laparoscopic surgery (LPS) and robotic surgery (RBT).

Fifteen of these studies were published within the last 5 years. Thirteen economic evaluations were from the USA and the remaining were from Europe. Two studies were prospective [25, 26], three were randomised controlled trials [27–29], one was case controlled [30] and another was a statistical economic evaluation modelling based on published literature [31]; all others were retrospective studies. The studies compared robotic surgery with laparoscopic surgery only [27, 28, 30, 32–35]; with laparoscopic and laparotomic surgery [26, 31, 36–40]; with laparoscopic, laparotomic and vaginal surgery [41, 42]; with laparotomy only [43, 44]; a comparison of single port with multi-port robotic surgery [25]; with total laparoscopic hysterectomy (TLH) and laparoscopically assisted vaginal hysterectomy (LAVH) [45]; and with laparoscopy and vaginal hysterectomy [29], and one study examined TLH, LAVH and vaginal hysterectomy with robotic hysterectomy [46].

The publications appraised either benign and malignant conditions [32, 35, 45] or benign conditions only [25, 26, 30, 42, 46], whilst the remaining studies assessed treatment of malignant conditions only. The sources of clinical information were national databases in three studies [32, 39, 42]; published literature [31], multicentre [27, 34, 45] and the remaining studies were single centre studies.

In order to capture a more complete picture within the health economic evaluation, the time horizon of the study is important. Many of the studies only examined perioperative outcomes up to 30 days, whilst others had a time horizon of 3 months [26], 4 months [43], 6 months [27, 41], 12 months [25, 28] or 24 months [34, 37]. Some of the studies performed a cost-effectiveness analysis, whilst the remaining studies conducted a cost analysis [25, 29, 30, 33, 35, 37, 40, 41, 45, 46]; one study conducted a cost-utility analysis [27]. With regard to the perspective of the studies, two studies provided a societal and a hospital perspective [31, 40], further two studies provided a societal perspective only [27, 36], and all other studies provided a hospital perspective.

The source of data was single centre prospective observational studies in most cases, three studies used national healthcare databases [32, 39, 42], and two studies used multisource data [31, 34]. In all studies, the source of clinical data was the same jurisdiction as the cost data, except one publication which utilised a health economics model with local costing [31]. Similarly, except for the aforementioned study, all others used resource data from the same jurisdiction as where the unit cost was derived. No studies included a productivity effect analysis. The approach to economic evaluation was justified in all the papers.

In order for the findings to be generalisable, it is recommended that the resource use and costings are reported separately; this was clear in many of the studies [26, 31, 32, 34–36, 38, 39, 41] and unclear in two studies [25, 44], whilst others did not meet this recommendation adequately. Two studies utilised clinical decision tree modelling which is the recommended approach to studies evaluating short time horizon outcomes [31, 40]. Three studies performed sensitivity analysis [31, 34, 43]. None of the studies employed the 'discounting' component of the economic evaluation.

Robotic Hysterectomy for Endometrial Cancer

Three papers examined the cost of hysterectomy for endometrial cancer from a societal perspective [31, 36, 40]. All three compared open, laparoscopic and robotic approaches. Two of these studies used decision tree modelling and statistical simulation to derive costs. Shah et al. modified the decision tree developed by Barnett and colleagues [31, 40]. It is worth noting that these studies used data either from the literature for their cost simulation [31] or their institutional experience [36, 40]. The first study to report on costs of RBT surgery for endometrial cancer and factor the time to return to normal activity was published in 2008 [36]. Compared to LPT (52 days) and LPS (31.6 days), women returned to work significantly earlier following RBT surgery (24.1 days). This study reported on single surgeon experience. In this study, LPT was the most expensive, and LPS was the least expensive; the RBT approach was not statistically more expensive than LPS ($7569.80 versus $8212.00). Barnett et al., from a societal perspective analysis, found LPS to be least expensive and LPT to be most expensive; but from a hospital perspective, whether capital expenditure of robot is included or not, RBT becomes the most expensive, whilst LPS remained the most cost-effective [31]. These early publications could not exclude the learning curve effects, which have a bearing on theatre time utilisation and complications.

Coronado et al. report comparable costs between RBT and LPS/LPT [37]. In a large retrospective study spanning 8 years, the cost of RBT procedure was $5048.3, whilst LPT costs $4680.7 and LPS costs $4594.3. These costings were not statistically significant, and this could be related to the reduced hospital stay following minimal access surgery. In

this report, the LPS procedures took significantly longer to perform than RBT surgery. In a study focusing on morbidly obese patients with endometrial cancer, the Memorial Sloan Kettering group reported their experience from 1993 to 2012 [41]. The group introduced RBT surgery in 2007, and CEA was performed for the period 2009–2012. The RBT rate amongst this cohort of patients increased from less than 10% in 2008 to almost 70% by 2012. During the same period, the LPT rate was the reverse of RBT rates. The CEA revealed that both LPS and RBT were significantly less costly than LPT. The amortised cost of RBT was non-significantly higher than LPS and that the non-amortised costs revealed LPS to be marginally more expensive [41]. In a not dissimilar study from the United Kingdom, Ind et al. appraised the cost implications of introducing RBT for the management of endometrial cancer [38]. They reported that following the introduction of RBT surgery, the minimal access rates for hysterectomy improved from 40 to 74%. This shift was achieved by displacing the LPT cases towards RBT surgery, whilst the LPS rate remained the same. This change in operative profile was accompanied by statistically significant cost savings for the endometrial cancer cohort of patients, whether cost analysis computed amortised or non-amortised values [38].

Martino et al. reported exclusively on the cost of pain management in patients who had undergone RBT or LPS for endometrial cancer; RBT cohort reported less pain and incurred smaller costs on analgesic intervention [33]. The most rigorous economic evaluation of RBT in managing patients with endometrial cancer and complex atypical hyperplasia is from Denmark [43]. However, this study compared RBT with LPT only. The cost drivers included in this study were complications, operative time and hospital stay. Overall, their group reported that RBT was 17% (€1251.46) cheaper than LPT. When the cost of the robot was included, the cost difference was still in favour of RBT by €540.4. In addition, increasing age and type 2 diabetes also increased the cost of intervention.

Robotic Radical Hysterectomy for Cervical Cancer

In a national database study by Pasic et al., RBT radical hysterectomy cost was greater than LPS procedure ($10,065 versus $7635), but if lymphadenectomy is performed as a concomitant procedure, then the cost disparity is less pronounced ($12,367 versus $11,416) [32]. The difficulty in generalising this database study is that learning curves of various individuals and departments cannot be excluded. In a multicentre comparative study reported by Marino et al., the RBT and LPS patient demographics were similar, but the RBT procedure yielded significantly more lymph nodes and took longer to perform [34]. Interestingly 27% of LPS patients and 13% of RBT patients were admitted to intensive care unit; this approached statistical significance with a *P* value of 0.06. The cost of RBT was €7040 versus €5584 for LPS.

Persson's group reported on a comparison of LPT and RBT for radical hysterectomy and pelvic lymphadenectomy [44]. The LPT procedure cost was $12,986, whilst the first 30 cases of RBT cost $18,382; however, subsequent RBT costs were reduced to $12,759 by reducing the duration of the procedure and hospital stay. In a national database review for CEA, Wright et al. compared LPT, LPS and RBT procedures [39]. In this series of 1894 cases, only 3.5% of cases were performed as RBT radical hysterectomies, and 85% of cases were by LPT. This report provides the most striking cost analysis data regarding RBT gynaecological cancer procedures; the RBT cost was $10,176, LPS was $11,774 and LPT costs were $9618. This is particularly noteworthy as this study reports on early RBT experience between 2006 and 2010.

Robotic Procedures for Other Conditions

Three studies utilised outcome data from national databases on procedures performed between 2006 and 2010, to inform their cost-effectiveness analysis (CEA) [32, 39, 42]. These studies focused on either hysterectomy for benign conditions [42] or a heterogenous group of procedures [32]; the third study focused on cervical cancer, and this was discussed above [39]. In the study by Wright et al., the total cost of LPS hysterectomy was $6679 compared to $8868 for RBT hysterectomy during the period 2007–2010. Authors analysed the trends in different routes of surgery; a breakdown of CEA by each year was not provided. It is conceivable that with rapid uptake of RBT hysterectomy during the study period from 0.5% of hysterectomies in 2007 to 9.5% of the procedures in 2010, a favourable cost implication is likely to impact on RBT surgery [39]. In an earlier analysis of the same database but restricting procedures to between 2007 and 2008, Pasic et al. revealed that RBT was more expensive than LPS with regard to total laparoscopic hysterectomy ($11,790 versus $8031), subtotal hysterectomy ($11,026 versus $6963) or LAVH ($9609 versus $6666) [32].

The only study to compare the cost of single site RBT and multisite RBT, the single site procedure was cheaper in patients undergoing surgery for benign conditions [25]. There were no significant differences between the groups in terms of theatre time, conversion rate or complications. However, the authors concluded that RBT option is best suited to selected patients because of cost implications. Another study compared RBT single site surgery with LPS surgery for benign and malignant conditions [35]. Even though the patient profile and perioperative performance appeared to be

comparable, the cost of RBT single site surgery was significantly higher than LPS ($6463 versus $8686).

Dayaratna and colleagues performed a retrospective analysis to define the cost savings that may be associated with 'total vaginal hysterectomy' (TVH compared to LAVH, TLH or RBT hysterectomy) [46]. This study revealed that TVH cost was $7903, compared to LAVH ($10,068), TLH ($11,558) and RBT ($13,429). TLH and RBT hysterectomies also took significantly longer to perform.

Two studies performed cost analysis to compare RBT hysterectomy with LPS or with LPS and LPT [26, 30]. In a single surgeon's series, the patient demographics, perioperative performance, duration of procedure and complications were comparable, but the RBT cost was more than twice that of LPS; the cost of LPT was in between the other two modalities (€4695 versus €2846 versus €2052.7) [26]. Similarly Sarlos et al. reported a significantly higher cost for RBT hysterectomy compared to LPS (€4066.84 versus €2150.76) [30]. In both these reports, the learning curve effect had not been excluded. In a multicentre retrospective study of RBT and LPS hysterectomies for both benign and malignant indications, the RBT procedure was more expensive than the LPS hysterectomy ($7956.3 versus $6398.1) [45]. In this study, the RBT took significantly longer to perform, and the weight of the uterus was significantly greater in the RBT group. It is important to note that the analysis was performed after the learning curve.

When examining the cost-effectiveness of robotic intervention, the final verdict will be shaped by the perspective of the analysis. If the reimbursement is fixed, then viability and profitability of the intervention will depend on the impact on hospital length of stay as well as the direct and indirect operative costs. Indeed, reduced operative time and increased case volume are associated with cost savings [47].

Generally, cost analyses are more common than cost-effectiveness studies in evaluating robotic gynaecological surgery. Most studies address the analysis from the hospital perspective. However, no two studies are identical in their methodology. Therefore, a meta-analysis of objective data is virtually impossible. The evidence base to differentiate robotic and standard laparoscopic surgery in terms of economics advantages lacks consistency in terms of methodology. The narrative impression is that current evidence base supports minimally invasive surgery compared to open procedures in terms of cost efficiency. During this past decade of technological transition, robotic surgery certainly appears to cost more than laparoscopic surgery. As the industrial landscape in surgical robotics is expected to change very rapidly over the coming years, the financial viability and business modelling will also change. It is likely that within a few years of publication of this chapter, the economic arguments in relation to robotic surgery will have experienced a paradigm shift. This should enable a wider application of robotics technology in surgery.

Clinical Impact of Robotic Surgery

Randomised surgical trials are challenging to conduct, and as a result the number of level 1 studies (Table 24.1) on robotic surgery is small. Other chapters in this book will address the role of robotic surgery and its advantages in individual procedures; however, in this section, the review will be limited to high-quality evidence, that is, only randomised studies (RCT).

Pelvic Floor Reconstruction Surgery

Two RCTs have examined robotic (RBT) with laparoscopic surgery (LPS) for post-hysterectomy apical prolapse (stage 2–4) [28] or pelvic organ prolapse (stage 2–4) [27]. In a trial containing of 68 patients, Paraiso et al. [28] found that robotic surgery took longer to perform and pain scores were significantly higher after RBT compared to LPS surgery. There was no significant difference in intra- or post-operative complications, although in the RBT arm, there were two cases of small bowel obstruction. Activity and quality of life assessment did not reveal any differences. In the second study, Anger et al. [27] showed no significant difference in perioperative outcomes or quality of life as measured by several validated questionnaires of pelvic floor dysfunction syndrome. At week 1 post surgery, however, the level of activity and pain score adversely associated with RBT surgery [27].

Gynaecological Oncology Surgery

To date only one RCT has been conducted in women undergoing surgery for an endometrial cancer comparing RBT and LPS. In this trial [48] of 99 patients, RBT was compared with laparoscopically assisted vaginal hysterectomy (LAVH). There were no differences in terms of patient profile, lymph node harvest, post-operative complications or pain score. The surgical time with RBT surgery was shorter, and the conversion rate was 0, whereas the LPS conversion rate was 10%. The incidence of intraoperative complications approached significance in favour of RBT surgery [48].

Benign Gynaecological Surgery

Three RCTs and one quasi-randomised trial have examined RBT against LPS with one study grouping vaginal hysterectomy and LPS procedures as 'traditional minimally invasive hysterectomy' [29, 49–51]. A meta-analysis of these four studies by Albright et al. [52] revealed that RBT was associated with significantly less blood loss and length of stay. RBT

procedures took longer to perform, but the complication rates were comparable. In the largest of these studies, vault haematoma and post-operative complications were significantly more likely after LPS than RBT procedures [29]. Sarlos et al. [50] found that there were no differences between the two groups in terms of length of stay, return to activity, work or analgesic use. These findings were confirmed by Paraiso et al. [49] in a smaller RCT, and in addition the quality of life assessed by 36 item Short Form Health Survey failed to reveal any differences. Due to the size of the studies, however, type 2 errors cannot be excluded.

Conclusion

The volume of research on robotic surgery in gynaecology is increasing with time, but as with other surgical platforms, it is difficult to perform studies that can identify the impact of the robotic aspect of surgery alone, due to the many potential confounding factors and sources of bias. As robotic surgery becomes a more established and accepted technique and surgeons/institutions move out of the learning curve phase, evidence will be generated which will allow meaningful comparison with standard laparoscopy or open surgery.

References

1. RCOG Development of RCOG Green-top Guidelines. 2015 https://www.rcog.org.uk/en/guidelines-research-services/guidelines/clinical-governance-advice-1c/, Accessed 19.10.2017.
2. Pannucci CJ, Wilkins EG. Identifying and avoiding bias in research. Plast Reconstr Surg. 2010;126(2):619–25.
3. Paradis C. Bias in surgical research. Ann Surg. 2008;248(2):180–8.
4. Steckler A, McLeroy KR. The importance of external validity. Am J Public Health. 2008;98(1):9–10.
5. Bornhoft G, Maxion-Bergemann S, Wolf U, Kienle GS, Michalsen A, Vollmar HC, Gilbertson S, Matthiessen PF. Checklist for the qualitative evaluation of clinical studies with particular focus on external validity and model validity. BMC Med Res Methodol. 2006;6:56.
6. Lim PC, Kang E, Park DH. Learning curve and surgical outcome for robotic-assisted hysterectomy with lymphadenectomy: case-matched controlled comparison with laparoscopy and laparotomy for treatment of endometrial cancer. J Minim Invasive Gynecol. 2010;17(6):739–48.
7. Stegemann AP, Ahmed K, Syed JR, Rehman S, Ghani K, Autorino R, Sharif M, Rao A, Shi Y, Wilding GE, et al. Fundamental skills of robotic surgery: a multi-institutional randomized controlled trial for validation of a simulation-based curriculum. Urology. 2013;81(4):767–74.
8. Moss EL, Sarhanis P, Kong W, Ind T, Smith M, Davies Q, Zecca M. Surgeon muscular activity during robotics. Society of Robotic Gynaecological Surgery annual conference, Barcelona 2016.
9. Miller K, Benden M, Pickens A, Shipp E, Zheng Q. Ergonomics principles associated with laparoscopic surgeon injury/illness. Hum Factors. 2012;54(6):1087–92.
10. Szeto GP, Ho P, Ting AC, Poon JT, Cheng SW, Tsang RC. Work-related musculoskeletal symptoms in surgeons. J Occup Rehabil. 2009;19(2):175–84.
11. Sutton E, Irvin M, Zeigler C, Lee G, Park A. The ergonomics of women in surgery. Surg Endosc. 2014;28(4):1051–5.
12. van Det MJ, Meijerink WJ, Hoff C, van Veelen MA, Pierie JP. Ergonomic assessment of neck posture in the minimally invasive surgery suite during laparoscopic cholecystectomy. Surg Endosc. 2008;22(11):2421–7.
13. Elhage O, Challacombe B, Shortland A, Dasgupta P. An assessment of the physical impact of complex surgical tasks on surgeon errors and discomfort: a comparison between robot-assisted, laparoscopic and open approaches. BJU Int. 2015;115(2):274–81.
14. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982;14(5):377–81.
15. Rosenblatt PL, McKinney J, Adams SR. Ergonomics in the operating room: protecting the surgeon. J Minim Invasive Gynecol. 2013;20(6):744.
16. Nguyen NT, Ho HS, Smith WD, Philipps C, Lewis C, De Vera RM, Berguer R. An ergonomic evaluation of surgeons' axial skeletal and upper extremity movements during laparoscopic and open surgery. Am J Surg. 2001;182(6):720–4.
17. Jafri M, Brown S, Arnold G, Abboud R, Wang W. Kinematical analysis of the trunk, upper limbs and fingers during minimal access surgery when using an armrest. Ergonomics. 2015;58(11):1868–77.
18. Lee G, Lee T, Dexter D, Godinez C, Meenaghan N, Catania R, Park A. Ergonomic risk associated with assisting in minimally invasive surgery. Surg Endosc. 2009;23(1):182–8.
19. Albayrak A, van Veelen MA, Prins JF, Snijders CJ, de Ridder H, Kazemier G. A newly designed ergonomic body support for surgeons. Surg Endosc. 2007;21(10):1835–40.
20. Smith WD, Berguer R, Rosser JC Jr. Wireless virtual instrument measurement of surgeons' physical and mental workloads for robotic versus manual minimally invasive surgery. Stud Health Technol Inform. 2003;94:318–24.
21. Zhang D, Sessa S, Kong W, Cosentino S, Magistro D, Ishii H, Zecca M, Takanishi A. Development of subliminal persuasion system to improve the upper limb posture in laparoscopic training: a preliminary study. Int J Comput Assist Radiol Surg. 2015;10(11):1863–71.
22. Porter ME. What is value in health care? N Engl J Med. 2010;363(26):2477–81.
23. Husereau D, Drummond M, Petrou S, Carswell C, Moher D, Greenberg D, Augustovski F, Briggs AH, Mauskopf J, Loder E, et al. Consolidated health economic evaluation reporting standards (CHEERS) statement. BJOG. 2013;120(6):765–70.
24. Goeree R, Diaby V. Introduction to health economics and decision-making: is economics relevant for the frontline clinician? Best Pract Res Clin Gastroenterol. 2013;27(6):831–44.
25. Bogliolo S, Ferrero S, Cassani C, Musacchi V, Zanellini F, Dominoni M, Spinillo A, Gardella B. Single-site versus multiport robotic hysterectomy in benign gynecologic diseases: a retrospective evaluation of surgical outcomes and cost analysis. J Minim Invasive Gynecol. 2016;23(4):603–9.
26. Pellegrino A, Damiani GR, Fachechi G, Corso S, Pirovano C, Trio C, Villa M, Turoli D, Youssef A. Cost analysis of minimally invasive hysterectomy vs open approach performed by a single surgeon in an Italian center. J Robot Surg. 2016;11(2):115–21.
27. Anger JT, Mueller ER, Tarnay C, Smith B, Stroupe K, Rosenman A, Brubaker L, Bresee C, Kenton K. Robotic compared with laparoscopic sacrocolpopexy: a randomized controlled trial. Obstet Gynecol. 2014;123(1):5–12.
28. Paraiso MF, Jelovsek JE, Frick A, Chen CC, Barber MD. Laparoscopic compared with robotic sacrocolpopexy for vaginal prolapse: a randomized controlled trial. Obstet Gynecol. 2011;118(5):1005–13.
29. Lonnerfors C, Reynisson P, Persson J. A randomized trial comparing vaginal and laparoscopic hysterectomy vs robot-assisted hysterectomy. J Minim Invasive Gynecol. 2015;22(1):78–86.

30. Sarlos D, Kots L, Stevanovic N, Schaer G. Robotic hysterectomy versus conventional laparoscopic hysterectomy: outcome and cost analyses of a matched case-control study. Eur J Obstet Gynecol Reprod Biol. 2010;150(1):92–6.
31. Barnett JC, Judd JP, Wu JM, Scales CD Jr, Myers ER, Havrilesky LJ. Cost comparison among robotic, laparoscopic, and open hysterectomy for endometrial cancer. Obstet Gynecol. 2010;116(3):685–93.
32. Pasic RP, Rizzo JA, Fang H, Ross S, Moore M, Gunnarsson C. Comparing robot-assisted with conventional laparoscopic hysterectomy: impact on cost and clinical outcomes. J Minim Invasive Gynecol. 2010;17(6):730–8.
33. Martino MA, Shubella J, Thomas MB, Morcrette RM, Schindler J, Williams S, Boulay R. A cost analysis of postoperative management in endometrial cancer patients treated by robotics versus laparoscopic approach. Gynecol Oncol. 2011;123(3):528–31.
34. Marino P, Houvenaeghel G, Narducci F, Boyer-Chammard A, Ferron G, Uzan C, Bats AS, Mathevet P, Dessogne P, Guyon F, et al. Cost-effectiveness of conventional vs robotic-assisted laparoscopy in gynecologic oncologic indications. Int J Gynecol Cancer. 2015;25(6):1102–8.
35. El Hachem L, Andikyan V, Mathews S, Friedman K, Poeran J, Shieh K, Geoghegan M, Gretz HF III. Robotic single-site and conventional laparoscopic surgery in gynecology: clinical outcomes and cost analysis of a matched case-control study. J Minim Invasive Gynecol. 2016;23(5):760–8.
36. Bell MC, Torgerson J, Seshadri-Kreaden U, Suttle AW, Hunt S. Comparison of outcomes and cost for endometrial cancer staging via traditional laparotomy, standard laparoscopy and robotic techniques. Gynecol Oncol. 2008;111(3):407–11.
37. Coronado PJ, Herraiz MA, Magrina JF, Fasero M, Vidart JA. Comparison of perioperative outcomes and cost of robotic-assisted laparoscopy, laparoscopy and laparotomy for endometrial cancer. Eur J Obstet Gynecol Reprod Biol. 2012;165(2):289–94.
38. Ind TE, Marshall C, Hacking M, Harris M, Bishop L, Barton D, Bridges JE, Shepherd JH, Nobbenhuis M. Introducing robotic surgery into an endometrial cancer service—a prospective evaluation of clinical and economic outcomes in a UK institution. Int J Med Robot. 2016;12(1):137–44.
39. Wright KN, Jonsdottir GM, Jorgensen S, Shah N, Einarsson JI. Costs and outcomes of abdominal, vaginal, laparoscopic and robotic hysterectomies. JSLS. 2012;16(4):519–24.
40. Shah NT, Wright KN, Jonsdottir GM, Jorgensen S, Einarsson JI, Muto MG. The feasibility of societal cost equivalence between robotic hysterectomy and alternate hysterectomy methods for endometrial cancer. Obstet Gynecol Int. 2011;2011:570464.
41. Leitao MM, Narain WR, Boccamazzo D, Sioulas V, Cassella D, Ducie JA, Eriksson AG, Sonoda Y, Chi DS, Brown CL, et al. Impact of robotic platforms on surgical approach and costs in the management of morbidly obese patients with newly diagnosed uterine cancer. Ann Surg Oncol. 2016;23(7):2192–8.
42. Wright JD, Ananth CV, Lewin SN, Burke WM, YS L, Neugut AI, Herzog TJ, Hershman DL. Robotically assisted vs laparoscopic hysterectomy among women with benign gynecologic disease. JAMA. 2013;309(7):689–98.
43. Herling SF, Palle C, Moller AM, Thomsen T, Sorensen J. Cost-analysis of robotic-assisted laparoscopic hysterectomy versus total abdominal hysterectomy for women with endometrial cancer and atypical complex hyperplasia. Acta Obstet Gynecol Scand. 2016;95(3):299–308.
44. Reynisson P, Persson J. Hospital costs for robot-assisted laparoscopic radical hysterectomy and pelvic lymphadenectomy. Gynecol Oncol. 2013;130(1):95–9.
45. Winter ML, Leu SY, Lagrew DC Jr, Bustillo G. Cost comparison of robotic-assisted laparoscopic hysterectomy versus standard laparoscopic hysterectomy. J Robot Surg. 2015;9(4):269–75.
46. Dayaratna S, Goldberg J, Harrington C, Leiby BE, McNeil JM. Hospital costs of total vaginal hysterectomy compared with other minimally invasive hysterectomy. Am J Obstet Gynecol. 2014;210(2):120.e1-6.
47. Geller EJ, Matthews CA. Impact of robotic operative efficiency on profitability. Am J Obstet Gynecol. 2013;209(1):20.e1-5.
48. Maenpaa MM, Nieminen K, Tomas EI, Laurila M, Luukkaala TH, Maenpaa JU. Robotic-assisted vs traditional laparoscopic surgery for endometrial cancer: a randomized controlled trial. Am J Obstet Gynecol. 2016;215(5):588.e1–7.
49. Paraiso MF, Ridgeway B, Park AJ, Jelovsek JE, Barber MD, Falcone T, Einarsson JI. A randomized trial comparing conventional and robotically assisted total laparoscopic hysterectomy. Am J Obstet Gynecol. 2013;208(5):368.e1-7.
50. Sarlos D, Kots L, Stevanovic N, von Felten S, Schar G. Robotic compared with conventional laparoscopic hysterectomy: a randomized controlled trial. Obstet Gynecol. 2012;120(3):604–11.
51. Martinez-Maestre MA, Gambadauro P, Gonzalez-Cejudo C, Torrejon R. Total laparoscopic hysterectomy with and without robotic assistance: a prospective controlled study. Surg Innov. 2014;21(3):250–5.
52. Albright BB, Witte T, Tofte AN, Chou J, Black JD, Desai VB, Erekson EA. Robotic versus laparoscopic hysterectomy for benign disease: a systematic review and meta-analysis of randomized trials. J Minim Invasive Gynecol. 2016;23(1):18–27.

Complications of Robotic Surgery: Prevention and Management

25

Celine Lönnerfors and Jan Persson

Introduction

In the 1880s, the mortality rate following an abdominal hysterectomy exceeded 70% [1]. The advancements in the control of pain, infection, and bleeding were important in the development of gynecologic surgery during the nineteenth and early twentieth century. A milestone within gynecologic surgery was the introduction of the laparoscope in 1901 with its associated advantages of less postoperative pain and lower morbidity, shorter hospital stay, and shorter convalescence than after laparotomy [2, 3]. An effort to preserve the clinical benefits of laparoscopic surgery and facilitate the performance of more advanced surgery has led to the development of robotic surgery.

Despite rapidly improving technical equipment and surgical skill, no surgery is risk-free. The actual incidence of complications possibly exceeds reported rates. Because levels of operative procedure, study population, definitions of complications, and the difference in the length of follow-up vary in different series, the exact incidence of complications is difficult to determine. Delayed recognition and intervention adds to morbidity and mortality.

The overall rate of complications following laparoscopic gynecologic surgery is reported to be in the range of 0.1–10% [4–7]. Up to 50% have been reported to occur during initial access [4]. Risk factors include high body weight, previous intraabdominal surgery, medical comorbidity and the presence of endometriosis, and pelvic adhesions or pelvic inflammatory disease. The presence of surgical comorbidities provides a measure of the complexity and potential difficulty of a surgery, and these high-risk surgeries have therefore traditionally been performed by laparotomy [8–10]. In addition to the complexity of the surgery, the experience of the surgeon and the assistant also influence the rate of complications [4–6, 11–16]. Dry-lab studies have shown that the robot is more advantageous compared to traditional laparoscopy when the procedure becomes technically more challenging regardless of the level of the surgeon's experience [17]. Suggested complicating factors motivating robotic surgery are malignant disease, extensive intraabdominal adhesions, severe endometriosis, large uteri, high burden of comorbidity, and obesity [18–23]. Several recent retrospective studies have shown robotics to be more commonly utilized in women with a complicating factor without compromising perioperative outcome [18, 22].

Robotic surgery is laparoscopic surgery utilizing an advanced tool and the complication rates are expected to be similar. However, robotic technology has several unique features that might influence the complication rate and pose new challenges when managing these complications. Deciding whether the complication is patient related, procedure specific, or associated to a laparoscopic approach, the robotic devise itself, user error, or inadequate surgical proficiency is sometimes difficult. Most studies have shown perioperative outcome to be similar for robotic and traditional laparoscopic surgery [10, 24–32]. Overall complications are reported in 0–57% of robotic gynecologic surgical procedures. Major complications are reported in up to 22%, intraoperative complications in 0–18.2%, and postoperative complications in 0–50% (Table 25.1) [3, 10, 18–21, 23–27, 29, 33, 34, 35–37, 38–105].

This chapter describes intraoperative considerations specific to robotic surgery (anesthesia, patient positioning), intraoperative complications with a potential of high morbidity and mortality (vascular injury, bowel injury, urinary tract injury) as well as postoperative complications where features associated with robotic surgery might play a contributory role (cuff dehiscence, port-site hernia, port-site metastases). A summary is presented in Table 25.2.

The focus, rather than including all surgical complications, is on robot-specific considerations and complications

The best and most effective management of complications is to prevent their occurrence.

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Table 25.1 The rate of intraoperative and postoperative complications reported after robotic gynecological surgical procedures

Procedure performed			Complications		
Diagnosis	Publication	Patients (*n*=)	Total	Intraoperative	Postoperative
Various—malignant disease	Veljovich et al. 2008	118	17.8%	17.8%	17.8%
Full staging—endometrial cancer	Boggess et al. 2008	103	5.9%	5.9%	5.9%
Full staging—endometrial cancer	DeNardis et al. 2008	56	21.5%	1.8%	19.7%
Full staging—endometrial cancer	Bell et al. 2008	40	7.5%	0	7.5%
Full staging—endometrial cancer	Seamon et al. 2009	92	13%	4.3%	8.7%
Full staging—endometrial cancer	Lowe et al. 2009	405	18.1%	3.5%	14.6%
Full staging—endometrial cancer	Hoekstra et al. 2009	32	18.7%	3.1%	12.5%
Full staging—endometrial cancer	Cardenas-Goicoechea et al. 2010	102	25.5%	2%	23.5%
Full staging—endometrial cancer	Lim et al. 2010	56	14.3%	0	14.3%
Full staging—endometrial cancer	Shah et al. 2011	40	7%	0	7%
Full staging—endometrial cancer	Backes et al. 2012	503	37.9%	1.6%	36.3%
Full staging—endometrial cancer	Coronado et al. 2012	71	21.2%	2.8%	18.4%
Full staging—endometrial cancer	Wright et al. 2012	1437	8.1%	3%	5.1%
Full staging—endometrial cancer	El Sahwi et al. 2012	155	13.2%	3.2%	10%
Full staging—endometrial cancer	Mok et al. 2012	34	8.8%	0	8.8%
Full staging—endometrial cancer	Escobar et al. 2012	30	N/R	3.3%	N/R
Full staging—endometrial cancer	Nevadunsky et al. 2012	110	9.8%	3%	6.8%
Full staging—endometrial cancer	Zakhari et al. 2015	6313	20.6%	3.3%	17.3%
Full staging—endometrial cancer	Mäenpää et al. 2016	50	N/R	0	22% major
Full staging—endometrial cancer	Gehrig et al. 2008	49	12.2%	2%	10.2%
Full staging—endometrial cancer	Seamon et al. 2009	92	13%	1.1%	11.9%
Full staging—endometrial cancer	Subramaniam et al. 2011	73	15%	N/R	N/R
Full staging—endometrial cancer	Tang et al. 2012	129	41.9%	7%	34.9%
Full staging—endometrial cancer in morbidly obese women	Bernardini et al. 2012	45	23.5%	5.8%	17.7%
Radical hysterectomy+ pelvic lymphadenctomy	Sert and Abeler 2007	7	57%	N/R	N/R
Radical hysterectomy+ pelvic lymphadenctomy	Magrina et al. 2008	27	26%	0%	26%
Radical hysterectomy+ pelvic lymphadenctomy	Kim et al. 2008	10	10%	0%	10%
Radical hysterectomy+ pelvic lymphadenctomy	Boggess et al. 2008	51	7.8%	0	7.8%
Radical hysterectomy+ pelvic lymphadenctomy	Fanning et al. 2008	20	10%	5%	5%
Radical hysterectomy+ pelvic lymphadenctomy	Ko et al. 2008	16	18.8%	0	18.8%
Radical hysterectomy+ pelvic lymphadenctomy	Nezhat et al. 2008	13	46%	15.4%	30.8%
Radical hysterectomy+ pelvic lymphadenctomy	Lowe et al. 2009	42	16.8%	4.8%	12%
Radical hysterectomy+ pelvic lymphadenctomy	Maggioni et al. 2009	40	52.5%	2.5%	50%
Radical hysterectomy+ pelvic lymphadenctomy	Estape et al. 2009	32	21.9%	3.1%	18.8%
Radical hysterectomy+ pelvic lymphadenctomy	Persson et al. 2009	80	59%	N/R	N/R
Radical hysterectomy+ pelvic lymphadenctomy	Cantrell et al. 2010	63	6.3%	1.6%	4.8%
Radical hysterectomy+ pelvic lymphadenctomy	Wright et al. 2012	67	13.4%	7.5%	5.9%
Radical hysterectomy+ pelvic lymphadenctomy	Soliman et al. 2012	34	20.6%	5.9%	14.7%

Table 25.1 (continued)

Procedure performed / Diagnosis	Publication	Patients (*n*=)	Complications		
			Total	Intraoperative	Postoperative
Radical hysterectomy+ pelvic lymphadenctomy	Kim et al. 2014	23	21.6%	4.3%	17.3%
Various—benign and malignant disease	Field et al. 2007	41	9.8%	2.4%	7.3%
Various—benign and malignant disease	Paley et al. 2011	1000	5.7%	2%	3.7%
Various—benign and malignant disease	Lönnerfors and Persson 2013	1000	N/R	1.9%	N/R
Various—benign and malignant disease	Wechter et al.	1155	21.6%	3.2%	18.4%
Hysterectomy—benign and malignant disease	Diaz-Arrastia et al. 2002	11	N/R	9.1%	N/R
Hysterectomy—benign and malignant disease	Marchal et al. 2005	30	17%	0%	17%
Hysterectomy—benign and malignant disease	Gallo et al. 2012	442	12%	5.2%	6.8%
Hysterectomy—benign and malignant disease	Lönnerfors et al. 2015	949	22.7%	3.3%	19.4%
Various—benign and malignant disease in obese women	Wysham et al. 2015	1032	17%	N/R	N/R
Various—benign and malignant disease in obese women	Cosin et al. 2016	128	30.5%	5.5%	25%
Hysterectomy—benign and malignant disease in obese women	Geppert et al. 2011	50	12%	2%	10%
Hysterectomy—complex benign disease	Advincula et al. 2005	6	16.7%	0	16.7%
Hysterectomy—complex benign disease	Boggess et al. 2009	152	5.6%	2.1%	3.5%
Hysterectomy—complex benign disease	Smorgick et al. 2013	30	10%	0%	10%
Hysterectomy—benign disease	Beste et al. 2005	11	18.2%	18.2%	0
Hysterectomy—benign disease	Fiorentino et al. 2006	20	5%	0%	5%
Hysterectomy—benign disease	Reynolds and Advincula 2006	16	25%	6.3%	18.8%
Hysterectomy—benign disease	Kho et al. 2007	91	8.8%	1.1%	7.7%
Hysterectomy—benign disease	Payne et al. 2008	100	2%	1%	1%
Hysterectomy—benign disease	Sarlos et al. 2010	45	17.3%	4.4%	13.3%
Hysterectomy—benign disease	Landeen et al. 2011	569	8.4%	N/R	N/R
Hysterectomy—benign disease	Wright et al. 2012	14	N/R	0	N/R
Hysterectomy—benign disease	Gocmen et al. 2012	60	8.3%	6.7%	1.7%
Hysterectomy—benign disease	Orady et al. 2012	133	10%	N/R	N/R
Hysterectomy—benign disease	Patzkowsky et al. 2013	288	27.7%	1.7%	26%
Hysterectomy—benign disease	Wright et al. 2013 Cohort	10797	5.7%	2.5%	3.2%
Hysterectomy—benign disease	Rosero et al. 2013 Cohort	7788	8.8%	N/R	8.8%
Hysterectomy—benign disease	Lönnerfors et al. 2014	61	6.6%	1.6%	5%
Hysterectomy—benign disease	Lim et al. 2016	2300	7%	0.7%	6.3%
Various for benign disease	Nezhat et al. 2006	15	0	0	0
Various for benign disease	Lenihan et al. 2008	113	3.5%	0.9%	2.6%
Various—endometriosis	Nezhat et al. 2010	40	0	0	0
Various—stage IV endometriosis	Brudie et al. 2012	80	10%	5%	5%
Myomectomy	Advincula et al. 2004	35	14.2%	5.7%	5.7%
Myomectomy	Lönnerfors and Persson 2009	31	3.2%	0	3.2%
Myomectomy	Gargiulo et al. 2012	174	8.6%	0	8.6%
Myomectomy	Mansour et al. 2012	38	5.3%	0	5.3%
Myomectomy	Gobern et al. 2013	66	12%	0	12%
Myomectomy	Asmar et al. 2015	36	8.3%	2.7%	5.6%
Myomectomy	Gunnala et al. 2016	207	1.4%	0	1.4%
Sacrocolpopexy	Geller et al. 2008	73	19.2%	1.4%	17.8%
Sacrocolpopexy	Paraiso et al. 2011	35	54.2%	11.4%	42.9%
Sacrocolpopexy	Ploumidis et al. 2014	95	6.4%	3.2%	3.2%
Sacrocolpopexy	Unger et al. 2014	121	26.1%	6.6%	19.5%
Sacrocolpopexy	Serati et al. 2014 review	1488	11%	3%	8%

Table 25.2 Risk factors, clinical presentation and management of complications reported after robotic gynecological surgical procedures

Complication	Rate (%)	Range (%)	Related to procedure	Cause of complication	Patient-related risk factors	Clinical presentation	Intraoperative management	Management if delayed detection
Anesthetics	<0.5	0–3.9	Prolonged procedures	Trendelenburg position, pneumo-peritoneum, prolonged procedure	Cardio-pulmonary disease, obesity	Subcutaneous emphysema, hypothermia, CO_2 embolism, acidosis, cardiac arrhythmia, respiratory symptoms, cardiac arrest	According to anesthesio-logical guidelines	According to anesthesio-logical guidelines
Positioning injuries	<0.5	0–6.6	Prolonged procedures	Inadequate positioning, prolonged surgery, Trendelenburg's position	Obesity, low body weight, diabetes, steep Trendelenburg	Pain or neural symptoms postopera-tively	Immediate postoperative fasciotomy in case of compartment syndrome	Physiotherapy
Abdominal wall vascular injury	<0.5	0–0.5	No	Entry related	None	Intraoperative bleeding from trocar site, postoperative hemorrhage, hematoma, abdominal wall pain, ecchymosis	Coagulation, tamponade, suturing, Foley catheter	Conservative or surgical repair
Intestinal injury	<1	0–6.3	No	Entry related, thermal injury, dissection	Intraabdominal adhesions, inadequate exposure	Direct visualization, postoperative peritonitis	Robotic repair or laparotomy	Laparotomy if delayed detection
Intra-abdominal vascular injury	<1	0–9	Lympha-denectomy	Entry related, thermal injury, dissection	Lean patients, inadequate exposure, obesity, intraabdominal adhesions	Intra-abdominal hemorrhage	Compression, coagulation, hemostatic agents, suturing. Robotic repair or by laparotomy	Surgical repair usually by laparotomy
Bladder injury	<1	0–15.4	Sacrocol-popexy	Thermal injury, dissection	Intraabdominal adhesions	Direct visualization, abdominal pain, oliguria	Robotic repair if detected	Conservative with indwelling catheter or surgical repair
Ureteral injury	<2	0–6.3	Radical hysterectomy	Thermal injury, dissection, suturing	Intraabdominal adhesions, endometriosis, obesity	Direct visualization, fever, hematuria, dysuria, abdominal pain, peritonitis, vaginal leakage, incontinence, flank pain	Robotic repair including JJ stent or laparotomy	Ureteral stent or laparotomy
Vaginal cuff dehiscence	0–7.5	0–7.5	Radical hysterectomy	Thermal injury, closure technique	Postmeno-pausal women, vaginal cuff hematoma, sexual intercourse	Vaginal bleeding, prolapse of intestine	NA	Conservative if small, otherwise surgical

Table 25.2 (continued)

Complication	Rate (%)	Range (%)	Related to procedure	Cause of complication	Patient-related risk factors	Clinical presentation	Intraoperative management	Management if delayed detection
Port-site hernia	<0.5	0–6.1	Procedures for malignant disease, multiquadrant surgery	Entry related, trocar size, movement outside pivotal point	Diabetes, advanced age, anemia, steroid therapy, malignant disease, wound infection	Bulge at port site, bowel obstruction	NA	Surgery or conservative in the absence of bowel symptoms
Port-site metastasis	<0.5	0–2	Procedures for malignant disease	Multifactorial (contaminated instruments, pneumo-peritoneum, CO_2 related, chimney effect)	Disseminated disease	Tumor at port site	NA	Resection, chemotherapy, radiotherapy

in gynecologic surgery. Complications associated with a specific surgical procedure such as lymphatic complications after lymphadenectomy and general surgical complications, for example, postoperative infections, postoperative anemia, thrombosis, and other cardiopulmonary events are not included.

Anesthetic Considerations

The steep Trendelenburg position and the pneumoperitoneum necessary in robotic surgery can have significant physiological consequences that are usually compensated for in a young, healthy patient but may be hazardous to those with underlying disease [108]. Most susceptible to problems with the head-down extreme position are the cardiac, respiratory, and central nervous systems [108]. However, without proper exposure, the procedure is prolonged and there is an increased risk of intraoperative complications [109, 110].

The pneumoperitoneum restricts diaphragmatic excursion and lung expansion, which decreases pulmonary compliance and functional residual capacity, causes pulmonary edema, and exacerbates ventilation/perfusion mismatch [34, 111, 112]. In addition, the combination of pneumoperitoneum and the dorsal lithotomy position influences cardiopulmonary physiology, increased left ventricular filling pressure and systemic vascular resistance, and decreased cardiac output [113, 114]. Patients with impaired pulmonary function and obese patients are particularly vulnerable to these physiological changes. Subcutaneous emphysema resulting from preperitoneal insufflation can lead to postoperative respiratory hypercarbia and acidosis and pneumomediastinum [115, 116]. Hypothermia is another complication that may develop due to exposure, prolonged surgery, the use of cold intravenous fluids, respiratory gases, and CO_2 insufflation [108]. A severe complication is a CO_2 embolism which is usually caused by insufflation of a large volume of gas into a large vein either through a Verress needle or following intraoperative injury causing hypotension, hypoxia with cyanosis, and dysrhythmia or asystole due to inflow obstruction to the right heart [117, 118]. The increased intraabdominal pressure and steep Trendelenburg predispose patients to aspiration of gastric contents, necessitating the placement of an orogastric tube and endotracheal intubation [117, 118]. In addition, monitoring of the cardiovascular and pulmonary systems, temperature, urine output, muscle relaxation, central hemodynamic, and arterial blood gas monitoring in high-risk patients is key to anticipate, prevent, and manage possible anesthesiological complications during robotic surgery. In a review of the literature, the American Association of Gynecology reported an incidence of 1 in 2500 cases of asystole and cardiac arrest during laparoscopy, reflecting the potential for catastrophic morbidity and mortality [119, 120].

Publications addressing anesthesiological complications in robotic surgery are scarce. Wysham et al. evaluated pulmonary complications and overall complications in 1032 obese women at two institutions undergoing robotic surgery. The overall rate of pulmonary complications was 3%. The most common pulmonary complication was desaturation below 90% intra- or postoperatively, affecting 1.5%, followed by difficulty with extubation or need for reintubation in 1%. Only 0.2% of patients were unable to maintain adequate tidal volumes during surgery [81]. Cardiac arrhythmia was also noted in 0.3% and hypo- or hypertension in 0.6% [81]. In a recent review article, Kay et al. focused on the anesthetic and surgical implications of robot-assisted technology in gynecologic surgery and concluded that good communication and thorough knowledge of the nuances of robotic surgery have the potential to improve patient outcomes, increase efficiency, and reduce complications [108].

Patient Positioning

Optimal positioning maintains a functional airway and proper circulation, protects the patient from pressure injury to muscles and nerves, and provides adequate access for the anesthesiological staff to place intravenous lines and monitoring equipment while providing adequate exposure of the operative field [121]. The definition of a positioning injury varies where the usual definition includes weakness, paresthesia, numbness, or any other peripheral neurological or muscular complaint [122].

Patients placed in a steep Trendelenburg position necessary for robotic gynecologic surgery are prone to sliding increasing the risk of dermal and nerve injury [123–125]. Nerve injury during suboptimal positioning is due to stretching or compression. The most common nerves susceptible to positioning injury are the peroneal nerve, the saphenous nerve, and the sciatic nerve. Suggested risk factors include hypothermia, hypotension, diabetes, malnutrition, and anatomic aberrations [126]. Positioning aids such as air mattresses that conform to the patient and help maintain their position should be used to minimize the risk [108]. The patient's face should be protected from the sheer force of the robotic arms, intermittent pneumatic compression should be applied to the lower extremities to help prevent deep vein thromboembolism, and the arms and elbows should be padded to protect against ulnar nerve injury [108, 127]. To avoid brachial plexus injury, the patient's head must be in the midline position avoiding either a dorsal extension or lateral flexion of the head, and shoulder braces should be avoided [121, 125, 128, 129].

In the obese patient, extra care must be taken as the extra subcutaneous fat, rather than protecting from injury, actually increases strain on the body and compresses tissue against the table and positional aids [129].

The lithotomy position causes a reduction of systolic blood pressure in the lower extremities [130]. Hypoperfusion due to increased intracompartmental pressure causes compartment syndrome. Although rare (0.01%) several cases following robotic surgery have been reported [29, 131]. Prolonged operative time is the single most important risk factor, although blood loss, peripheral vascular disease, muscular calves, and a high body mass index have been suggested as possible contributing factors [132].

Other complications caused by the steep Trendelenburg position are substantial facial edema, increased intracranial pressure (ICP), and increased intraocular pressure (IOP). Wysham reported facial edema in 0.3% in their study in obese women [81]. Increased ICP is particularly hazardous for patients with intracranial pathology and increased IOP might lead to blindness if maintained for a long period of time [125, 133–135]. Avoiding prolonged surgery and using ophthalmic ointment and eye patches reduces the risk. Postoperative alopecia is another rare positioning complication that has been described following robotic surgery [136].

Positioning injuries are under-recognized in robotic surgery, and literature addressing this complication is scarce. Mills et al. found an overall incidence of neurological positioning complications to be 6.6% in a study on 334 operations, 60% resolved within 6 months. Prolonged surgical time and patients with multiple medical comorbidities had an increased risk [122]. Cosin et al. found an overall rate of position-related nerve injury of 6.3% in their study on obese women undergoing robotic surgery for various benign and malignant conditions. There was a nonsignificant trend toward a greater likelihood of position-related nerve injury with increasing BMI [82]. Another study on robotic gynecological procedures in obese women reported a rate of neuropathy of 0.4% [81].

Optimal positioning according to guidelines and assessment at regular intervals as well as during the postoperative period decreases the risk of positioning complications [121, 137, 138].

Intraoperative Laceration Injuries

Severe intraoperative injures are the main cause of morbidity and mortality related to laparoscopic and robotic surgery. Initial abdominal access to establish a pneumoperitoneum and placement of camera and instrument ports can potentially cause vascular injuries, gastrointestinal injuries, and urinary tract injuries. Proper access technique is important to avoid these complications. However, no significant difference in the rate of initial access complications has been shown when comparing different techniques used for gas insufflation [139–141]. Inadvertent cautery and excessive thermal spread are the major reasons for inadvertent injury during tissue dissection. Lack of haptic feedback and overestimation of distance due to the magnification achieved in robotic surgery might theoretically be a robotic-specific feature that increases the risk of laceration injuries including delayed thermal injuries [29].

Vascular Injury

The overall reported rate of vascular injuries in robotic gynecologic surgery ranges from 0 to 9% although most report rates less than 1% (Table 25.3).

Contrary to studies on laparoscopic surgery, most injuries occur during tissue dissection and not during abdominal access. Most injuries can be controlled robotically without the need for conversion to laparotomy [6, 25, 29, 42, 44, 51, 58, 82, 85].

Table 25.3 The rate of vascular injuries reported after robotic gynecological surgical procedures

Type of procedure	Publication	Vascular injury
Robotic myomectomy	Advincula et al. 2004	0
Robotic myomectomy	Lönnerfors and Persson 2009	0
Robotic myomectomy	Gargiulo et al. 2012	0
Robotic myomectomy	Mansour et al. 2012	0
Robotic myomectomy	Gobern et al. 2013	0
Robotic myomectomy	Asmar et al. 2015	2.7%
Robotic myomectomy	Gunnala et al. 2016	0
Robotic sacrocolpopexy	Geller et al. 2008	0
Robotic sacrocolpopexy	Paraiso et al. 2011	0
Robotic sacrocolpopexy	Ploumidis et al. 2014	0
Robotic sacrocolpopexy	Unger et al. 2014	0.8%
Hysterectomy for benign disease	Beste et al. 2005	9.1%
Hysterectomy for benign disease	Fiorentino et al. 2006	0
Hysterectomy for benign disease	Reynolds and Advincula 2006	0
Hysterectomy for benign disease	Kho et al. 2007	0
Hysterectomy for benign disease	Payne et al. 2008	0
Hysterectomy for benign disease	Sarlos et al. 2010	2.2%
Hysterectomy for benign disease	Wright et al. 2012	0
Hysterectomy for benign disease	Gocmen et al. 2012	0
Hysterectomy for benign disease	Patzkowsky et al. 2013	0
Hysterectomy for benign disease	Lönnerfors et al. 2014	0
Various for benign disease	Lenihan et al. 2008	0
Various for benign disease	Nezhat et al. 2006	0
Endometriosis	Nezhat et al. 2010	0
Stage IV endometriosis	Brudie et al. 2012	0
Hysterectomy in complex benign cases	Advincula et al. 2005	0
Hysterectomy in complex benign cases	Boggess et al. 2009	0
Hysterectomy in complex benign cases (obese women)	Geppert et al. 2011	0
Hysterectomy in complex benign cases (large uteri)	Smorgick et al. 2013	0
Robotic surgery for benign and malignant disease in obese women	Field et al. 2007	2.4%
Robotic surgery for benign and malignant disease in obese women	Paley et al. 2011	0.4%
Robotic surgery for benign and malignant disease in obese women	Wysham et al. 2015	0.2%
Robotic surgery for benign and malignant disease in obese women	Cosin et al. 2016	1.6%
Hysterectomy for malignant and benign disease	Diaz-Arrastia et al. 2002	9.1%
Hysterectomy for malignant and benign disease	Marchal et al. 2005	3.3%
Various for malignant disease	Veljovich et al. 2008	1.7%
Hysterectomy for malignant and benign disease	Gallo et al. 2012	0.2%
Robotic surgery for benign and malignant disease	Lönnerfors and Persson 2013	0.4%
Hysterectomy for malignant and benign disease	Lönnerfors et al. 2015	0.6%
Endometrial cancer staging	Boggess et al. 2008	0
Endometrial cancer staging	DeNardis et al. 2008	0
Endometrial cancer staging	Bell et al. 2008	0
Endometrial cancer staging	Seamon et al. 2009	1.1%
Endometrial cancer staging	Lowe et al. 2009	1.2%
Endometrial cancer staging	Hoekstra et al. 2009	0
Endometrial cancer staging	Cardenas-Goicoechea et al. 2010	0
Endometrial cancer staging	Lim et al. 2010	0
Endometrial cancer staging	Shah et al. 2011	0
Endometrial cancer staging	Backes et al. 2012	1%
Endometrial cancer staging	Coronado et al. 2012	2.8%
Endometrial cancer staging	Wright et al. 2012	0.1%
Endometrial cancer staging	El Sahwi et al. 2012	0
Endometrial cancer staging	Mok et al. 2012	0

(continued)

Table 25.3 (continued)

Type of procedure	Publication	Vascular injury
Endometrial cancer staging	Escobar et al. 2012	0
Endometrial cancer staging	Nevadunsky et al. 2012	1%
Endometrial cancer staging	Zakhari et al. 2015	0
Endometrial cancer staging	Mäenpää et al. 2016	0
Endometrial cancer staging in obese women	Gehrig et al. 2008	0
Endometrial cancer staging in obese women	Seamon et al. 2009	0
Endometrial cancer staging in obese women	Tang et al. 2012	0.8%
Endometrial cancer staging in morbidly obese women	Bernardini et al. 2012	0
Radical hysterectomy and staging for cervical cancer	Sert and Abeler 2007	0
Radical hysterectomy and staging for cervical cancer	Magrina et al. 2008	0
Radical hysterectomy and staging for cervical cancer	Kim et al. 2008	0
Radical hysterectomy and staging for cervical cancer	Boggess et al. 2008	0
Radical hysterectomy and staging for cervical cancer	Fanning et al. 2008	0
Radical hysterectomy and staging for cervical cancer	Ko et al. 2008	0
Radical hysterectomy and staging for cervical cancer	Nezhat et al. 2008	0
Radical hysterectomy and staging for cervical cancer	Lowe et al. 2009	0
Radical hysterectomy and staging for cervical cancer	Maggioni et al. 2009	0
Radical hysterectomy and staging for cervical cancer	Estape et al. 2009	0
Radical hysterectomy and staging for cervical cancer	Persson et al. 2009	0
Radical hysterectomy and staging for cervical cancer	Cantrell et al. 2010	0
Radical hysterectomy and staging for cervical cancer	Wright et al. 2012	0
Radical hysterectomy and staging for cervical cancer	Soliman et al. 2012	0
Radical hysterectomy and staging for cervical cancer	Kim et al. 2014	0

Injuries affecting vessels of the abdominal wall, mesentery, or other organs are usually depicted as minor, whereas injuries to the aorta, inferior vena cava, and the iliac vessels are described as major [142]. Most injuries involve minor vessels; however, injury to a major vessel during laparoscopic surgery is a life-threatening complication with a mortality rate of up to 15% [143].

Injury to the superficial or inferior epigastric vessels during trocar insertion results in bleeding into the abdominal cavity or an abdominal wall hematoma formation. Abdominal wall elevation while inserting a semi-blunt trocar at Palmers point, confirmation of correct placement prior to insufflation, and insertion of secondary trocars under direct vision minimize the risk. Hemostasis can be achieved using cautery, by placing a suture around the vessel above and below the port using an Endo Close needle or by placing a Foley catheter through the trocar and inflating the balloon. The latter is quick and effective but eliminates the possibility of using the trocar and does not eliminate the risk of an abdominal wall hematoma formation. Bleeding at the port site may not be observed with the trocar in place. Complete hemostasis must be assured at the end of the procedure. Reduction of the intraabdominal pressure and removal of the trocars under visualization increases the detection rate. Delayed bleeding from the port site typically occurs within 1 h while hematomas can present up to 3 days postsurgery [144]. Abdominal wall pain, ecchymosis, external bleeding, and hemodynamic instability are possible symptoms. Most can be managed conservatively, but intervention is necessary if the patient is hemodynamically unstable and if the hematoma expands or becomes infected, usually using an open surgical approach.

Injury to major retroperitoneal vessels might occur during initial access or during the course of surgery. The former is reported to occur in 0.1–1.0% of laparoscopic surgeries [142]. The distal aorta and the right common iliac artery are particularly prone to injury during initial access due to their close proximity to the anterior abdominal wall, especially in lean patients [9, 145]. Vascular injury during surgery is often due to inadvertent cautery, excessive thermal spread, or failure to recognize a significant structure prior to division. Aberrant vessels or an aberrant course of vessels are not uncommon and sometimes difficult to recognize even when a CT scan has been performed prior to surgery. Mild-to-moderate bleeding can often be controlled with compression, either by gauze sponges or by direct pressure of the robotic instruments. Hemostatic agents can be used in conjunction with mechanical compression. Irrigation rather than suction is helpful when identifying the source of the bleeding, and once bleeding has slowed or ceased, inspection of the area and hemostatic control and applying suture, clips, cautery, or hemostatic agents can be obtained. Adequate visibility is key.

Major vascular injuries are usually recognized immediately due to free blood in the abdominal cavity although bleeding into the mesentery or retroperitoneum may lead to delayed detection. To minimize ongoing blood loss, pressure should be

applied directly to the bleeding site for initial control. The anesthesiologist should be notified immediately for fluid resuscitation, transfusion, or the potential need to convert to an open procedure. Initial control is usually possible using robotic instruments or placement of clamps by the assistant. If initial control is obtained, this allows for assessment of the situation including all members of the surgical team prior to attempting a robotic repair of the injury or prior to performing a laparotomy if robotic repair is deemed impossible.

The need to convert to laparotomy is determined by the clinical status of the patient, the rate of bleeding, the amount of blood loss, the presence of (or lack of) a clearly defined source, and the experience level of the surgeon in robotic repair of a vascular injury. Patient factors such as advanced age or poor functional status and comorbidities (cardiopulmonary conditions, obesity, cirrhosis, clotting disorders) should be taken into account when determining whether robotic attempts at hemostasis are likely to be successful and deciding how long to persist [142].

The patient should be stabilized and the anesthesiologist prepared for further blood loss, blood products should be available, additional team members and a vascular surgeon should be called, and the necessary equipment should be present. If initial control is not possible, the abdomen should be rapidly opened with a midline incision, pressure should be applied directly to the bleeding site for initial control, and the abdominal cavity can be packed while awaiting the vascular surgeon.

Due to a large machine impeding access to the patient in robotic surgery and the need to de-dock the robot or remove instruments that are mechanically controlling a bleeding, robotic surgery offers additional challenges to the surgical team when a swift conversion to laparotomy is necessary. Specific team training on how to deal with a major hemorrhage is necessary at all institutions performing robotic surgery.

Bowel Injury

Enterotomies have been reported to occur in up to 6.3% following robotic surgery, although the most recent studies report rates lower than 1% (Table 25.4).

Table 25.4 The rate of bowel injuries reported after robotic gynecological surgical procedures

Type of procedure	Publication	Bowel injury
Robotic myomectomy	Advincula et al. 2004	0
Robotic myomectomy	Lönnerfors and Persson 2009	0
Robotic myomectomy	Gargiulo et al. 2012	0
Robotic myomectomy	Mansour et al. 2012	0
Robotic myomectomy	Gobern et al. 2013	0
Robotic myomectomy	Asmar et al. 2015	0
Robotic myomectomy	Gunnala et al. 2016	0
Robotic sacrocolpopexy	Geller et al. 2008	0
Robotic sacrocolpopexy	Paraiso et al. 2011	3%
Robotic sacrocolpopexy	Ploumidis et al. 2014	0
Robotic sacrocolpopexy	Unger et al. 2014	2.5%
Robotic sacrocolpopexy	Serati et al. 2014	<1%
Hysterectomy for benign disease	Beste et al. 2005	0
Hysterectomy for benign disease	Fiorentino et al. 2006	0
Hysterectomy for benign disease	Reynolds and Advincula 2006	6.3%
Hysterectomy for benign disease	Kho et al. 2007	1.1%
Hysterectomy for benign disease	Payne et al. 2008	0
Hysterectomy for benign disease	Sarlos et al. 2010	0
Hysterectomy for benign disease	Wright et al. 2012	0
Hysterectomy for benign disease	Gocmen et al. 2012	0
Hysterectomy for benign disease	Lönnerfors et al. 2014	0
Various for benign disease	Nezhat et al. 2006	0
Various for benign disease	Lenihan et al. 2008	0
Endometriosis	Nezhat et al. 2010	0
Stage IV endometriosis	Brudie et al. 2012	0
Hysterectomy in complex benign cases	Advincula et al. 2005	0
Hysterectomy in complex benign cases	Boggess et al. 2009	0.7%
Hysterectomy in complex benign cases (obese women)	Geppert et al. 2011	0

(continued)

Table 25.4 (continued)

Type of procedure	Publication	Bowel injury
Hysterectomy in complex benign cases (large uteri)	Smorgick et al. 2013	0
Robotic surgery for benign and malignant disease in obese women	Field et al. 2007	2.4%
Robotic surgery for benign and malignant disease in obese women	Paley et al. 2011	0.5%
Robotic surgery for benign and malignant disease in obese women	Wechter et al. 2014	1.2%
Robotic surgery for benign and malignant disease in obese women	Wysham et al. 2015	0.6%
Robotic surgery for benign and malignant disease in obese women	Cosin et al. 2016	0.8%
Hysterectomy for malignant and benign disease	Diaz-Arrastia et al. 2002	0
Hysterectomy for malignant and benign disease	Marchal et al. 2005	0
Various for malignant disease	Veljovich et al. 2008	0.8%
Hysterectomy for malignant and benign disease	Gallo et al. 2012	1.4%
Robotic surgery for benign and malignant disease	Lönnerfors and Persson 2013	0.5%
Hysterectomy for malignant and benign disease	Lönnerfors et al. 2015	0.8%
Endometrial cancer staging	Boggess et al. 2008	1%
Endometrial cancer staging	DeNardis et al. 2008	1.8%
Endometrial cancer staging	Bell et al. 2008	0
Endometrial cancer staging	Seamon et al. 2009	2.2%
Endometrial cancer staging	Lowe et al. 2009	1.0%
Endometrial cancer staging	Hoekstra et al. 2009	3.1%
Endometrial cancer staging	Cardenas-Goicoechea et al. 2010	2.0%
Endometrial cancer staging	Lim et al. 2010	0
Endometrial cancer staging	Shah et al. 2011	0
Endometrial cancer staging	Backes et al. 2012	0.4%
Endometrial cancer staging	Coronado et al. 2012	0
Endometrial cancer staging	Wright et al. 2012	0.6%
Endometrial cancer staging	El Sahwi et al. 2012	0.6%
Endometrial cancer staging	Mok et al. 2012	0
Endometrial cancer staging	Escobar et al. 2012	0
Endometrial cancer staging	Nevadunsky et al. 2012	0
Endometrial cancer staging	Zakhari et al. 2015	<1%
Endometrial cancer staging	Mäenpää et al. 2016	2%
Endometrial cancer staging in obese women	Gehrig et al. 2008	2%
Endometrial cancer staging in obese women	Seamon et al. 2009	1.1%
Endometrial cancer staging in obese women	Tang et al. 2012	3.9%
Endometrial cancer staging in morbidly obese women	Bernardini et al. 2012	2.2%
Radical hysterectomy and staging for cervical cancer	Sert and Abeler 2007	0
Radical hysterectomy and staging for cervical cancer	Magrina et al. 2008	0
Radical hysterectomy and staging for cervical cancer	Kim et al. 2008	0
Radical hysterectomy and staging for cervical cancer	Boggess et al. 2008	0
Radical hysterectomy and staging for cervical cancer	Fanning et al. 2008	0
Radical hysterectomy and staging for cervical cancer	Ko et al. 2008	0
Radical hysterectomy and staging for cervical cancer	Nezhat et al. 2008	0
Radical hysterectomy and staging for cervical cancer	Lowe et al. 2009	0
Radical hysterectomy and staging for cervical cancer	Maggioni et al. 2009	2.5%
Radical hysterectomy and staging for cervical cancer	Estape et al. 2009	0
Radical hysterectomy and staging for cervical cancer	Persson et al. 2009	0
Radical hysterectomy and staging for cervical cancer	Cantrell et al. 2010	0
Radical hysterectomy and staging for cervical cancer	Wright et al. 2012	0
Radical hysterectomy and staging for cervical cancer	Soliman et al. 2012	0
Radical hysterectomy and staging for cervical cancer	Kim et al. 2014	0

Contrary to studies on laparoscopic surgery where 50% are recognized at the time of surgery, approximately 75% of injuries were detected during the procedure. A majority was managed without the need for conversion to laparotomy [6, 25, 29, 41, 47, 48, 56, 58, 68, 80, 87, 88, 106, 146, 147]. Studies on laparoscopic surgery have shown that 30–50% of intestinal injuries occur during initial access whereas the remaining result from dissection, thermal injury, insertion and reinsertion

of instruments, or inadvertent tissue grasping [142, 148–150]. Thermal injuries may be caused by insulation failure or direct capacitive coupling and can occur outside the field of vision [150]. Gastrointestinal injury is the second most common cause of fatality following laparoscopic surgery [151]. The commonest site of injury during laparoscopic surgery is small bowel (58%), colon (32%), and stomach (8%) [150]. Surgery for malignant disease, previous intraabdominal surgery, or the presence of adhesions increases the risk of bowel injury. The entry technique has not been shown to influence the rate of this complication [139–141]. Inspection of the bowel below the entry site, minimizing bowel handling, using atraumatic graspers when manipulating the bowel, working inside the visual field, insertion of instruments under direct vision, performing adhesiolysis only when clinically indicated, limiting the use of thermal injury when in close proximity to the bowel, and checking instruments for insulation failures are measures that might help reduce intestinal injuries [150].

Delayed detection has a major impact on morbidity and mortality. A large review of 21 studies on laparoscopic surgery showed that no patient with a bowel injury that was recognized intraoperatively sustained a postoperative adverse event, whereas patients with delayed detection needed multiple procedures to manage the injury [146].

Gastrointestinal injury should be managed when recognized. Submerging bowel under irrigation fluid may reveal air bubbles or bowel content spillage from the defect [150]. If detected during the primary procedure, reapproximation and repair of the bowel wall in one or two layers using 4/0 Vicryl or PDS sutures is often sufficient, either robotically, laparoscopically, through a mini-laparotomy, or a laparotomy depending on the surgeon's experience and skill. Thermal injuries might need tissue resection to ensure healthy margins. Patency should be checked. A thorough peritoneal lavage and antibiotic coverage are recommended [150]. A colorectal surgeon should be consulted at surgeon's discretion. Initial repair is usually associated with an uncomplicated postoperative period [146].

Symptoms related to bowel injury can, depending on the type and site of injury, manifest themselves as long as 30 days postsurgery. Injuries to the large intestine normally present at 5.4 days (range 1–29) and small bowel injuries at 4.5 days (range 2–14) [147]. Delayed diagnosis is a significant cause of morbidity and mortality [142]. Patients with continued abdominal pain, especially if associated with tachycardia or fever must be evaluated. A CT scan should be performed. Free intraabdominal air is common after a laparoscopic/robotic procedure; however increasing amounts are concerning. Delayed detection usually entails a laparotomy and appropriate repair according to grade of injury.

Urinary Tract Injury

Studies on robotic gynecological procedures report bladder injury rates from 0 to 15.4% and ureteral injuries rates from 0 to 6.3% (Table 25.5).

Table 25.5 The rate of urinary tract injuries reported after robotic gynecological surgical procedures

Type of procedure	Publication	Bladder injury	Ureteric injury
Robotic myomectomy	Advincula et al. 2004	0	0
Robotic myomectomy	Lönnerfors and Persson 2009	0	0
Robotic myomectomy	Gargiulo et al. 2012	0	0
Robotic myomectomy	Mansour et al. 2012	0	0
Robotic myomectomy	Gobern et al. 2013	0	0
Robotic myomectomy	Asmar et al. 2015	0	0
Robotic myomectomy	Gunnala et al. 2016	0	0
Robotic sacrocolpopexy	Geller et al. 2008	1.4%	0
Robotic sacrocolpopexy	Paraiso et al. 2011	6%	0
Robotic sacrocolpopexy	Ploumidis et al. 2014	2.1%	0
Robotic sacrocolpopexy	Unger et al. 2014	3.3%	0
Robotic sacrocolpopexy	Serati et al. 2014	2%	<1%
Hysterectomy for benign disease	Beste et al. 2005	9.1%	0
Hysterectomy for benign disease	Fiorentino et al. 2006	0	0
Hysterectomy for benign disease	Reynolds and Advincula 2006	0	0
Hysterectomy for benign disease	Kho et al. 2007	0	0
Hysterectomy for benign disease	Payne et al. 2008	1%	0
Hysterectomy for benign disease	Sarlos et al. 2010	0	0
Hysterectomy for benign disease	Wright et al. 2012	0	0
Hysterectomy for benign disease	Gocmen et al. 2012	0	0
Hysterectomy for benign disease	Patzkowsky et al. 2013	0	0.3%
Hysterectomy for benign disease	Lönnerfors et al. 2014	1.6%	0
Various for benign disease	Nezhat et al. 2006	0	0
Various for benign disease	Lenihan et al. 2008	0	0.9%
Endometriosis	Nezhat et al. 2010	0	0

Table 25.5 (continued)

Type of procedure	Publication	Bladder injury	Ureteric injury
Stage IV endometriosis	Brudie et al. 2012	0	1.3%
Hysterectomy in complex benign cases	Advincula et al. 2005	0	0
Hysterectomy in complex benign cases	Boggess et al. 2009	0	1
Hysterectomy in complex benign cases (obese women)	Geppert et al. 2011	0	2%
Hysterectomy in complex benign cases (large uteri)	Smorgick et al. 2013	0	0
Robotic surgery for benign and malignant disease in obese women	Field et al. 2007	0	0
Robotic surgery for benign and malignant disease in obese women	Paley et al. 2011	0.2%	0.2%
Robotic surgery for benign and malignant disease in obese women	Wysham et al. 2015	0.6% urinary tract injury	
Robotic surgery for benign and malignant disease in obese women	Cosin et al. 2016	0.8%	1.6%
Hysterectomy for malignant and benign disease	Diaz-Arrastia et al. 2002	0	0
Hysterectomy for malignant and benign disease	Marchal et al. 2005	0	0
Various for malignant disease	Veljovich et al. 2008	0	0
Hysterectomy for malignant and benign disease	Gallo et al. 2012	2.5% urinary tract injury	
Robotic surgery for benign and malignant disease	Lönnerfors and Persson 2013	0.8%	0.1%
Hysterectomy for malignant and benign disease	Lönnerfors et al. 2015	1.2%	0.5%
Endometrial cancer staging	Boggess et al. 2008	0	0
Endometrial cancer staging	DeNardis et al. 2008	0	0
Endometrial cancer staging	Bell et al. 2008	0	0
Endometrial cancer staging	Seamon et al. 2009	0	0
Endometrial cancer staging	Lowe et al. 2009	0.7%	0
Endometrial cancer staging	Hoekstra et al. 2009	0	0
Endometrial cancer staging	Cardenas-Goicoechea et al. 2010	0	0
Endometrial cancer staging	Lim et al. 2010	0	0
Endometrial cancer staging	Shah et al. 2011	0	0
Endometrial cancer staging	Backes et al. 2012	0	0.2%
Endometrial cancer staging	Coronado et al. 2012	0	0
Endometrial cancer staging	Wright et al. 2012	0.3%	0.4%
Endometrial cancer staging	El Sahwi et al. 2012	0.6%	1.9%
Endometrial cancer staging	Mok et al. 2012	0	0
Endometrial cancer staging	Escobar et al. 2012	0	0
Endometrial cancer staging	Nevadunsky et al. 2012	0	0
Endometrial cancer staging	Zakhari et al. 2015	<1%	<1%
Endometrial cancer staging	Mäenpää et al. 2016	0	0
Endometrial cancer staging in obese women	Gehrig et al. 2008	0	0
Endometrial cancer staging in obese women	Seamon et al. 2009	0	0
Endometrial cancer staging in obese women	Tang et al. 2012	0.8%	1.6%
Endometrial cancer staging in morbidly obese women	Bernardini et al. 2012	0	0
Radical hysterectomy and staging for cervical cancer	Sert and Abeler 2007	14.3%	0
Radical hysterectomy and staging for cervical cancer	Magrina et al. 2008	0	0
Radical hysterectomy and staging for cervical cancer	Kim et al. 2008	0	0
Radical hysterectomy and staging for cervical cancer	Boggess et al. 2008	0	0
Radical hysterectomy and staging for cervical cancer	Fanning et al. 2008	5%	5%
Radical hysterectomy and staging for cervical cancer	Ko et al. 2008	0	6.3%
Radical hysterectomy and staging for cervical cancer	Nezhat et al. 2008	15.4%	0
Radical hysterectomy and staging for cervical cancer	Lowe et al. 2009	2.4%	2.4%
Radical hysterectomy and staging for cervical cancer	Maggioni et al. 2009	0	0
Radical hysterectomy and staging for cervical cancer	Estape et al. 2009	3.1%	0
Radical hysterectomy and staging for cervical cancer	Persson et al. 2009	0	1.3%
Radical hysterectomy and staging for cervical cancer	Cantrell et al. 2010	0	0
Radical hysterectomy and staging for cervical cancer	Wright et al. 2012	3%	3%
Radical hysterectomy and staging for cervical cancer	Soliman et al. 2012	0	5.9%
Radical hysterectomy and staging for cervical cancer	Kim et al. 2014	0	4.3%

Similar to laparoscopic surgery, the incidence is dependent on the surgical procedure performed with the highest incidence reported after radical hysterectomy.

Following the rapid expansion of minimally invasive laparoscopic procedures, the leading cause of iatrogenic ureteric injury has shifted from urologic to gynecologic surgeries [152]. A reported 64% of iatrogenic ureteral injuries are due to laparoscopic gynecologic surgeries, followed by general surgical and urology procedures [153, 154]. The presence of endometriosis, an inflamed operative field, intraabdominal adhesions, or previous pelvic surgery increases the risk. For surgery for malignant disease, the stage of the disease, obesity, diabetes, and postoperative surgical infection acted as predisposing factors of the urinary tract complications. A recent systematic review found a frequency of urinary tract injury during laparoscopic hysterectomy to be approximately 0.73%, similar to rates reported after abdominal hysterectomy [155]. Bladder injury rates range from 0.5 to 0.66% and ureteral injuries occur in 0.02–0.4%. No studies involving robotic hysterectomy were included in the review. Contrary to ureteral injuries, most bladder injuries following laparoscopic surgery are recognized intraoperatively [155]. The incidence of vesicovaginal fistula and ureterovaginal fistula formation is 3.4% and 2.4%, respectively, after urinary tract injury associated with laparoscopic hysterectomy [155]. Prevention of urinary tract injuries requires a thorough knowledge of pelvic anatomy, meticulous dissection skills, use of the avascular surgical spaces, and good principles of hemostasis [150]. Sharp rather than blunt dissection of the bladder from the cervix during hysterectomy and the ability to visualize the course of the ureters from the pelvic brim to the bladder during any gynecological procedure minimizes the risk of injury [150].

Bladder Injury

The majority of bladder injuries in robotic gynecological surgery are detected during surgery and primary repair is performed robotically [6, 25, 29, 41, 58, 66, 85, 89, 106, 107].

Hysterectomy is the gynecological procedure most frequently associated with bladder injury occurring during dissection [156]. The use of an electrocautery device in close proximity to the bladder can result in intraoperative bladder injury or delayed thermal injury [157]. The bladder dome is the most common injury site, followed by the posterior bladder base [150].

A bladder injury might be directly visualized or may be suspected due to the presence of air or blood in the urine catheter collection bag or urine in the operative field [158]. If a bladder injury is suspected despite the absence of these symptoms, installation of saline or methylene blue dye followed by observation for extravasation and an intraoperative cystoscopy are tools that might assist in the diagnosis [158–160]. Postoperatively, a bladder injury may present with a variety of clinical signs and symptoms such as abdominal pain, suprapubic pain, hematuria, and oliguria [156, 161, 162]. With extravasation of urine, the abdominal pain increases and abdominal distension, peritonitis, and sepsis might occur [162, 163]. A creatinine level in peritoneal fluid exceeding the serum creatinine level should raise suspicion [164]. A CT cystography is the diagnostic method of choice when bladder injury is suspected; however, usually even an evaluation of the ureters is warranted and a CT urography is performed.

Once diagnosed, bladder injuries are managed depending on the time of diagnosis and on their location [165]. Small 3–5 mm punctures in the dome of the bladder generally resolve spontaneously with an indwelling catheter bladder for up to 7–10 days. Larger or irregular defects will require a double layer closure using absorbable sutures. The Foley catheter should be left in place for up to 10 days depending on the size and location of the puncture or tear. Bladder injuries are easily sutured robotically and performing a laparotomy or consulting an urologist is rarely necessary. For injuries detected during the postoperative period, operative repair is usually needed for intraperitoneal injuries and for large extraperitoneal injuries. The standard repair is a two-layer closure including the mucosa with absorbable sutures. Conservative treatment comprises decompression of the bladder and observation.

Ureteral Injury

Up to half of the ureteral injuries in robotic gynecologic injuries are detected during surgery. A conversion to laparotomy is rarely necessary. Delayed thermal injuries have usually been successfully treated with ureteric stents [6, 25, 29, 41, 44, 52, 58, 65, 67, 73, 82, 96, 98]. In contrast, according to the literature, only 12.5% of iatrogenic injuries to the ureter occurring during laparoscopic surgery are identified during the primary surgical procedure [165].

Ureteral injury occurs in less than 2% of pelvic procedures [142, 165, 166]. However, up to 75% of ureteric injuries are caused by gynecologic surgery, and most injuries occur during procedures for benign diseases [153]. The surgical steps associated with the highest risk of injury are ligation of uterine and ovarian vessels, attempts to control bleeding, and mobilization of the ureter [167, 168]. Ligation of the ureter is the most common injury [167]. The ureter can even be obstructed by suture or angulation, partially or completely transected, perforated, crushed, or devascularized by electrocoagulation [165]. The distal 3 cm of the ureter is most at risk, accounting for 91% of injuries [169].

Advances in surgical techniques and approaches, particularly the shift toward minimally invasive surgery for more complex cases, have expanded the potential for iatrogenic injury. Ureteral stents can be placed preoperatively in cases where an increased risk exist, but does not eliminate the risk of injury. In an analysis of gynecologic surgery, universal ureteral catheterization was only considered cost-effective when the rate of ureteral injury exceeded 3.2% [170].

Identifying the ureter and observing peristalsis are the best way of preventing injury [171]. Complex procedures might necessitate dissection and mobilization. Anatomical aberrations including double ureters are not uncommon and are not always recognized on preoperative radiological examinations. The integrity of the ureters should be confirmed and documented prior to closing. An AAGL practice report indicates that the rate of detectable but unsuspected lower urinary tract injuries is enough to suggest that surgeons should consider cystoscopic evaluation following laparoscopic total hysterectomy as a routine procedure [172].

If a ureteral injury is suspected, the area should be dissected and the ureter visualized and assessed. Retrograde pyelography or ureteroscopy or the placement of a ureteral catheter can help identify ureteral injury [173]. Intraoperative repair is usually associated with an uncomplicated postoperative period. Initial management depends on the type, location, and degree of injury, the urological expertise available, and whether the injury is detected intraoperatively or postoperatively [174]. Preservation of the kidney with adequate drainage by urethral stent or nephrostomy is the primary goal [175]. For upper and middle third injuries, a ureteroureterostomy or transureteroureterostomy is usually performed, whereas lower third injuries are managed with direct reimplantation.

Unrecognized ureteral injury leads to extraperitoneal or intraperitoneal accumulation of urine. Urinary output is essentially unchanged if there is a unilateral lesion. A rise in serum creatinine and blood urea nitrogen levels might occur. Symptoms vary and include fever, hematuria, dysuria, anuria, abdominal pain, flank pain or lower back pain, peritonitis, incontinence, or a vaginal leakage [153, 161, 176]. Elevated creatinine levels in peritoneal fluid might assist in the diagnosis. Unrecognized injuries might lead to ureteral stricture, urinoma, fistula, and ipsilateral renal loss. Patients usually display symptoms within 48–72 h postsurgery. Early recognition is key to improve patient outcome. CT urography is the most common method for diagnosing missed ureteral injuries followed by intravenous urography and bilateral retrograde pyelography [165].

Vesicovaginal or ureterovaginal fistula has been reported to occur in up to 2% after abdominal hysterectomy. This usually develops within 14 days postsurgery and resolves spontaneously in up to 20% [161, 177, 178].

Vaginal Cuff Dehiscence

Vaginal cuff dehiscence is reported to occur in up to 7.5% after robotic surgery, most commonly after a radical hysterectomy and pelvic lymphadenectomy (Table 25.6).

Table 25.6 The rate of vaginal cuff dehiscence reported after robotic gynecological surgical procedures

Type of procedure	Publication	Vaginal cuff dehiscence
Hysterectomy for benign disease	Beste et al. 2005	0
Hysterectomy for benign disease	Fiorentino et al. 2006	0
Hysterectomy for benign disease	Reynolds and Advincula 2006	0
Hysterectomy for benign disease	Kho et al. 2007	0
Hysterectomy for benign disease	Payne et al. 2008	0
Hysterectomy for benign disease	Sarlos et al. 2010	0
Hysterectomy for benign disease	Wright et al. 2012	0
Hysterectomy for benign disease	Gocmen et al. 2012	0
Hysterectomy for benign disease	Patzkowsky et al. 2013	0.3%
Hysterectomy for benign disease	Lönnerfors et al. 2014	1.6%
Various for benign disease	Nezhat et al. 2006	0
Various for benign disease	Lenihan et al. 2008	0.9%
Endometriosis	Nezhat et al. 2010	0
Stage IV endometriosis	Brudie et al. 2012	0
Hysterectomy in complex benign cases	Advincula et al. 2005	0
Hysterectomy in complex benign cases	Boggess et al. 2009	0
Hysterectomy in complex benign cases	Geppert et al. 2011	2%
Hysterectomy in complex benign cases	Smorgick et al. 2013	0
Hysterectomy for malignant and benign disease	Diaz-Arrastia et al. 2002	0
Hysterectomy for malignant and benign disease	Marchal et al. 2005	0
Various for malignant disease	Veljovich et al. 2008	1.7%

Table 25.6 (continued)

Type of procedure	Publication	Vaginal cuff dehiscence
Hysterectomy for malignant and benign disease	Gallo et al. 2012	0.2%
Hysterectomy for malignant and benign disease	Lönnerfors et al. 2015	2.5%
Robotic surgery for benign and malignant disease in obese women	Paley et al. 2011	0.72%
Robotic surgery for benign and malignant disease in obese women	Wysham et al. 2015	0
Robotic surgery for benign and malignant disease in obese women	Cosin et al. 2016	0
Endometrial cancer staging	Bell et al. 2008	0
Endometrial cancer staging	Seamon et al. 2009	0
Endometrial cancer staging	Lowe et al. 2009	0.7%
Endometrial cancer staging	Hoekstra et al. 2009	0
Endometrial cancer staging	Lim et al. 2010	0
Endometrial cancer staging	Cardenas-Goicoechea et al. 2010	1%
Endometrial cancer staging	Shah et al. 2011	0
Endometrial cancer staging	Backes et al. 2012	2.4%
Endometrial cancer staging	Mok et al. 2012	2.9%
Endometrial cancer staging	Escobar et al. 2012	0
Endometrial cancer staging	Nevadunsky et al. 2012	1%
Endometrial cancer staging	El Sahwi et al. 2012	1.3%
Endometrial cancer staging	Coronado et al. 2012	2.8%
Endometrial cancer staging	Zakhari et al. 2015	0
Endometrial cancer staging	Mäenpää et al. 2016	0
Endometrial cancer staging in obese women	Gehrig et al. 2008	2%
Endometrial cancer staging in obese women	Seamon et al. 2009	0
Endometrial cancer staging in obese women	Tang et al. 2012	1.6%
Hysterectomy for malignant disease in morbidly obese women	Bernardini et al. 2012	0
Radical hysterectomy and staging for cervical cancer	Sert and Abeler 2007	0
Radical hysterectomy and staging for cervical cancer	Magrina et al. 2008	0
Radical hysterectomy and staging for cervical cancer	Kim et al. 2008	0
Radical hysterectomy and staging for cervical cancer	Ko et al. 2008	0
Radical hysterectomy and staging for cervical cancer	Boggess et al. 2008	2%
Radical hysterectomy and staging for cervical cancer	Nezhat et al. 2008	0
Radical hysterectomy and staging for cervical cancer	Fanning et al. 2008	0
Radical hysterectomy and staging for cervical cancer	Persson et al. 2009	6.3%
Radical hysterectomy and staging for cervical cancer	Lowe et al. 2009	0
Radical hysterectomy and staging for cervical cancer	Maggioni et al. 2009	7.5%
Radical hysterectomy and staging for cervical cancer	Estape et al. 2009	3.1%
Radical hysterectomy and staging for cervical cancer	Cantrell et al. 2010	1.6%
Radical hysterectomy and staging for cervical cancer	Wright et al. 2012	0
Radical hysterectomy and staging for cervical cancer	Soliman et al. 2012	5.9%
Radical hysterectomy and staging for cervical cancer	Kim et al. 2014	4.3%

The real incidence is unclear as definition and incidence varies in different studies, but has been reported in the range of 0.14–0.31% [179]. Increased age, vaginal atrophy, chronic coughing, postoperative lymphatic leakage, vaginal cuff infection or hematoma, and factors associated with poor wound healing are possible risk factors. The surgical mode also seems to be an important risk factor as this complication seems to occur more often following laparoscopic hysterectomy (0.64–4.9%) and robotic hysterectomy (0.5–7.5%) compared to abdominal (0.15–0.38%) or vaginal hysterectomy (0.08–0.25%) [179–189]. Uccella et al. reviewed ten studies and found an incidence of vaginal cuff dehiscence of 0–5.2% following robot-assisted laparoscopic hysterectomy [185].

Different methods for vaginal cuff incision and closure at the time of robotic hysterectomy may influence the risk of this complication. The use of electrocautery for colpotomy and hemostasis, different suturing techniques, and an overestimation of distance due to the magnification of the visual field leading to inadequate bites of viable tissue when suturing are believed to influence the risk of vaginal cuff dehiscence. Optimizing delineation of the vaginal fornices, using monopolar pure cutting current when performing the colpotomy to minimize thermal spread, achieving hemostasis

with sutures rather than electrocoagulation, ensuring adequate tissue edges, as well as using a two-layer or bidirectional barbed suture for cuff closure have all been suggested to decrease the risk of cuff dehiscence [29, 179, 188, 190, 191]. In addition, a prolonged pelvic rest of at least 8 weeks postsurgery might further decrease the rate [29].

Vaginal cuff dehiscence has been reported to occur as late as 30 years after surgery but is more commonly reported to occur within the first 8 weeks [179]. A majority present within 24 h of the onset of symptoms, most commonly pelvic or abdominal pain accompanied by vaginal bleeding or watery discharge [179]. Untreated, cuff dehiscence might lead to bowel perforation, peritonitis, and even sepsis [179]. Evisceration is reported in up to 70% of vaginal cuff dehiscence cases [179]. Most common preceding factors are intercourse (8–48%) or straining with defecation or Valsalva (16–30%) although in up to 70% no triggering event was reported [187, 192].

Cronin et al. reviewed the available literature and found no consensus on the ideal method of surgical repair [179]. Fifty-one percent of dehiscences were repaired vaginally, 32% were repaired abdominally, 2% were repaired laparoscopically, 10% were repaired with a combined approach, and 5% were allowed to heal by secondary intention. The risk of reoccurrence requiring a second repair was 4% [179]. The surgical approach is dependent on the surgeon's level of experience and should allow for assessment of the bowel when necessary, ensuring optimal tissue approximation and strength of repair [179].

Port-Site Hernia

Port-site hernia has been reported to occur in 0–6.1% of robotic procedures [6, 29, 38, 45, 46, 48, 50, 51, 54, 68, 70, 79–81, 89, 96]. The rates are similar to the rates reported after laparoscopic surgery and dependent on the length of follow-up. The strong lateral movements of the robotic arms leading to stretching and tearing of the fascia might theoretically influence the rate of port hernias. Suboptimal positioning, movement outside the pivotal point, and sliding of the patient due to the fixed position of the trocars and instruments in robotic surgery have been suggested to further aggravate fascial injury [193]. This would however entail an increased incidence of port-site hernias in robotic ports which has not been demonstrated [29].

Port-site hernia occurs less frequently than incisional hernia after open surgery [194–196]. Port-site hernias can be divided into early- and late-onset hernias and may present with bowel obstruction or strangulation requiring emergency surgery. Suggested patient-related risk factors are female sex, increased age, a high body mass index, previous abdominal surgery, and the occurrence of a wound infection. Technical risk factors include insertion technique, trocar design, port location, trocar size, fascial closure, the type of suture, and the duration of the surgery. The reported prevalence following laparoscopic surgery varies between 0 and 5.2% [194]. Port-site hernia appears to be related to more complex procedures that require multiple larger diameter ports and single-site surgery [197]. Other factors include older age, higher body mass index, and increased operative times. Port-site hernia has been reported for 5 mm trocar sites, but is rare. Most authors advocate fascial repair if a port >12 mm is used, whereas others advocate closure if the port is ≥10 mm [194, 197]. Closing of lateral port sites may cause chronic pain from nerve entrapment of the ilioinguinal and iliohypogastric nerves [25, 168].

An early-onset port-site hernia necessitates an acute surgical exploration. Symptoms include the presence of a bulge with exertion or Valsalva, port pain with or without a palpable bulge, or clinical signs of bowel obstruction. Late-onset hernias usually present with a bulge at the trocar site. Clinical suspicion and examination is often sufficient for diagnosis, whereas an ultrasound or a CT scan can be of additional help, although a negative scan does not rule out the presence of a hernia. The defect should be repaired either laparoscopically or by laparotomy to prevent the development of bowel obstruction or strangulation [198]. A general surgeon should be consulted at the surgeon's discretion.

Port-Site Metastases

Port-site metastasis refers to cancer growth at a port incision site after laparoscopic tumor resection [199]. The available data is limited but suggest a rate of up to 2% following robotic surgery for gynecological malignancies [200–207]. The rate reported in the early literature on laparoscopy in gynecologic malignancies was very high, primarily due to the use of diagnostic laparoscopy in patients with advanced stage disease [208, 209].

Port-site metastases was first described by Dobronte et al. in 1978 [210] and can occur as early as 10 days postsurgery. The etiology is probably multifactorial and possible contributing factors suggested are wound implantation by specimen removal or contaminated instruments, the leakage of insufflation gas containing tumor cells through the port ("chimney effect"), carbon dioxide, and secondary effects of pneumoperitoneum [211–216]. Little evidence regarding possible preventive measures is available [211]. Adequate surgical technique includes proper placement of trocars with minimal tissue trauma, trocar fixation and prevention of gas leakage, minimal removal and reintroduction of trocars and instruments, minimal handling of tumor, deflating the abdomen with trocars in place, use of protective bags to retrieve specimens, port-site excision, and closure of port sites as a possi-

ble measure of minimizing the occurrence of port-site metastases [205, 209, 217, 218].

Involuntary desufflation of the pneumoperitoneum or sliding of the patient as well as the strong lateral movements of the robot arms may theoretically inflict more traumas to the abdominal wall and thereby increase the risk of port-site metastases. On the other hand, in addition to enhanced precision reducing tissue trauma, the robotic instruments remain in place throughout the procedure thereby reducing the risk of port-site contamination by repeated extraction, and reinsertion decreases the risk of port-site metastases [205]. Many port-site metastases are part of a general recurrence and probably have little effect on the patients' prognosis as the general outcome is poor [202, 219, 220]. Isolated, resectable metastases should be surgically excised, and adjuvant chemotherapy or radiation therapy should be considered [221].

Conclusion

Robotic surgery was introduced into clinical practice without adequate trials showing its superiority to existing surgical approaches. The uptake was rapid and as robotic surgery became more widely adopted, reports of morbidity related to robotic complications increased related to the increased number of procedure, to the increased performance of surgery for malignant disease and complex cases, and to the learning curve associated with the adoption of robotic techniques.

Adequate assessment and optimization of patients prior to, during, and postsurgery is important from an anesthesiological and surgical point of view. Proper training and credentialing including simulation training as well as reaching a level of competence in low-risk robotic procedures prior to performing more challenging surgery is key to minimize the risk for the patient. A sufficient institutional caseload to achieve and maintain a level of proficiency for the surgical team is important to optimize patient care. Meticulous surgical technique and performing well-defined surgery in a standardized, reproducible, and safe fashion including proper visualization of the anatomical structure reduce the risk of intraoperative complications.

A well-trained team with thorough knowledge of the robotic system, its properties, and potential unique risk factors as well as possible medical and surgical complications is important to identify, prevent, and overcome difficulties.

The rate of complications possibly related to robotic-specific risk factors is low, and adequate compensation occurs with time and increased experience. Most initial publications on robotic surgery showed a complication rate similar to laparoscopic surgery, and due to the high economical cost associated with the robotic approach, its role within gynecologic surgery has been questioned. However, in addition to facilitating the performance of gynecological surgery in complex procedures and high-risk patients, recent studies have shown a potential of better perioperative outcome following robotic surgery even in low-risk patient when performed by highly trained surgeons.

The effort, time, and dedication required to gain the level of experience needed for successful implementation of a robotic program and to reduce the rate of complications should not be underestimated.

References

1. Sutton C. Past, present, and future of hysterectomy. J Minim Invasive Gynecol. 2010;17(4):421–35.
2. Horn L, Johnson DH. Ephraim McDowell, the first ovariotomy, and the birth of abdominal surgery. J Clin Ocol. 2010;28(7):1262–8.
3. Hollender LF. Eugene Koeberle (1828-1915), founder of modern surgery. Ann Chir. 2001;126(6):572–81.
4. Rock JA, Jones HW, editors. Te Linde's operative gynecology. 9th ed. Philadelphia: Lipincott Williams & Wilkins; 2009.
5. Walker JL, Piedmonte MR, Spirtos NM, Eisenkop SM, Schlaerth JB, Mannel RS, Spiegel G, Barakat R, Pearl ML, Sharma SK. Laparoscopy compared with laparotomy for comprehensive staging of uterine cancer: Gynecologic Oncology Group Study LAP2. J Clin Oncol. 2009;27(32):5331–6.
6. Backes FJ, Brudie LA, Farrell MR, et al. Short- and long term morbidity and outcomes after robotic surgery for comprehensive endometrial cancer staging. Gynecol Oncol. 2012;125(3):546–51.
7. Magrina JF. Complications of laparoscopic surgery. Clin Obstet Gynecol. 2002;45:469.
8. Trottier DC, Martel G, Boushey RP. Complications in laparoscopic intestinal surgery: prevention and management. Minerva Chir. 2009;64(4):339–54.
9. Philips PA, Amaral JF. Abdominal access complications in laparoscopic surgery. J Am Coll Surg. 2001;192(4):525–36.
10. Ahmad G, O'Flynn H, Duffy JM, et al. Laparoscopic entry techniques. Cochrane Database Syst Rev. 2012;(2):CD006583
11. Leonard F, Chopin N, Borghese B, et al. Total laparoscopic hysterectomy: preoperative risk factors for conversion to laparotomy. J Minim Invasive Gynecol. 2005;12(4):312–7.
12. Bonilla DJ, Mains L, Whitaker R, et al. Uterine weight as a predictor of morbidity after a benign abdominal and total laparoscopic hysterectomy. J Reprod Med. 2007;52(6):490–8.
13. Boggess JF, Gehrig PA, Cantrell L, Shafer A, Ridgway M, Skinner EN, et al. A comparative study of 3 surgical methods for hysterectomy with staging for endometrial cancer: robotic assistance, laparoscopy, laparotomy. Am J Obstet Gynecol. 2008;199(4):360.e1–9.
14. McPherson K, Metcalfe MA, Herbert A, Maresh M, Casbard A, Hargreaves J, et al. Severe complications of hysterectomy: the VALUE study. BJOG. 2004;111:688–94.
15. Birkmeyer JD, Siewers AE, Finlayson EV, Stukel TA, Lucas FL, Batista I, et al. Hospital volume and surgical mortality in the United States. N Engl J Med. 2002;346:1128–37.
16. Birkmeyer JD, Stukel TA, Siewers AE, Goodney PP, Wennberg DE, Lucas FL. Surgeon volume and operative mortality in the United States. N Engl J Med. 2003;349:2117–27.
17. Gruen RL, Pitt V, Green S, Parkhill A, Campbell D, Jolley D. The effect of provider case volume on cancer mortality: systematic review and meta-analysis. CA Cancer J Clin. 2009;59:192–211.

18. Juillard C, Lashoher A, Sewell CA, Uddin S, Griffith JG, Chang DC. A national analysis of the relationship between hospital volume, academic center status, and surgical outcomes for abdominal hysterectomy done for leiomyoma. J Am Coll Surg. 2009;208:599–606.
19. Rogo-Gupta LJ, Lewin SN, Kim JH, Burke WM, Sun X, Herzog TJ. The effect of surgeon volume on outcomes and resource use for vaginal hysterectomy. Obstet Gynecol. 2010;116(6):1341–7.
20. Gaia G, Holloway RW, Santoro L, Ahmad S, Di Silverio E, Spinillo A. Robotic assisted hysterectomy for endometrial cancer compared with traditional laparoscopic and laparotomy approaches: a systematic review. Obstet Gynecol. 2010;116:1422–31.
21. Wright KN, Jonsdottir GM, Jorgensen S, Shah N, Einarsson JI. Costs and outcomes of abdominal, vaginal, laparoscopic and robotic hysterectomies. JSLS. 2012;16(4):519–24.
22. Wright JD, Burke WM, Wilde ET, et al. Comparative effectiveness of robotic versus laparoscopic hysterectomy for endometrial cancer. J Clin Oncol. 2012;30:783–91.
23. Zakhari A, Czuzoj-Schulman N, Spence AR, Gotlieb WH, Abenhaim HA. Laparoscopic and robot-assisted hysterectomy for uterine cancer: a comparison of costs and complications. Am J Obstet Gynecol. 2015;213(5):665.e1–7.
24. Lönnerfors C, Persson J. Robot-assisted laparoscopic myomectomy; a feasible technique for removal of unfavorably localized myomas. Acta Obstet Gynecol Scand. 2009;88(9):994–9.
25. Lönnerfors C, Persson J. Implementation and applications of robotic surgery within gynecologic oncology and gynecology; analysis of the first thousand cases. Ceska Gynekol. 2013;78(1):12–9.
26. Lönnerfors C, Persson J. Pregnancy following robot-assisted laparoscopic myomectomy in women with deep intramural myomas. Acta Obstet Gynecol Scand. 2011;90(9):972–7.
27. Geppert B, Lönnerfors C, Persson J. Robot assisted laparoscopic hysterectomy in obese and morbidly obese women. Surgical technique and comparison with open surgery. Acta Obstet Gynecol Scand. 2011;90:1211–7.
28. Lönnerfors C, Reynisson P, Persson J. A randomized trial comparing vaginal and laparoscopic hysterectomy to robot assisted hysterectomy. J Minim Invasive Gynecol. 2015 Jan;22(1):78–86.
29. Lönnerfors C, Reynisson P, Geppert B, Persson J. The effect of increased experience on complications in robotic hysterectomy for malignant and benign gynecological disease. J Robot Surg. 2015;9(4):321–30.
30. Tan SJ, Lin CK, Fu PT, et al. Robotic surgery in complicated gynecologic diseases: experience of Tri-Service General Hospital in Taiwan. Taiwan J Obstet Gynecol. 2012;51(1):18–25.
31. Liu H, Lu D, Wang L, Shi G, Song H, Clarke J. Robotic surgery for benign gynecological disease. Cochrane Database Syst Rev. 2012;(2):CD008978.
32. Weinberg L, Rao S, Escobar PF. Robotic surgery in gynecology: an updated systematic review. Obstet Gynecol Int. 2011;2011:852061.
33. Swan K, Advincula AP. Advances in urogynaecological robotic surgery. BJU Int. 2011;108(6 Pt 2):1024–7.
34. Kalmar AF, Foubert L, Hendrickx JF, et al. Influence of steep Trendelenburg position and CO(2) pneumoperitoneum on cardiovascular, cerebrovascular, and respiratory homeostasis during robotic prostatectomy. Br J Anaesth. 2010;104(4):433–9.
35. Wright JD, Ananth CV, Lewin SN, et al. Robotically assisted vs laparoscopic hysterectomy among women with benign gynecologic disease. JAMA. 2013;309:689–98.
36. Jonsdottir GM, Jorgensen S, Cohen SL, Wright KN, Shah NT, Chavan N, et al. Increasing minimally invasive hysterectomy: effect on cost and complications. Obstet Gynecol. 2011;117:1142–9.
37. Rosero EB, Kho KA, Joshi GPMD, Giesecke M, Schaffer JI. Comparison of robotic and laparoscopic hysterectomy for benign gynecologic disease. Obstet Gynecol. 2013;122:778–86.
38. Gehrig PA, Cantrell LA, Shafer A, Abaid LN, Mendivil A, Boggess JF. What is the optimal minimally invasive surgical procedure for endometrial cancer staging in the obese and morbidly obese woman? Gynecol Oncol. 2008;111:41–5.
39. Subramaniam A, Kim KH, Bryant SA, et al. A cohort study evaluating robotic versus laparotomy surgical outcomes of obese women with endometrial carcinoma. Gynecol Oncol. 2011;122:604–7.
40. Lim PC, Crane JT, English EJ, Farnam RW, Garza DM, Winter ML, Rozeboom JL. Multicenter analysis comparing robotic, open, laparoscopic, and vaginal hysterectomies performed by high-volume surgeons for benign indications. Int J Gynaecol Obstet. 2016;133(3):359–64. https://doi.org/10.1016/j.ijgo.2015.11.010. Epub 2016 Feb 16.
41. Boggess JF, Gehrig PA, Cantrell L, et al. Perioperative outcomes of robotically assisted hysterectomy for benign cases with complex pathology. Obstet Gynecol. 2009;14(3):585–93.
42. Veljovich DS, Paley PJ, Drescher CW, Everett EN, Shah C, Peters WA III. Robotic surgery in gynecologic oncology: program initiation and outcomes after the first year with comparison with laparotomy for endometrial cancer staging. Am J Obstet Gynecol. 2008;198(679):e1–9.
43. DeNardis SA, Holloway RW, Bigsby GE IV, et al. Robotically assisted laparoscopic hysterectomy versus total abdominal hysterectomy and lymphadenectomy for endometrial cancer. Gynecol Oncol. 2008;111:412–7.
44. Lowe MP, Johnson PR, Kamelle SA, Kumar S, Chamberlain DH, Tillmanns TD. A multiinstitutional experience with robotic-assisted hysterectomy with staging for endometrial cancer. Obstet Gynecol. 2009;114(2 Pt 1):236–43.
45. Bell MC, Torgerson J, Seshadri-Kreaden U, Suttle AW, Hunt S. Comparison of outcomes and cost for endometrial cancer staging via traditional laparotomy, standard laparoscopy and robotic techniques. Gynecol Oncol. 2008;111(3):407–11.
46. Seamon LG, Cohn DE, Henretta MS, Kim KH, Carlson MJ, Phillips GS, Fowler JM. Minimally invasive comprehensive surgical staging for endometrial cancer: robotics or laparoscopy? Gynecol Oncol. 2009;113(1):36–41.
47. Hoekstra AV, Jairam-Thodla A, Rademaker A, et al. The impact of robotics on practice management of endometrial cancer: transitioning from traditional surgery. Int J Med Robot. 2009;5:392–7.
48. Cardenas-Goicoechea J, Adams S, Bhat SB, Randall TC. Surgical outcomes of robotic-assisted surgical staging for endometrial cancer are equivalent to traditional laparoscopic staging at a minimally invasive surgical center. Gynecol Oncol. 2010;117(2):224–8.
49. Lim PC, Kang E, Park DH. A comparative detail analysis of the learning curve and surgical outcome for robotic hysterectomy with lymphadenectomy versus laparoscopic hysterectomy with lymphadenectomy in treatment of endometrial cancer: a case-matched controlled study in the first one hundred twenty two patients. Gynecol Oncol. 2011;120(3):413–8.
50. Shah NT, Wright KN, Jonsdottir GM, Jorgensen S, Einarsson JI, Muto MG. The feasibility of societal cost equivalence between robotic hysterectomy and alternate hysterectomy methods for endometrial cancer. Obstet Gynecol Int. 2011;2011:570464.
51. Coronado PJ, Herraiz MA, Magrina JF, Fasero M, Vidart JA. Comparison of perioperative outcomes and cost of robotic-assisted laparoscopy, laparoscopy and laparotomy for endometrial cancer. Eur J Obstet Gynecol Reprod Biol. 2012;165(2):289–94.
52. El Sahwi KS, Hooper C, De Leon MC, et al. Comparison between 155 cases of robotic vs. 150 cases of open surgical staging for endometrial cancer. Gynecol Oncol. 2011;124:260–4.

53. Mok ZW, Yong EL, Low JJ, Ng JS. Clinical outcomes in endometrial cancer care when the standard of care shifts from open surgery to robotics. Int J Gynecol Cancer. 2012;22(5):819–25.
54. Escobar PF, Frumovitz M, Soliman PT, et al. Comparison of single port laparoscopy, standard laparoscopy, and robotic surgery in patients with endometrial cancer. Ann Surg Oncol. 2012;19:1583–8.
55. Nevadunsky N, Clark R, Ghosh S, et al. Comparison of robot-assisted total laparoscopic hysterectomy and total abdominal hysterectomy for treatment of endometrial cancer in obese and morbidly obese patients. J Robot Surg. 2010;4:247–52.
56. Mäenpää MM, Nieminen K, Tomás EI, Laurila M, Luukkaala TH, Mäenpää JU. Robotic-assisted vs traditional laparoscopic surgery for endometrial cancer: a randomized controlled trial. Am J Obstet Gynecol. 2016. pii: S0002-9378(16)30314-3. doi: 10.1016/j.ajog.2016.06.005. Epub ahead of print.
57. Seamon LG, Bryant SA, Rheaume PS, Kimball KJ, Huh WK, Fowler JM, Phillips GS, Cohn DE. Comprehensive surgical staging for endometrial cancer in obese patients: comparing robotics and laparotomy. Obstet Gynecol. 2009;114(1):16–21.
58. Tang KY, Gardiner SK, Gould C, Osmundsen B, Collins M, Winter WE III. Robotic surgical staging for obese patients with endometrial cancer. Am J Obstet Gynecol. 2012;206(513):e1–6.
59. Bernardini MQ, Gien LT, Tipping H, Murphy J, Rosen BP. Surgical outcome of robotic surgery in morbidly obese patient with endometrial cancer compared to laparotomy. Int J Gynecol Cancer. 2012;22:76–81.
60. Sert BM, Abeler VM. Robotic-assisted laparoscopic radical hysterectomy (Piver type III) with pelvic node dissection—case report. Eur J Gynaecol Oncol. 2006;27:531–3.
61. Magrina JF, Kho RM, Weaver AL, Montero RP, Magtibay PM. Robotic radical hysterectomy: comparison with laparoscopy and laparotomy. Gynecol Oncol. 2008;109:86–91.
62. Kim YT, Kim SW, Hyung WJ, Lee SJ, Nam EJ, Lee WJ. Robotic radical hysterectomy with pelvic lymphadenectomy for cervical carcinoma: a pilot study. Gynecol Oncol. 2008;108(2):312–6.
63. Boggess JF, Gehrig PA, Cantrell L, et al. A case–control study of robot-assisted type III radical hysterectomy with pelvic lymph node dissection compared with open radical hysterectomy. Am J Obstet Gynecol. 2008;199(357):e1–7.
64. Fanning J, Fenton B, Purohit M. Robotic radical hysterectomy. Am J Obstet Gynecol. 2008;198(649):e1–4.
65. Ko EM, Muto MG, Berkowitz RS, Feltmate CM. Robotic versus open radical hysterectomy: a comparative study at a single institution. Gynecol Oncol. 2008;111:425–30.
66. Nezhat FR, Datta MS, Liu C, Chuang L, Zakashansky K. Robotic radical hysterectomy versus total laparoscopic radical hysterectomy with pelvic lymphadenectomy for treatment of early cervical cancer. JSLS. 2008;12:227–37.
67. Lowe MP, Chamberlain DH, Kamelle SA, Johnson PR, Tillmanns TD. A multi-institutional experience with robotic-assisted radical hysterectomy for early stage cervical cancer. Gynecol Oncol. 2009;113:191–4.
68. Maggioni A, Minig L, Zanagnolo V, et al. Robotic approach for cervical cancer: comparison with laparotomy: a case control study. Gynecol Oncol. 2009;115:60–4.
69. Estape R, Lambrou N, Estape E, Vega O, Ojea T. Robotic-assisted total laparoscopic hysterectomy and staging for the treatment of endometrial cancer: a comparison with conventional laparoscopy and abdominal approaches. J Robot Surg. 2012;6:199–205.
70. Persson J, Reynisson P, Borgfeldt C, Kannisto P, Lindahl B, Bossmar T. Robot assisted laparoscopic radical hysterectomy and pelvic lymphadenectomy with short and long term morbidity data. Gynecol Oncol. 2009;113:185–90.
71. Cantrell LA, Mendivil A, Gehrig PA, Boggess JF. Survival outcomes for women undergoing type III robotic radical hysterectomy for cervical cancer: a 3-year experience. Gynecol Oncol. 2010;117(2):260–5.
72. Wright JD, Herzog TJ, Neugut AI, et al. Comparative effectiveness of minimally invasive and abdominal radical hysterectomy for cervical cancer. Gynecol Oncol. 2012;127:11–7.
73. Soliman PT, Frumovitz M, Sun CC, et al. Radical hysterectomy: a comparison of surgical approaches after adoption of robotic surgery in gynecologic oncology. Gynecol Oncol. 2011;123:333–6.
74. Kim TH, Choi CH, Choi JK, Yoon A, Lee YY, Kim TJ, et al. Robotic versus laparoscopic radical hysterectomy in cervical cancer patients: a matched-case comparative study. Int J Gynecol Cancer. 2014;24(8):1466–73.
75. Field JB, Benoit MF, Dinh TA, Diaz-Arrastia C. Computer-enhanced robotic surgery in gynecologic oncology. Surg Endosc. 2007;21(2):244–6.
76. Paley PJ, Veljovich DS, Shah CA, Everett EN, Bondurant AE, Drescher CW, et al. Surgical outcomes in gynecologic oncology in the era of robotics: analysis of first 1000 cases. Am J Obstet Gynecol. 2011;204(6):551.e1–9.
77. Wechter ME, Mohd J, Magrina JF, Cornella JL, Magtibay PM, Wilson JR, Kho RM. Complications in robotic-assisted gynecologic surgery according to case type: a 6-year retrospective cohort study using Clavien-Dindo classification. J Minim Invasive Gynecol. 2014;21(5):844–50.
78. Diaz-Arrastia C, Jurnalov C, Gomez G, Townsend C Jr. Laparoscopic hysterectomy using a computer-enhanced surgical robot. Surg Endosc. 2002;16(9):1271–3.
79. Marchal F, Rauch P, Vandromme J, et al. Telerobotic-assisted laparoscopic hysterectomy for benign and oncologic pathologies: initial clinical experience with 30 patients. Surg Endosc. 2005;19:826–83.
80. Gallo T, Kashani S, Patel DA, Elsahwi K, Silasi DA, Azodi M. Robotic-assisted laparoscopic hysterectomy: outcomes in obese and morbidly obese patients. JSLS. 2013;16:421–7.
81. Wysham WZ, Kim KH, Roberts JM, Sullivan SA, Campbell SB, Rogue DR, et al. Obesity and perioperative pulmonary complications in robotic gynecologic surgery. Am J Obstet Gynecol. 2015;213(1):33.e1–7.
82. Cosin JA, Brett Sutherland MA, Westgate CT, Fang H. Complications of robotic gynecologic surgery in the severely morbidly obese. Ann Surg Oncol. 2016;23:4035–41.
83. Advincula AP, Reynolds RK. The use of robot-assisted laparoscopic hysterectomy in the patient with a scarred or obliterated anterior cul-de-sac. JSLS. 2005;9(3):287–91.
84. Smorgick N, Dalton VK, Patzkowsky KE, Hoffman MR, Advincula AP, As-Sanie S. Int J Gynaecol Obstet. 2013;122(2):128–31.
85. Beste TM, Nelson KH, Daucher JA. Total laparoscopic hysterectomy utilizing a robotic surgical system. JSLS. 2005;9(1):13–5.
86. Fiorentino RP, Zepeda MA, Goldstein BH, John CR, Rettenmaier MA. Pilot study assessing robotic laparoscopic hysterectomy and patient outcomes. J Minim Invasive Gynecol. 2006;13(1):60–3.
87. Reynolds RK, Advincula AP. Robot-assisted laparoscopic hysterectomy: technique and initial experience. Am J Surg. 2006;191(4):555–60.
88. Kho RM, Hilger WS, Hentz JG, Magtibay PM, Magrina JF. Robotic hysterectomy: technique and initial outcomes. Am J Obstet Gynecol. 2007;197(1):113.e1–4.
89. Payne TN, Dauterive FR. A comparison of total laparoscopic hysterectomy to robotically assisted hysterectomy: surgical outcomes in a community practice. J Minim Invasive Gynecol. 2008;15(3):286–91.

90. Sarlos D, Kots L, Stevanovic N, von Felten S, Schär G. Robotic compared with conventional laparoscopic hysterectomy: a randomized controlled trial. Obstet Gynecol. 2012;120(3):604–11.
91. Landeen L, Bell M, Hubert H, Bennis L, Knutsen-Larson S, Seshadri-Kreaden U. Clinical and cost comparisons for hysterectomy via abdominal, standard laparoscopic, vaginal and robot-assisted approaches. S D Med. 2011;64:197–9.
92. Gocmen A, Sanlıkan F, Ucar MG. Robot-assisted hysterectomy vs total laparoscopic hysterectomy: a comparison of short-term surgical outcomes. Int J Med Robot. 2012;8:453–7.
93. Orady M, Hrynewych A, Nawfal AK, Wegienka G. Comparison of robotic assisted hysterectomy to other minimally invasive approaches. JSLS. 2012;16:542–8.
94. Patzkowsky KE, As-Sanie S, Smorgick N, Song AH, Advincula AP. Perioperative outcomes of robotic versus laparoscopic hysterectomy for benign disease. JSLS. 2013;17(1):100–6.
95. Nezhat C, Saberi NS, Shahmohamady B, Nezhat F. Robotic-assisted laparoscopy in gynecological surgery. JSLS. 2006;10(3):317–20.
96. Lenihan JP, Kovanda C, Sheshadri-Kreaden U. What is the learning curve for robotic assisted gynaecologic surgery? J Minim Invasive Surg. 2008;15:589–94.
97. Nezhat C, Lewis M, Kotikela S, Veeraswamy A, Saadat L, Hajhosseini B, et al. Robotic versus standard laparoscopy for the treatment of endometriosis. Fertil Steril. 2010;94(7):2758–60.
98. Brudie LA, Gaia G, Ahmad S, Finkler NJ, Bigsby GE 4th, Ghurani GB, Kendrick IV JE, Rakowski JA, Groton JH, Holloway RW. Peri-operative outcomes of patients with stage IV endometriosis undergoing robotic-assisted laparoscopic surgery. J Robot Surg 2012;6(4):317-322.
99. Advincula AP, Song A, Burke W, Reynolds RK. Preliminary experience with robot-assisted laparoscopic myomectomy. J Am Assoc Gynecol Laparosc. 2004;11(4):511–8.
100. Gargiulo AR, Srouji SS, Missmer SA, Correia KF, Vellinga TT, Einarsson JI. Robot-assisted laparoscopic myomectomy compared with standard laparoscopic myomectomy. Obstet Gynecol. 2012;120(2 Pt 1):284–91.
101. Mansour FW, Kives S, Urbach DR, Lefebvre G. Robotically assisted laparoscopic myomectomy: a Canadian experience. J Obstet Gynaecol Can. 2012;34(4):353–8.
102. Gobern JM, Rosemeyer CJ, Barter JF, Steren AJ. Comparison of robotic, laparoscopic, and abdominal myomectomy in a community hospital. JSLS. 2013;17(1):116–20.
103. Gunnala V, Setton R, Pereira N, Huang JQ. Robot-Assisted myomectomy for large uterine myomas: a single center experience. J Minim Invasive Surg. 2016;2016:4905292. https://doi.org/10.1155/2016/4905292. Epub 2016 Feb 29.
104. Asmar J, Even M, Carbonnel M, Goetgheluck J, Revaux A, Ayoubi JM. Myomectomy by robotically assisted laparoscopic surgery: results at Foch Hospital, Paris. Front Surg. 2015;2:40. https://doi.org/10.3389/fsurg.2015.00040. eCollection 2015.
105. Geller EJ, Siddiqui NY, Wu JM, Visco AG. Short-term outcomes of robotic sacrocolpopexy compared with abdominal sacrocolpopexy. Obstet Gynecol. 2008;112(6):1201–6.
106. Paraiso MF, Jelovsek JE, Frick A, Chen CC, Barber MD. Laparoscopic compared with robotic sacrocolpopexy for vaginal prolapse: a randomized controlled trial. Obstet Gynecol. 2011;118(5):1005–13.
107. Unger CA, Paraiso MF, Jelovsek JE, Barber MD, Ridgeway B. Perioperative adverse events after minimally invasive abdominal sacrocolpopexy. Am J Obstet Gynecol. 2014;211(5):547.e1–8.
108. Kaye AD, Vadivelu N, Ahuja N, et al. Anesthetic considerations in robotic-assisted gynecologic surgery. Ochsner J. 2013;13(4):517–24.
109. Klauschie J, Wechter ME, Jacob K, et al. Use of anti-skid material and patient-positioning to prevent patient shifting during robotic assisted gynecologic procedures. J Minim Invasive Gynecol. 2010;17(4):504–7.
110. Ramanathan R, Carey RI, Lopez-Pujals A, Leveillee RJ. Patient positioning and trocar placement for robotic urologic procedures. In: Patel VR, editor. Robotic urologic surgery. 2nd ed. London: Springer; 2012. p. 107–20.
111. Hirvonen EA, Nuutinen LS, Kauko M. Hemodynamic changes due to Trendelenburg positioning and pneumoperitoneum during laparoscopic hysterectomy. Acta Anaesthesiol Scand. 1995;39(7):949–55.
112. Choi SJ, Gwak MS, Ko JS, et al. The effects of the exaggerated lithotomy position for radical perineal prostatectomy on respiratory mechanics. Anaesthesia. 2006;61(5):439–43.
113. Lestar M, Gunnarsson L, Lagerstrand L, et al. Hemodynamic perturbations during robot-assisted laparoscopic radical prostatectomy in 458 Trendelenburg position. Anesth Analg. 2011;113(5):1069–75.
114. Joris JL, Noirot DP, Legrand MJ, et al. Hemodynamic changes during laparoscopic cholecystectomy. Anesth Analg. 1993;76(5):1067–71.
115. Carry PY, Gallet D, Francois Y, et al. Respiratory mechanics during laparoscopic cholecystectomy: the effects of the abdominal wall lift. Anesth Analg. 1998;87(6):1393–7.
116. Koivusalo AM, Lindgren L. Respiratory mechanics during laparoscopic cholecystectomy. Anesth Analg. 1999;89(3):800.
117. Joshi GP. Complications s of laparoscopy. Anesthesiol Clin North America. 2001;19(1):89–105.
118. Gerges FJ, Kanazi GE, Jabbour-Khoury SI. Anesthesia for laparoscopy: a review. J Clin Anesth. 2006;18(1):67–78.
119. Shifren JL, Adlestein L, Finkler NJ. Asystolic cardiac arrest: a rare complication of laparoscopy. Obstet Gynecol. 1992;79(5 Pt 2):840–1.
120. Loris JL. Anesthesia for laparoscopic surgery. In: Miller RD, Fleisher LA, Jones RA, Savarese JJ, Wiener-Kronish JP, Young WL, editors. Miller's anesthesia. 6th ed. Philadelphia: Churchill Livingstone; 2005. p. 2289.
121. Guideline for positioning the patient. In: Guidelines for perioperative practice. Denver: AORN; 2014. p. 563–81.
122. Mills JT, Burris MB, Warburton DJ, Conaway MR, Schenkman NS, Krupski TL. Positioning injuries associated with robotic assisted urological surgery. J Urol. 2013;190:580–4.
123. Ghomi A. Robotics in practice: new angles on safer positioning. Contemp OB/GYN; 1 Oct 2012. http://contemporaryobgyn.modernmedicine.com/contemporary-obgyn/news/modern-medicine/modern-medicine-feature-articles/robotics-practice-newangles?page.full. Accessed 27 Sept 2015.
124. Allen D. Positioning and the surgical robot. Surgical Products. 2013. http://www.surgicalproductsmag.com/articles/2013/02/positioning-and-surgical-robot. Accessed 27 Sept 2016.
125. Sutton S, Link T, Flynn-Makic M. A quality improvement project for safe and effective patient positioning during robot-assisted surgery. AORN J. 2013;97(4):448–56.
126. Winfree CJ, Kline DG. Intraoperative positioning nerve injuries. Surg Neurol. 2005;63(1):5–18.
127. Shveiky D, Aseff J, Iglesia C. Brachial plexus injury after laparoscopic and robotic surgery. J Minim Invasive Gynecol. 2010;17(4):414–20.
128. Kent CD, Cheney FW. A case of bilateral brachial plexus palsy due to shoulder braces. J Clin Anesth. 2007;19(6):482–4.
129. Bale E, Berrecloth R. The obese patient anaesthetic issues: airway and positioning. J Perioper Pract. 2010;20(8):294–9.
130. Bildsten SA, Dmochowski RR, Spindel MR, et al. The risk of rhabdomyolysis and acute renal failure with the patient in the exaggerated lithotomy position. J Urol. 1994;152:1970–2.
131. Akhavan A, Gainsburg DM, Stock JA. Complications associated with patient positioning in urologic surgery. Urology. 2010;76(6):1309–16.

132. Simms MS, Terry TR. Well leg compartment syndrome after pelvic and perineal surgery in the lithotomy position. Postgrad Med J. 2005;81:534–6.
133. Molloy B. A preventative intervention for rising intraocular pressure: development of the Molloy/Bridgeport anesthesia associates observation scale [serial online]. AANA J. 2012;80(3):213–22.
134. Taketani Y, Mayama C, Suzuki N, Wada A, Oka T, Inamochi K, Nomoto Y. Transient but significant visual field defects after robot-assisted laparoscopic radical prostatectomy in deep Trendelenburg position. PLoS One. 2015;10(4):e0123361. https://doi.org/10.1371/journal.pone.0123361. eCollection 2015.
135. Sampat A, Parakati I, Kunnavakkam R, Glck DB, Lee NK, Tenney M, Eggener S, Roth S. Corneal abrasion in hysterectomy and prostatectomy: role of laparoscopic and robotic assistance. Anesthesiology. 2015;122(5):994–1001.
136. Bagaria M, Luck AM. Postoperative (pressure) alopecia following sacrocolpopexy. J Robot Surg. 2015;9(2):149–51.
137. Abdullah HR, Chung F. Perioperative management for the obese outpatient. Curr Opin Anaesthesiol. 2014;27(6):576–82.
138. Spruce L, Van Wicklin S. Back to basics: positioning the patient. AORN J. 2014;100(3):298–305.
139. Jansen FW, Kolkman W, Bakkum EA, de Kroon CD, Trimbos-Kemper TC, Trimbos JB. Complications of laparoscopy: an inquiry about closed- versus open-entry technique. Am J Obstet Gynecol. 2004;190(3):634–8.
140. Nuzzo G, Giuliante F, Tebala GD, et al. Routine use of open technique in laparoscopic operations. J Am Coll Surg. 1997;184(1):58–62.
141. Deziel DJ, Milikan KW, Economou SG, et al. Complications of laparoscopic cholecystectomy: a national survey of 4,292 hospitals and an analysis of 77,604 cases. Am J Surg. 1993;165(1):9–14.
142. Pryor A, Stovall TG, Mann WJ Jr, Gracia G. Complications of laparoscopic surgery. In: Marks JM, Falcone T, Collins KA, editors. UptoDate, Waltham, MA; 2013. Accessed 29 Sept 2016.
143. Nordestgaard AG, Bodily KC, Osborne RW Jr, Burrorff JD. Major vascular injuries during laparoscopic procedures. Am J Surg. 1995;169(5):543–5.
144. Fernandez EM, Malagon AM, Arteaga I, et al. Conservative treatment of a huge abdominal wall hematoma after laparoscopic appendectomy. J Laparoendosc Adv Surg Tech A. 2005;15(6):634–7.
145. Levinson CJ. Laparoscopy is easy – except for the complications: a review with suggestions. J Reprod Med. 1974;13(5):187–94.
146. Schwartz MJ, Faiena I, Cinman N, et al. Laparoscopic bowel injury in retroperitoneal surgery: current incidence and outcomes. J Urol. 2010;184(2):589–94.
147. Bishoff JT, Allaf ME, Kirkels W, et al. Laparoscopic bowel injury: incidence and clinical presentation. J Urol. 1999;161(3):887–90.
148. Chapron C, Pierre F, Harchaoui Y, et al. Gastrointestinal injuries during gynaecological laparoscopy. Hum Reprod. 1999;14(2):333–7.
149. Chapron C, Querleu D, Bruhat MA, et al. Surgical complications of diagnostic and operative gynaecological laparoscopy: a series of 29,966 cases. Hum Reprod. 1998;13(4):867–72.
150. Lam A, Kaufman Y, Khong SY, Liew A, Ford S, Condous G. Dealing with complications in laparoscopy. Best Pract Res Clin Obstet Gynaecol. 2009;23(5):631–46.
151. Fuller J, Ashar BS, Carey-Corrado J. Trocar-associated injuries and fatalities: an analysis of 1399 reports to the FDA. J Minim Invasive Gynecol. 2005;12(4):302–7.
152. Teeluckdharry B, Gilmour D, Flowerdew G. Urinary tract injury at benign gynecologic surgery and the role of cystoscopy: a systematic review and meta-analysis. Obstet Gynecol. 2015;126(6):1161–9.
153. Abboudi H, Ahmed K, Royle J, Khan MS, Dasgupta P, N'Dow J. Ureteric injury: a challenging condition to diagnose and manage. Nat Rev Urol. 2013;10(2):108–15.
154. Esparaz AM, Pearl JA, Herts BR, LeBlanc J, Kapoor B. Iatrogenic urinary tract injuries: etiology, diagnosis, and management. Semin Intervent Radiol. 2015;32(2):195–208.
155. Adelman MR, Bardsley TR, Sharp HT. Urinary tract injuries in laparoscopic hysterectomy: a systematic review. J Minim Invasive Gynecol. 2014;21(4):558–66.
156. Gomez RG, Ceballos L, Coburn M, et al. Consensus statement on bladder injuries. BJU Int. 2004;94(1):27–32.
157. Delacroix SE Jr, Winters JC. Urinary tract injuries: recognition and management. Clin Colon Rectal Surg. 2010;23(3):104–12.
158. Mendez LE. Iatrogenic injuries in gynecologic cancer surgery. Surg Clin North Am. 2001;81(4):897–923.
159. Tulikangas PK, Weber AM, Larive AB, Walters MD. Intraoperative cystoscopy in conjunction with anti-incontinence surgery. Obstet Gynecol. 2000;95(6, Pt 1):794–6.
160. Nezhat CH, Seidman DS, Nezhat F, Rottenberg H, Nezhat C. Laparoscopic management of intentional and unintentional cystotomy. J Urol. 1996;156(4):1400–2.
161. Summerton DJ, Kitrey ND, Lumen N, Serafetinidis E, Djakovic N, European Association of Urology. EAU guidelines on iatrogenic trauma. Eur Urol. 2012;62(4):628–39.
162. Carroll PR, McAninch JW. Major bladder trauma: the accuracy of cystography. J Urol. 1983;130(5):887–8.
163. Morey AF, Hernandez J, JW MA. Reconstructive surgery for trauma of the lower urinary tract. Urol Clin North Am. 1999;26(1):49–60.
164. Manahan KJ, Fanning J. Peritoneal fluid urea nitrogen and creatinine reference values. Obstet Gynecol. 1999;93(5 Pt 1):780–2.
165. Gilmour D. Urinary tract injury in gynecologic surgery: identification and management. In: Brubaker L, Sharp HT, Eckler K, editors. UptoDate, Waltham, MA; 2016. Accessed 29 Sept 2016.
166. Grainger DA, Soderstrom RM, Schiff SF, et al. Ureteral injuries at laparoscopy: insights into diagnosis, management, and prevention. Obstet Gynecol. 1990;75(5):839–43.
167. Likic IS, Kadija S, Ladjevic NG, Stefanovic A, Jeremic K, Petkovic S, Dzamic Z. Analysis of urologic complications after radical hysterectomy. Am J Obstet Gynecol. 2008;199(6):644.e1–3.
168. Goldberg JM, Chen CCG, Falcone T. Complications of laparoscopic surgery. Basic, advanced and robotic laparoscopic surgery. Philadelphia: Saunders; 2010.
169. Torres-Labaton A, Rueda-Mesias M, Roman-Bassaure E, Guadaluperojo-Herrera, Barra Martinez R. Complications of radical hysterectomy during management of stage Ib and IIa cervix uteri cancer. Experience with 145 patients. Gynecol Obstet Mex. 1996;64:265–71.
170. Schimpf MO, Gottenger EE, Wagner JR. Universal ureteral stent placement at hysterectomy to identify ureteral injury: a decision analysis. BJOG. 2008;115:1151–8.
171. Shirk GJ, Johns A, Redwine DB. Complications of laparoscopic surgery: how to avoid them and how to repair them. J Minim Invasive Gynecol. 2006;13(4):352–9.
172. AAGL Advancing Minimally Invasive Gynecology Worldwide. AAGL Practice Report: Practice guidelines for intraoperative cystoscopy in laparoscopic hysterectomy. J Minim Invasive Gynecol. 2012;19(4):407–11.
173. American College of Obstetricians and Gynecologists. ACOG Committee Opinion. Number 372. The role of cystourethroscopy in the generalist obstetrician-gynecologist practice. Obstet Gynecol. 2007;110(1):221–4.
174. Chi AM, Curran DS, Morgan DM, et al. Universal cystoscopy after benign hysterectomy: examining the effects of an institutional policy. Obstet Gynecol. 2016;127(2):369–75.
175. Packiam VT, Cohen AJ, Pariser JJ, Bales GT. The impact of minimally invasive surgery on major iatrogenic ureteral injury and subsequent ureteral repair during hysterectomy: a national analysis of risk factors and outcomes. Urology. 2016. pii:

S0090-4295(16)30532-5. doi: 10.1016/j.urology.2016.08.020. [Epub ahead of print] No abstract available.
176. Brandes S, Coburn M, Armenakas N, McAninch J. Diagnosis and management of ureteric injury: an evidence-based analysis. BJU Int. 2004;94(3):277–89.
177. Shiloach M, Frencher SK, Steeger JE, et al. Toward robust information: data quality and inter-rater reliability in the American College of Surgeons National Surgical Quality Improvement Program. J Am Coll Surg. 2010;210:6–16.
178. Davenport DL, Holsapple CW, Conigliaro J. Assessing surgical quality using administrative and clinical data sets: a direct comparison of the University Health System Consortium Clinical Database and the National Surgical Quality Improvement Program data set. Am J Med Qual. 2009;24:395–402.
179. Cronin B, Sung VW, Matteson KA. Vaginal cuff dehiscence: risk factors and management. Am J Obstet Gynecol. 2012;206(4):284–8.
180. Iaco PD, Ceccaroni M, Alboni C, Roset B, Sansovini M, D'Alessandro L, Pignotti E, Aloysio DD. Transvaginal evisceration after hysterectomy: is vaginal cuff closure associated with a reduced risk? Eur J Obstet Gynecol Reprod Biol. 2006;125(1):134–8.
181. Hur HC, Donnellan N, Mansuria S, et al. Vaginal cuff dehiscence after different modes of hysterectomy. Obstet Gynecol. 2011;118(4):794–801.
182. Uccella S, Ceccaroni M, Cromi A, et al. Vaginal cuff dehiscence in a series of 12,398 hysterectomies: effect of different types of colpotomy and vaginal cuff closure. Obstet Gynecol. 2012;120(3):516–23.
183. Robinson BL, Liao JB, Adams SF, Randall TC. Vaginal cuff dehiscence after robotic total laparoscopic hysterectomy. Obstet Gynecol. 2009;114(2 Pt 1):369–71.
184. Agdi M, Al-Ghafri W, Antolin R, et al. Vaginal vault dehiscence after hysterectomy. J Minim Invasive Gynecol. 2009;16(3):313–7.
185. Uccella S, Ghezzi F, Mariani A, Cromi A, Bogani G, Serati M, et al. Vaginal cuff closure after minimally invasive hysterectomy: our experience and systematic review of the literature. Am J Obstet Gynecol. 2011;205(2):119.e1–12.
186. Hur HC, Guido RS, Mansuria SM, Hacker MR, Sanfilippo JS, Lee TT. Incidence and patient characteristics of vaginal cuff dehiscence after different modes of hysterectomies. J Minim Invasive Gynecol. 2007;14(3):311–7.
187. Nick AM, Lange J, Frumovitz M, Soliman PT, Schmeler KM, Schlumbrecht MP, dos Reis R, Ramirez PT. Rate of vaginal cuff separation following laparoscopic or robotic hysterectomy. Gynecol Oncol. 2011;120(1):47–51.
188. Kho RM, Akl MN, Cornella JL, Magtibay PM, Wechter ME, Magrina JF. Incidence and characteristics of patients with vaginal cuff dehiscence after robotic procedures. Obstet Gynecol. 2009;114:231–5.
189. Ramirez PT, Klemer DP. Vaginal evisceration after hysterectomy: a literature review. Obstet Gynecol Surv. 2002;57(7):462–7.
190. Siedhoff MT, Yunker AC, Steege JF. Decreased incidence of vaginal cuff dehiscence after laparoscopic closure with bidirectional barbed suture. J Minim Invasive Gynecol. 2011;18(2):218–23.
191. Harris WJ. Complications of hysterectomy. Clin Obstet Gynecol. 1997;40(4):928–38.
192. Croak AJ, Gebhart JB, Klingele CJ, Schroeder G, Lee RA, Podratz KC. Characteristics of patients with vaginal rupture and evisceration. Obstet Gynecol. 2004;103(3):572–6.
193. Beck S, Skarecky D, Osann K, Juarez R, Ahlering TE. Transverse versus vertical camera port incision in robotic radical prostatectomy: effect on incisional hernias and cosmesis. Urology. 2011;78(3):586–90.
194. Swank HA, Mulder IM, la Chapelle CF, et al. Systematic review of trocar-site hernia. Br J Surg. 2012;99(3):315–23.
195. George JP. Presentation and management of laparoscopic incisional hernias. J Am Assoc Gynecol Laparosc. 1994;1(4, Part 2):S12.
196. Bensley RP, Schermerhorn ML, Hurks R, et al. Risk of late-onset adhesions and incisional hernia repairs after surgery. J Am Coll Surg. 2013;216(6):1159–67.
197. Johnson WH, Fecher AM, McMahon RL, et al. VersaStep trocar hernia rate in unclosed fascial defects in bariatric patients. Surg Endosc. 2006;20(10):1584–6.
198. Bruyère F, Sun J, Cosson JP, Kouri G. Incarceration of bowel through opening of a 5-mm port. J Endourol. 2004;18(7):675–6.
199. Abu-Rustum NR, Rhee EH, Chi DS, Sonoda Y, Gemignani M, Barakat RR. Subcutaneous tumor implantation after laparoscopic procedures in women with malignant disease. Obstet Gynecol. 2004;103(3):480–7.
200. Bih T, Ndofor MD, Pamela T, Soliman MD, Kathleen M, Schmeler MD, Alpa M, Nick MD, Michael Frumovitz MD, Pedro T, Ramirez MD. Rate of port-site metastasis is uncommon in patients undergoing robotic surgery for gynecological malignancies. Int J Gynecol Cancer. 2011;21:936–40.
201. Grabosch S, Xynos F. Isolated port-site metastasis after robotic hysterectomy for stage IA endometrial adenocarcinoma. Obstet Gynecol. 2013;122:437–9.
202. Lönnerfors C, Bossmar T, Persson J. Port-site metastases following robot-assisted laparoscopic surgery for gynecological malignancies. Acta Obstet Gynecol Scand. 2013;92:1361–8.
203. Iavazzo C, Gkegkes ID. Port site metastases after robot-assisted surgery: a systematic review. Int J Med Robot. 2013;9(4):423–7.
204. Rindos N, Curry CL, Tabbarah R, Wright V. Port-site metastases after robotic surgery for gynecologic malignancy. JSLS. 2014;18(1):66–70.
205. Barraez D, Godoy H, McElrath T, Kredentser D, Timmins P. Low incidence of port-site metastasis after robotic assisted surgery for endometrial cancer staging: descriptive analysis. J Robot Surg. 2015;9(1):91–5.
206. Ramirez PT, Frumovitz M, Wolf JK, Levenback C. Laparoscopic port-site metastases in patients with gynecological malignancies. Int J Gynecol Cancer. 2004;14:1070–7.
207. Ndofor BT, Soliman PT, Schmeler KM, Nick AM, Frumovitz M, Ramirez PT. Rate of port-site metastasis in uncommon in patients undergoing robotic surgery for gynecological malignancies. Int J Gynecol Cancer. 2011;21:936–40.
208. Kruitwagen RFPM, Swinkels BM, Keyser KGG, Doesburg WH, Schijf CPT. Incidence and effect on survival of abdominal wall metastases at trocar or puncture sites following laparoscopy or paracentesis in women with ovarian cancer. Gynecol Oncol. 1996;60:233–7.
209. Ramirez PT, Wolf JK, Levenback C. Laparoscopic port-site metastasis: etiology and prevention. Gynecol Oncol. 2003;91:179–89.
210. Dobronte Z, Wittmann T, Karacsony G. Rapid development of malignant metastases in the abdominal wall after laparoscopy. Endoscopy. 1978;10:127–30.
211. Curet MJ. Port site metastases. Am J Surg. 2004;187:705–12.
212. Castillo OA, Vitagliano G. Port site metastasis and tumor seeding in oncologic laparoscopic urology. Urology. 2008;71(3):372–8.
213. Tseng LN, Berends FJ, Wittich P, Bouvy ND, Marquet RL, Kazemier G, et al. Port-site metastase. Impact of local tissue trauma and gas leakage. Surg Endosc. 1998;12(12):1377–80.
214. Burns JM, Matthews BD, Pollinger HS, Mostafa G, Joels CS, Austin CE, et al. Effect of carbon dioxide pneumoperitoneum and wound closer technique on portsite tumor implantation in a rat model. Surg Endosc. 2005;19:441–7.

215. Lee BR, Tan BJ, Smith AD. Laparoscopic port site metastases: incidence, risk factors, and potentional preventive measures. Urology. 2005;65:639–44.
216. Agostini A, Robin F, Jais JP, Aggereck M, Vildé F, Blanc B, Lècuru F. Peritoneal closure reduces port site metastases. Surg Endosc. 2002;16:289–91.
217. Martınez A, Querleu D, Leblanc E, et al. Low incidence of port-site metastases after laparoscopic staging of uterine cancer. Gynecol Oncol. 2010;118:145–50.
218. Reymond MA, Schneider C, Kastl S, et al. The pathogenesis of port-site recurrences. J Gastrointest Surg. 1998;2:406–14.
219. Pearlstone DB, Mansfield PF, Curley SA, Kumparatana M, Cook P, Feig BW. Laparoscopy in 533 patients with abdominal malignancy. Surgery. 1999;125:67–72.
220. Zivanovic O, Sonoda Y, Diaz JP, et al. The rate of port-site metastasis after 2251 laparoscopic procedures in women with underlying malignant disease. Gynecol Oncol. 2008;111:431–7.
221. National Comprehensive Cancer Network. National Comprehensive Cancer Network; Fort Washington, PA: 2014. NCCN Clinical Practice Guidelines in Oncology Endometrial Cancer Version 1.2013 [Internet]. Available from: http://www.nccn.org/) Accessed 29 Sept 2016.

The Surgical Assistant in Robotic-Assisted Laparoscopy

26

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The assistant surgeon in any procedure is the first officer of the operating room and, under the direction and supervision of the surgeon, aids with all aspects of the procedure. However, the increasing complexity of surgical operations, particularly minimally invasive, has necessitated the addition of surgical assistants.

History of Surgical Assistants

Surgical assistants can be traced back to the early nineteenth century when the Royal Navy created the position of "surgical mate," later called "assistant surgeon" [1]. One of the first famous surgical assistants was Sister Mary Joseph Dempsey, assistant to Dr. William J. Mayo at the turn of the nineteenth century [2]. She was not only an excellent assistant, but very knowledgeable and instrumental to the Mayo brothers' success in establishing their world famous surgical practice. Similarly, during World War II, surgeon Dr. Michael DeBakey, while serving as a consultant to the Surgeon General of the Army, proposed creating specialized surgical teams which consisted of surgeons' assistants stationed close to the front lines [3]. This change greatly improved care of wounded soldiers.

Assistant Surgeon Versus Surgical Assistant

When discussing the assistant surgeon, one must distinguish this term from surgical assist. An assistant surgeon is a physician who aids the primary surgeon with part or all of the surgical procedure. A surgical assist is a non-physician, usually a physician assistant (PA), registered nurse (RN), licensed practical nurse (LPN), or surgical technologist (scrub tech) who is certified by the American Board of Surgical Assistants or other certifying authority. Non-physician assistants are more commonly used in community hospitals and are not allowed to perform any part of the procedure independently and without supervision [4]. Large university medical centers and teaching hospitals much more commonly use residents, fellows, as well as attending surgeons and assistant surgeons.

The surgical assistant has multiple important roles during surgery, and with the increasing complexity of modern surgery and equipment, these roles are frequently expanded. In traditional procedures, the tasks required of an assistant surgeon are to aid with patient positioning, providing access to the area of surgery, achieving hemostasis, retraction, and closing of the incision, among many others [4].

Surgical Assistants in Robotic-Assisted Laparoscopy

Surgical robots were first introduced in the mid-1990s [5]. With the new surgical platform, the responsibilities of the surgical assistant expanded from intraoperative tasks to many other activities at the patient bedside. Up to this point, the surgical assistant typically worked across from the surgeon, receiving directions under direct supervision, which included verbal, visual, and tactile clues. With the introduction of the surgical robot, the surgeon is now stationed at the console, controlling the instruments, and the assistant stationed at the patient bedside, with some capabilities of on-screen directionality [5]. The high complexity of surgical robots obligated surgical assistants to not only have good knowledge of surgical steps and anatomy but also technical knowledge of the robot itself and the ability to efficiently troubleshoot independently at the bedside. Changing of instrumentation also introduces an element of difficulty, as often this task is performed without direct visualization, particularly as the instrument enters

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and exits the port. The assistant must reach target anatomy without causing damage to surrounding structures. These changes also increase some of the burden on the surgeon; since the surgeon does not always have a clear view of the robotic arms, the assistant is responsible for making sure the arms do not collide with each other or the patient, both of which could potentially lead to severe and permanent injury. This physical distance between surgeon and assistant, as created by use of the surgical robot, required even further development of trust within the surgical team. All of these factors significantly increased the difficulty and skill set demanded of the role of surgical assistant in robotic surgery.

The robotic first assistant is vital to the efficient and safe performance of every procedure. This individual must have knowledge of the pertinent anatomy, instruments, and fundamentals of laparoscopy. Various individuals can fulfill the role of a surgical first assistant.

Surgical Assistant Guidelines: American Medical Association and American College of Surgeons

The American Medical Association (Policy H-475.986) [6] states that only licensed physicians with appropriate, education and training should perform surgical procedures. The association recognizes however that it may be necessary for the surgeon to delegate parts of a given procedure to surgical assistants provided the surgeon is still actively involved in the essential portions of the procedure.

The American College of Surgeons [4] also recognizes that use of non-physicians as first assistants may be necessary. The ACS Statement on Principles states:

(a) The surgical assistant is limited to performing specific functions as defined in the medical staff bylaws, rules, and regulations. This typically includes tasks such as maintaining exposure, cutting suture, clamping or ligating vessels, and, in selected instances, performing designated parts of a procedure.
(b) It is the surgeon's responsibility to select the most appropriate individual for this purpose with the medical staff bylaws. A first assistant should be a credentialed healthcare professional, preferably a physician, capable of actively assisting the surgeon.
(c) Practice privileges of surgical assistants should be based on verified credentials and the supervising physician's capability and competence to supervise such an individual. These should be approved by the institution's medical staff credentialing committee and be within the defined limits of state law.
(d) If a procedure or a complication requires the assistant to have the skills of a surgeon, the surgical assistant must be a licensed surgeon qualified within that specialty.
(e) Ideally the first assistant should be a qualified surgeon or resident in an accredited surgical training program.

Certification for Surgical Assistant: Association of Surgical Assistants

There are multiple routes to achieve ,certification as a surgical first assistant. The Association of Surgical Assistants recommends completion of a program accredited by the Commission on Accreditation of Allied Health Education Programs (CAAHEP). Surgical assistant programs may also be offered through independent institutions and accredited by the US Department of Education, The Joint Commission, or a state agency approved by CAAHEP. Credentialing is currently provided by multiple organizations including the National Board of Surgical Technology and Surgical Assisting (NBSTSA), National Surgical Assistant Association (NSAA), and the American Board of Surgical Assistants (ABSA). Each of these credentialing bodies requires completion of its own national certifying exam prior to bestowing the title of Certified Surgical First Assistant (CSFA), Certified Surgical Assistant (CSA), and Surgical Assistant-Certified (SA-C), respectively [7].

The ACS also recognizes that registered nurses (RN) with appropriate training may function as first assistants. It is imperative that they not simultaneously act as the instrument technician so their attention is not interrupted between either of these duties. RNs must act within the level defined within their states' nursing scope of practice guidelines. In our state, RNs must meet the following minimum qualifications [8]:

(a) Certification as a Certified Nurse of the Operating Room (CNOR) or as an Advanced Practice Registered Nurse
(b) Completion of an approved Registered Nurse First Assistant (RNFA) program that meets the Association of periOperative Registered Nurses (AORN) RNFA criteria
(c) Compliance with all statutes, regulations, and institutional policies related to role of RNFA

Training specific to the role of robotic assistant can be pursued through certificate courses offered by Intuitive Surgical. A 1-day course specific to first assistants is offered at a Da Vinci training centers for $250. This course offers hands-on training with the various responsibilities of the assistant to include draping, docking, troubleshooting, and emergency procedures.

First Surgical Assistant Roles

The first assistant's role starts prior to incision. It should begin preoperatively to include knowledge of patient history and surgical indications that may present challenges specific to the individual case. The assistant should ensure any specific instruments or accessories are available. Da Vinci provides procedure cards, guides, and videos for reference, and these should be reviewed until the assistant has gained adequate knowledge of each procedure as well various surgeon preferences.

Proper patient positioning during robotic surgery is extremely important, particularly in the obese population. An improperly positioned patient can lead to injury as well as increased difficulty and duration of surgery. It is a more significant problem to have a patient slide on the OR table during robotic surgery than laparoscopy; because the robot remains stationary, there is subsequently increased tension at the port sites. The robot must be undocked to safely reposition the patient, which leads to significant increases in overall operative time. It is reasonable to place patients in maximal Trendelenburg position prior to draping to ensure that the patient does not slide prior to proceeding with draping. There are multiple devices on the market to decrease patient movement once placed in the steep Trendelenburg unique to robotic surgery. The first assistant should have knowledge of these various devices, as well as adjuncts such as arm sleds or table extenders, and in which patients they may be most beneficial.

The first assistant will also assist in draping the patient. It is important during this step to make sure cords for the various electrosurgical instruments are long enough to reach the instrument throughout each arm's full range of motion. Keeping these cords organized will also make switching instruments more efficient. Placement of the foley catheter, and uterine manipulator if utilized, should be performed following draping but prior to docking. This will allow both items to remain part of the sterile field for easier removal and/or replacement by the second assistant should concomitant procedures such as cystoscopy be necessary.

In traditional laparoscopy, ports for pelvic surgery are typically placed in the lower quadrants of the abdomen. However, to accommodate for the robotic arms, port placement for robotic surgery has seen increasing placement in the upper quadrants as well. Because port placement occurs prior to docking the robotic arms, it is typically performed under direct visualization. However, whether the surgeon themselves or the assistant places these ports, it is executed under the direction of the surgeon. Surgeon preference, comfort with the team, and specific skill level of the assistant will serve to guide this aspect of surgery. Robotic surgery employs up to three surgical arms, plus the camera port, for a max of four robotically occupied port sites. Ports are placed in the lateral aspects of the lower or upper quadrants. This method allows for the third robotic arm to be placed between the umbilical and lateral port, side dependent on surgeon preference and procedure. In this manner, triangulation toward target organ is achieved. Parallel to the third robotic arm, in the contralateral quadrant, we will place either a 5 or 12 mm accessory port. The size of the accessory port is determined by its function. For larger specimen removal, passage of suture with CT-1 needle or greater, morcellation, or need for bowel retractor, we will employ a 12 mm port. For typical suction/irrigation/smoke evacuation type of tasks or small specimen retrieval, we will use a 5 mm.

When deciding the side for the third robotic arm, our preference is to place it on the patient's right side. This allows for a right-hand-dominant surgeon to toggle between two arms with their dominant hand. By extension, the accessory port would now be placed on the patients left side. This orientation allows for a right-hand-dominant assist, sitting on the patient's left side, to use their dominant hand for performance of major surgical tasks. However, this orientation can be altered to best suit both the surgeon's and patient's needs. Normally we use one assistant port with three robotic arms, plus the camera port. However, if only two arms can be docked, due to a narrow patient, uni- or bilateral assistant ports can be placed in the upper quadrants to allow for dual-sided retraction. Once ports have been placed, the robot may then be docked. An experienced assistant can decrease docking time to mere minutes.

Once the robot has been docked, the surgeon is now ready to operate at the console. While the surgeon is executing the procedure, the assistant will remain at the bedside, facilitating every step. If only two robotic arms are docked, the assistant will need to be more active, especially if two assistant ports are used. The assistant port is primarily used for retraction, suction, irrigation, smoke evacuation, and specimen retrieval. The assistant may also need to use other energy sources through the assistant port, such as uni- or bipolar cautery, or even vessel sealing devices, again at the discretion of the surgeon. The assistant port can also be used to pass and retrieve needles. CT-1 or larger can only pass the 12 mm ports, so if smaller assist port is placed, the camera may need to be removed to use this 10 mm port, or the vagina if during a hysterectomy. In addition to these duties, the assistant must also manage the robotic arms.

Robotic arms must be managed to ensure no collision with other arms or the patient. This is best achieved by ensuring 8–10 cm of space surrounding each robotic arm site during port placement, prior to docking. However, if this is not possible, then rotating the arms, so that the elbows face away from each other, even by a few centimeters, thereby adjusting these angles, can help accommodate for this lack of space. The assistant must also clean the camera and exchange robotic instruments. As stated earlier, due to higher port placement, often the robotic ports cannot be visualized during instrument exchange. The robot itself compensates for

this lack of visualization. After confirmation, the instrument is in view of the screen, and not actively holding tissue or retracting, and under direction of the surgeon, the instrument can be removed without activating the port clutch button. This method holds the position of the arm static. As long as the new instrument is replaced, without activating the port clutch button, it will return to the same position, angle, and depth as was the instrument originally removed. While direct visualization of instruments entering and exiting the abdomen is always preferable, this feature of the robot helps compensate for the lack of visualization.

Assistant duties will also vary based on the type of procedure being performed. In most cases, traction and countertraction are key factors to successful execution of surgery. For example, in procedures such as hysterectomy or myomectomy, tissue handling by the assistant is paramount for adequate exposure and suturing. Simultaneously, the assistant may need to maneuver a uterine manipulator if required by the surgeon. Other aspects of surgery for which the assistant may need to be prepared are hand port activities as well as intraoperative cystoscopy, both while the robot is docked. While many of these responsibilities are procedure specific, this additional fund of knowledge and skills adds to the already tremendous role of the surgical assistant.

Specific to gynecology, an important role of the assistant occurs during creation of the colpotomy during hysterectomy. The assistant must be adept at maintaining adequate tension along the cervicovaginal epithelium while concurrently manipulating the uterus in a way to allow adequate exposure for the surgeon to complete the incision. Once the colpotomy is completed, the assistant must then deliver the uterus into the vagina. Depending on the type of manipulator, the specimen and manipulator may be removed in tandem, or a tenaculum may be inserted under direct visualization to grasp the uterus. During this time frame, adequate pneumoperitoneum must also be maintained, so removal of additional specimens should be expeditious. Lastly, the assistant may be required to perform concomitant procedures such as cystoscopy, proctoscopy, or ureteral stent placement under direction of the primary surgeon. While typically performed at completion of the procedure, such evaluation may need to be performed intraoperatively, i.e., while the robot is still docked, so as to assist in identification of these structures prior to dissection. The assistant's ability to perform these procedures allows the primary surgeon to remain at the robotic console and continue to proceed with the procedure in a relatively uninterrupted fashion.

Conclusion

The first assistant is a vital part of every surgical team but is even more important during robotic procedures due to the reasons discussed throughout this chapter. The robotic surgical assistant must have good laparoscopic skills for a variety of intraoperative tasks along with good communication skills that can safely allow for the surgeon to be removed from the surgical field. Their skill set is paramount in the efficient and safe performance of robotic-assisted laparoscopy.

References

1. The Naval Surgeon. n.d.. Retrieved from http://www.pdavis.nl/Ranks.htm#COM.
2. Lelson CW. 100th anniversary of sister Mary Joseph Dempsy. Mayo Clin Proc. 1992;67(6):512.
3. Altman LK. Dr. Michael E. DeBakey, Rebuilder of Hearts, Dies at 99. The New York Times; 2008.
4. American College of Surgeons. American College of Surgeons statement on principles. 2016. From American College of Surgeons: https://www.facs.org/about-acs/statements/stonprin. Retrieved 17 Aug 2016.
5. Anthony R, Lanfranco BA. Robotic surgery: a current perspective. Ann Surg. 2004;239(1):14–21. Retrieved from http://www.roboticoncology.com/history/.
6. American Medical Association. Surgical assistants other than licensed physicians. 2013. From American Medical Association: https://searchpf.ama-assn.org/SearchML/searchDetails.action?uri=%2FAMADoc%2FHOD.xml-0-4320.xml. Retrieved 17 Aug 2016.
7. Association of Surgical Assistants. What does a surgical assistant do? 2015. Retrieved from SurgicalAssistant.org: http://www.surgicalassistant.org/index.php/surgical-assisting/surgical-assisting.
8. Arizona State Board of Nursing. Advisory Opinion Registered Nurse First Assistant-RNFA. 2014. From Arizona State Board of Nursing: https://www.azbn.gov/documents/advisory_opinion/AO%20Registered%20Nurse%20First%20Assistant.pdf). Retrieved 18 Aug 2016.

Tips and Tricks for Robotic Surgery

27

O.E. O'Sullivan, B.A. O'Reilly, and M. Hewitt

Introduction

The introduction of new surgical technology brings with it new challenges for the surgeon and the surgical team. One of those advances is the development of robot-assisted surgery. Intuitive Surgical® released its first robot in 1999, and its efficiency and functionality ensured its wide take-up by a large number of surgical specialities, including gynaecology. Most new advances in surgery represent an evolutionary step, which is often incremental and can be easily adopted by the surgical team. However, the introduction of the robot is widely regarded as a revolutionary step. Such significant advances can be unsettling for the surgical team, and, therefore, the introduction of this novel technology requires appropriate training and supervision to ensure that its application is safe, efficient and fluid.

In this chapter, we describe some valuable tips and tricks, which we believe will make the transition to robot-assisted surgical proficiency as seamless and swift as possible.

Learning Curves

Studies assessing the learning curves associated with robot-assisted laparoscopic colorectal surgery have revealed that it consists of three distinct phases [1]. The first or initial, phase occurs over the first 15 cases. During this phase, the operating time decreases exponentially. The second or plateau, phase occurs over the next ten cases; during this phase, the operator becomes more competent with the robotic technology. The third or the mastery phase occurs during the subsequent cases. During the mastery phase, the complexity of the cases undertaken increases.

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With regard to gynaecological surgery, the learning curves reported range from 20 cases for hysterectomy and pelvic lymphadenectomy for endometrial cancer [2], 50 cases for benign hysterectomies [3] and 10 cases for sacrocolpopexy [4]. In a retrospective review of robotic operating room experience, Pulliam and colleagues found the learning curve was short for surgeons with laparoscopic experience [5].

Ng et al. made the following recommendations to shorten the learning curve. Firstly, have a designated surgical team, with no introduction of new members until 20–50 cases have been performed. Secondly, patient positioning is of paramount importance and should be standardised for all cases. Lastly, familiarisation with the instruments is required before any deviation is considered [6]. The use of dry labs facilitates gaining familiarity with the process of docking, insertion/changing instruments and performing surgical tasks such as suturing, knot tying and dissection. This, combined with gaining experience changing arms, adjusting the camera and the finger controls, makes dry lab training invaluable.

The Si, Si-E and Xi intuitive robots have surgical skills simulators integrated into the system, which allow surgeons and surgical teams to engage in training with system skills exercises and 3D videos to align training pathways to specific surgical specialties. The skills simulator exercises range from basic to advanced and are designed to be relevant to surgeons from all specialties. We would recommend that all new surgeons become proficient on the simulator before they transfer their skills to operating directly on patients. We would even consider that a minimum number of hours or minimum assessment scores are reached before any surgeon is allowed to operate on a patient. Furthermore, this recommendation should be introduced at the time of commissioning of the robot and should apply to all surgeons who wish to use the robot.

Scheduling staff to allow for consistent team presence in theatre is paramount during the initial phase of introducing robotic training. Staff need to work consistently within the team until they become proficient in all aspects of robot-assisted surgery. The team must include anaesthetics, nurs-

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ing and the surgical team. The anaesthetist must be familiar with the potential complications associated with robot-assisted gynaecological surgery and its associated positioning. It is of paramount importance that the anaesthetists know that they cannot move the operating table once docking has taken place, unless the operating table is paired with the da Vinci Xi system. Pushing the articulating buttons in all four arms of the da Vinci Si and S systems will also allow movement of the operating table without undocking the arms. Nursing staff must be familiar with setting up and draping the robot for surgery and image alignment. Furthermore, the entire team needs to be proficient in emergency undocking of the robot. All staff must be familiar with the emergency undocking drill, the role they play and the need for clear communication. With this in mind, O'Sullivan et al. developed a simple logarithm clearly defining the role of each staff member depending on the emergency in question [7]. To decrease the time to undock the robot, assuming the instrument has been removed from the body cavity, trocars can be removed while they are still attached to the robotic arms providing the articulation button is pressed and the arm is pulled in the same axis as the trocar.

Case Scheduling

During the initial/learning phase, due care should be given to patient and case selection while scheduling theatre lists. During this phase, all aspects of the surgery will take longer, including set-up of the robot, patient positioning, anaesthetic time, docking, console time and undocking and theatre clean-up. Overburdening the surgical list with complex cases will lead to cancellations, which ultimately frustrates the entire surgical schedulers and decreases the team's enthusiasm for the technology. We advise careful patient selection. For example, consider performing cases like a bilateral salpingo-ophorectomy on a woman with no comorbidities and a normal body mass index initially. While initially it will take longer than conventional laparoscopy, it will ultimately allow the team to gain confidence in the robot-assisted approach before more complex cases are undertaken. During this initial phase, a further consideration when listing patients for hysterectomy is the ease with which conversion to either vaginal or a laparoscopic approach can occur if required. Once the initial phase of the learning curve is complete, the complexity of the cases on any given list can increase.

It is important to engage with hospital management to manage expectations and to inform them that during this learning phase, patient throughput and efficiency will decrease. This will need to be taken into account when managing theatre waiting lists.

Undergoing the first robotic cases
Choose a medically fit and slim patient
Choose an easy procedure
Rehearse the theatre layout and docking
Have an experienced proctor and intuitive representative present in theatre
Have an emergency undocking protocol in place
Work with the same assistants and theatre staff
Only schedule two cases for per day initially
Undertake as many cases as possible over the following 6 months

Patient Consent

The surgeon has an ethical obligation to explain to any patient consenting for robot-assisted surgery that it is a new tool and that the surgeon and surgical team are in training. The patient should be offered an alternative approach. In our experience, no one declined the option of undergoing robotic surgery during the initial/learning phase.

The patient must be informed that the surgery may potentially take longer and that this may be associated with an increased risk of complications secondary to the longer operative time. However, with appropriate preparation and training on the console, the increased risks to the patient can be minimised.

Anaesthetic Considerations

Where possible, the anaesthetic room should be used to anaesthetise the patient rather than the operating room. This facilitates draping and prepping of the robot by the surgical team in tandem with induction of anaesthesia. This decreases theatre time, increases efficiency and allows more cases to be done in any given day. Furthermore, the patient is not exposed to preparation of the robot; some patients find the high-tech nature of the robot overwhelming.

Operating Table Positioning and Robot Placement

Prior to the first case, we recommend rehearsing docking to establish the optimal configuration of the theatre with regard to positioning of the theatre table relative to the cart, stack, satellite screen and assistant/nurse. Marks can be placed on the floor to allow for accurate operating table placement. If the theatre is large enough, the ideal situation is to have the robot directly aligned with the docking position so minimal turning of the cart is required to dock. If this is not possible, a plastic template placed on the floor can be used to achieve the same docking for every patient without requiring verbal

commands. Initially the same person should drive the robot cart to gain familiarity with the docking procedure, increase speed of docking and minimise errors.

During docking while the cart is manoeuvred across the floor, the surgeon and first surgical assistant should use the articulation button to avoid the robot's arms clashing with the patient or theatre equipment.

The anaesthetist should be aware that the degree of Trendelenburg achieved will be inversely proportional to the duration of surgery, i.e. more head down leads to easier and thus quicker surgery. The anaesthetist should be able to continuously check the patient's ability to tolerate maximum Trendelenburg, which can compromise ventilation, and should liaise with the surgeon prior to commencing docking to discuss the necessary positional adjustments. Patient positioning is of great importance to minimise the potential adverse outcomes associated with potentially long operative times. In one study, there was a 6.6% incidence of nerve injury (almost a quarter of which persisted more than 6 months) associated with malpositioning during urological robotic surgery. The injury rate was significantly associated with longer operative times and ASA grade (American Society of Anaesthetists physical status classification system). Therefore, patients undergoing long surgeries should be counselled regarding the risk of nerve injury especially if they have multiple comorbidities [8].

Communication

A safe working operating room should avoid unnecessary noise pollution, thus allowing the surgeon to concentrate and to facilitate clear communication between the theatre team members. When placing instruments, the name of the instrument, the arm and the power source should be clearly relayed to members of the team. As with conventional laparoscopic surgery, instruments should only be introduced into the abdomen under direct vision. We would recommend that when removing any instrument, all instruments are free, within the field of view and not grasping tissue within the abdomen. This will avoid tearing of tissue if the incorrect instrument is accidentally removed. Making very gentle movements with the instrument while keeping the other instruments stationary can help the assistant identify the correct instrument to be removed.

Attaching power cables to instruments prior to insertion into the abdomen avoids accidental pressing of the articulation button, which could cause the instrument to be inadvertently advanced further into the abdomen causing visceral injury. If a cable is to be attached with the instrument in place, we recommend that its tip be well clear of vessels and viscera.

If the hospital is new to laparoscopic major surgery, it is also important to engage the ward staff. In order to fully exploit the financial savings offered by shorter inpatient stays and to offset the cost of the robot, it is imperative that the patients are discharged as soon as they are fit. The patient should be informed in clinic that they will be discharged the same or the following day, and on arrival onto the ward, the nurses should reinforce this information to the patient, and this expectation should be relayed at every point of contact with the patient. We recommend that the urinary catheter be removed in the recovery room or early the following day allowing the patient to be discharged early.

Communication
Keep unnecessary noise and talk to a minimum
Check speaker and microphone levels
Make all communications clear and precise
Engage with ward nursing staff
Keep management up to date with the developing robotic programme

Instrument insertion and removal
Always under direct vision
Attach power cables before insertion
Clearly communicate which instrument is to be removed
Free all instruments from tissue attachment before removal of any instrument
Use the memory function to reinserting instruments
The robot arm still retains memory if moved so long as no button is pressed

Port Placement

The actual port placement varies depending on the operation, the target organ size and the potential for concomitant surgery. A suitable port placement guide for hysterectomy and sacrocolpopexy is shown in Fig. 27.1a, b. A simple rule of thumb when placing ports for hysterectomy and lymph node dissection is to place two hands next to the lateral port and the camera port framing the area between which is the ideal location for the next port (Fig. 27.2). When performing pelvic sidewall surgery, the lower ports should be placed as lateral as possible to assist with such surgery. We recommend that the assistant's free port be placed cranial to the robot ports to allow easier insertion of a free grasper or suction. To reduce postoperative pain, care needs to be taken that the robot trocars are inserted and placed perpendicularly and slightly pointing towards the operating field and not tracked along the abdominal wall—often called Z-ing of the trocar. A tip to ensure the skin incision is appropriate to the port size is to remove the trocar from the port and use the port to mark the skin. The skin incision should follow the natural Langer's lines.

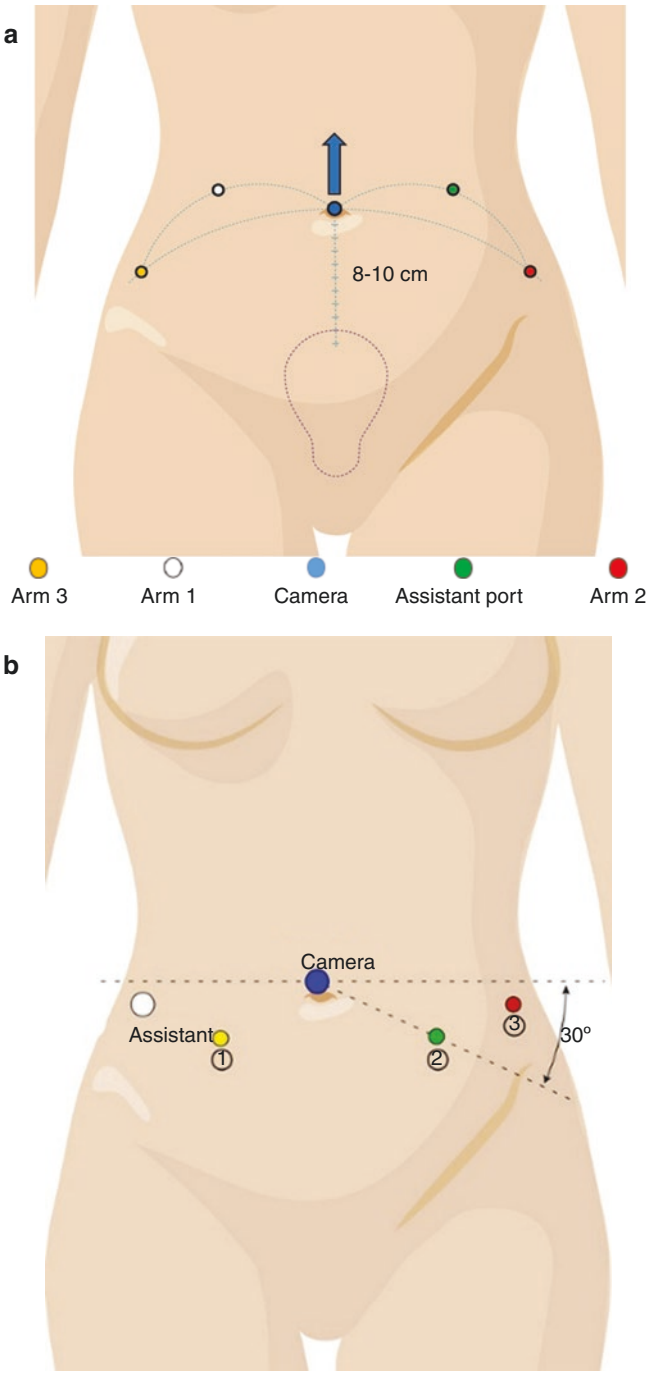

Fig. 27.1 (**a**) Port position for a hysterectomy with the cart docked from the patients right. The *blue arrow* indicates that the camera port should be placed supraumbilically if there is a large uterus or the symphysis umbilical distance is short. (**b**) Port position for a sacrocolpopexy docked from the patient's left

Prior to sitting at the console after docking, it is important to perform a secondary survey. The surgeon should complete this looking specifically at the arm and instrument placement, to ensure there will be no clashing of robot arms with each other or against a patient's arm or leg during the procedure. The surgeon should also review the position of each of the assistant's stool height and the screens available for all assistants to ensure that the team is as comfortable as possible. When operating within the pelvis, the tips of the instruments will be facing downwards such that the opposite end of the instrument will be well clear of the patient's arms. If there are anterior wall adhesions that need to be divided, the instruments will take up a reverse position such that the instruments can be facing upwards with the risk that they can press against the arms of the patient. This could potentially harm the patient.

Condensation build up on the camera can be avoided using the following tips:

- Ensure the camera is warm (place the camera into warm water prior to entering the abdominal cavity).
- Remove the gas tubing from the camera port and place it on the assistant port.
- Ensure the FRED antifog solution is placed indirectly in line with the camera port to ensure when the camera needs to be removed and cleaned; it is easily reachable and reduces the time taken to do this (Fig. 27.3).

Once the robot is docked and prior to insertion of the instruments, the robot arms including camera arm should be pointed towards the operating field. At this point, if the patient's skin is puckered and the trocars are 'digging in', we recommend a slight adjustment or as we say a 'burp' of the robot arm to adjust its position so it is no longer impinging into the skin (Fig. 27.4).

Conversely, if the robot arms are clashing, then they can be separated a short distance by doing the opposite to a 'burp' and separating the trocars by a few centimetres. Care must be taken that instruments are not within the patient when these manoeuvres are being performed as the instrument tips will move and potentially cause damage to abdominal structures.

We use a Veress needle to obtain a pneumoperitoneum via the umbilicus. We only make a small incision at this point to allow access for the Veress needle. After insufflation, we decide the position of the camera port, which may often be supraumbilical.

If the patient has had a midline incision, we insufflate via Palmer's point. If we are confident we can complete the surgery, we will use a camera-sized port and the robot camera at this point to then insert the remaining trocars before transferring the camera to the midline. This initial camera port then becomes the surgical assistant's free port. If we are unsure as to the suitability of the patient of surgery, we will use a 5 mm camera at Palmer's point and will not drape the robot until a full assessment has been made with conventional straight-

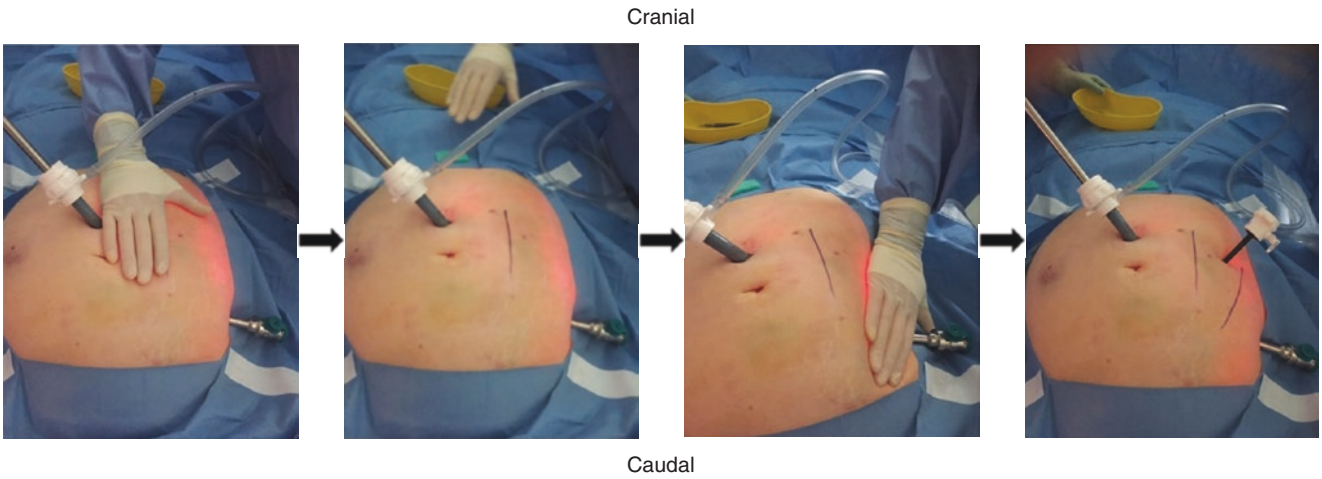

Fig. 27.2 Using a handbreadth and a pen to mark a zone between the camera port and the robot lateral port to guide the position in which the assistant port can be placed. The same principle can be used on the left to position the two robot ports

stick instruments. This will save the cost of the drapes if surgery cannot be completed.

Port placement
Handbreadth apart
Insufflate before deciding on the location of the camera port
Robot trocars can be used for straight-stick instruments
Point arms/trocars towards the operating field and check for skin indentation/puckering
Use Palmer's point for insufflation and then the assistant's port in presence of a previous midline laparotomy
Place all trocars higher than normal for the large uterus

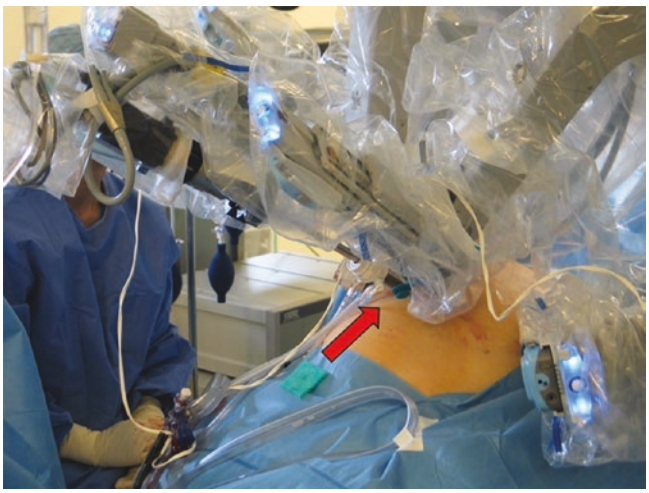

Fig. 27.3 The FRED antifog solution should be placed as close to the camera port as possible

Obese Patients

As with all modalities of surgery, the obese patient provides unique challenges to the surgical team. In extremes of obesity, where there may be anaesthetic concerns, delay draping the robot until insufflation has occurred and the patient is in Trendelenburg. If the anaesthetist decides that surgery is not safe to continue, then the drapes remain wrapped and unused and ready for the next patient.

Although we have found that trocar length is always sufficient to cope with even the most obese patient, when the trocars are attached to the robot, they will often be inadvertently withdrawn slightly when the cart is attached such that the tip disappears into the patient's abdomen wall. We suggest that in the obese patient the trocars are fully inserted well beyond the black guide marker until docking has been achieved and then withdrawn under camera control for fine adjustment.

We recommend an additional second assistant port, which can be used as access for an additional retractor (Fig. 27.5). An extra port will not significantly increase the pain encountered and increased bed stay but may reduce the overall time of surgery. The location of the first assistant's port is important to allow access for the second assistant's port, but the obese patient's abdomen should allow space for both to be placed without clashing of the instruments.

We do not normally recommend bowl prep, but in the obese patient, this may facilitate greater access to the pelvis by reducing the volume of bowel contents allowing it to fall into the upper abdomen on placing the patient in Trendelenburg.

Surgery on obese patients should only be attempted when the team is proficient in the use of the robot. In par-

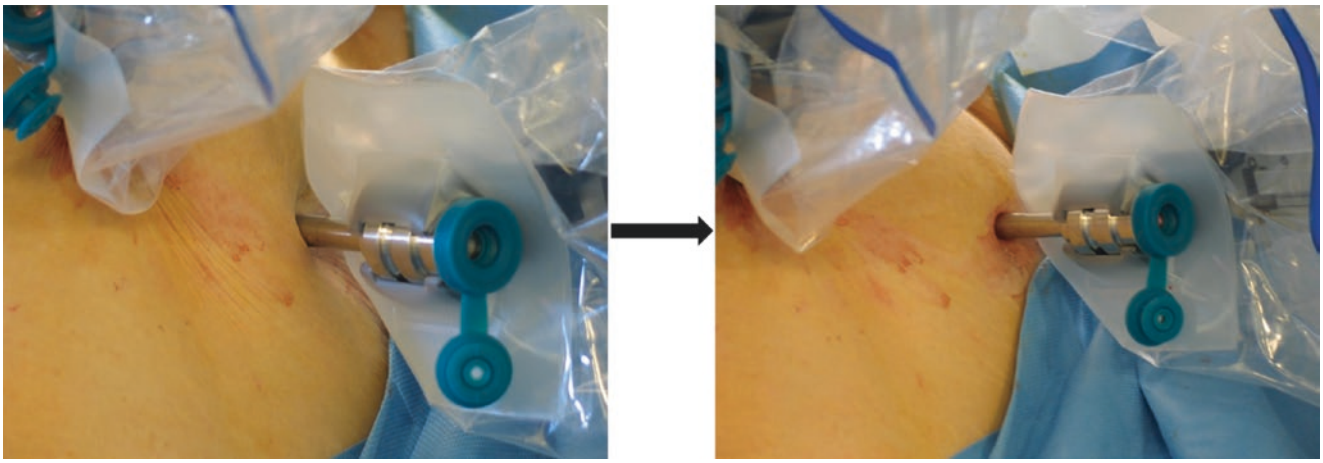

Fig. 27.4 The *left-hand picture* shows puckering of the skin and abdominal wall. Following a minor adjustment or 'burp' of the arms, they can move to a more natural position on the abdominal wall and thus potentially reduce pain. If arms are clashing, the reverse can be undertaken to separate the robot arms to reduce clashing

ticular, the anaesthetist is vital in facilitating the maximum Trendelenburg.

The obese patient
Do not attempt such a case until proficient with the robot
Do not drape the robot until head down and Trendelenburg is achieved
Use two assistant ports
Encourage the anaesthetist to give the maximum Trendelenburg possible
Consider bowel prep
Consider suturing bowel/bladder out of the surgical field

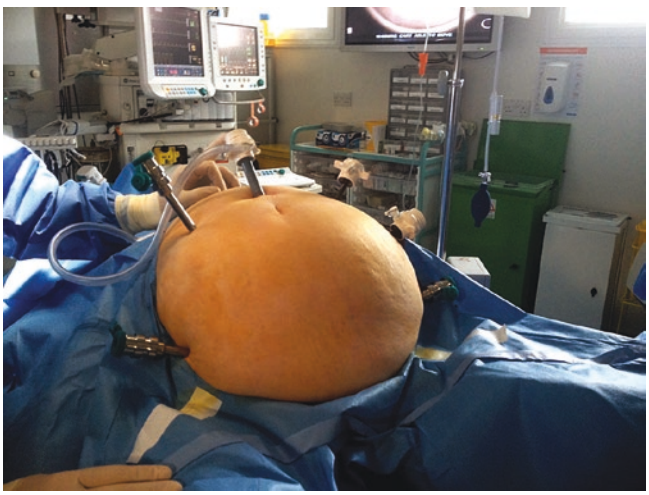

Fig. 27.5 Port position with an obese patient showing the two assistant ports on the patient's left-hand side

Proctor

A proctor should be present for a minimum of three to five cases depending on the skill level and experience of the surgeon. Intuitive Surgical will provide a registered, experienced proctor. To facilitate acquisition of skills, it is imperative that the first few cases are undertaken with only a short period of time between them. Ideally, a minimum of two cases a week should be undertaken on consecutive weeks for a minimum of 6–10 weeks. As with all surgery, loss of attained skills is reduced when techniques and procedures are repeated frequently and often. After each case, a 'time out' should be held involving the whole team to discuss in detail all aspects of the set-up, docking and the surgery. Constructive criticism and feedback should be given by all members of the team to each other to improve the outcome of the next case.

Surgeon Ergonomics

There is limited primary data regarding the effect of the robot on surgeon morbidity and discomfort. A pilot study by Lawson et al. [9] which assessed the differences between musculoskeletal discomfort and ergonomic strain in laparoscopic versus robotic surgery for gastric bypass surgery found that robotic cases were associated with more discomfort in the neck, while laparoscopic cases were associated with greater discomfort in the upper back and in both shoulders. Furthermore, analysis of ergonomic positioning during the procedures found that robot-assisted surgery scored lower for trunk positioning [9]. Thus ensuring the stool height and the console height that are appropriate to the sur-

geon will reduce the impact on the surgeon's lower back and neck. The armrest should be in use all the time by use of the clutch pedal to bring the master controls to a comfortable level with the forearms comfortable and placed firmly on the armrests—not the elbows! Infrequent use of the clutch pedal would suggest the surgeon is not using the robot appropriately in terms of comfort levels.

The surgical assistants must not be forgotten, and they should be afforded space to move and a seat to use. A screen for the assistants needs to be placed at an appropriate height.

Surgeon ergonomics
Constantly use the arm rest
Avoid unnecessary pressure of the surgeons head on the head rest
Set stool and console height appropriately
Use frequent clutch control to avoid hyperextension and flexion of the elbows
Check if all assistants are comfortable and have view of a screen
Take a short break during a difficult case

During the Surgery

Side docking is now our preferred mode as this allows access to the vagina during surgery. We also find it is less claustrophobic for the 'in-between-legs' assistant (Fig. 27.6).

Choice of instrument is paramount to the success of the procedure and also to the overall cost of the procedure. Therefore, prior to the case, consideration should be given to the instruments required, i.e. are two needle drivers needed for suturing or can a grasper be used instead? We find suturing with just one needle driver, and using the Maryland grasper is easy and reduces instruments costs.

While performing the surgery, the surgeon can utilise the third arm to great effect in anteverting/retroverting and manipulating the uterus to the left or right. A large boggy uterus can be forced into acute anteversion using the third arm placed behind the body of the uterus facilitating access to the pouch of Douglas (Fig. 27.7). The articulation of the third arm can be used as a hook particularly when performing the colpotomy on a hysterectomy.

A straight needle can be used to suture the bladder or the bowel to the anterior abdominal wall if this is repeatedly falling into the surgical field.

During a hysterectomy, where there is adherence of the bladder due to, for example, previous caesarean section or during dissection of the bladder of the vault during a sacrocolpopexy, the demarcation of the bladder can be difficult to ascertain. Filling the bladder with normal saline can easily help identify its position. Alternatively, where a bladder injury is suspected, the use of methylene blue can help identify a cystotomy and allow for intraoperative repair.

Another issue encountered during surgery is enlarged bulky ovaries, which limit the access to the pelvis by the surgeon. Draping the ovaries over the third arm while it is manipulating tissue can improve visualisation of the rest of the pelvis. An alternative option is to remove the ovaries and place them in the pouch of Douglas until the end of the surgery.

During the course of surgery, instruments may need to be exchanged. The robot arms may be positioned in such a way that it is difficult to insert the new instrument through the trocar because the angle of the arm may obscure the view of the trocar orifice. When an instrument

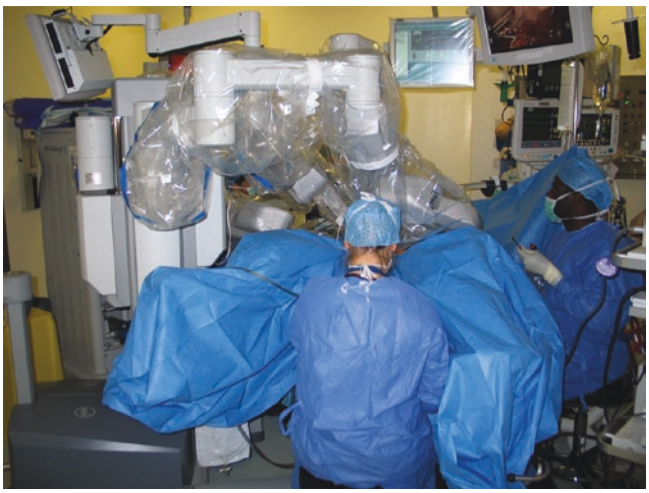

Fig. 27.6 A 'between the legs view' of a patient right side dock approach. This allows easy access to the vagina

Fig. 27.7 The use of the third arm to keep the uterus in acute anteversion which enables the posterior colpotomy to be undertaken. This is particularly useful in the large boggy uterus

is removed from a trocar, the robot arms may be moved by the assistant without the loss of memory. The arm can be moved by the assistant to allow visualisation of the trocar orifice and insertion of the new instrument. On releasing the robot arm, this will return to the 'memory position', and then the instrument can be pushed into the abdomen with the green memory light indicating the memory feature is still active.

During 'dead time' (e.g. during coagulation of large vessels), the surgeon is performing no other actions, and we recommend minor adjustments are made by pressing the clutch pedal, to reposition the surgeon's arm for comfort or readjust the camera slightly ready for the next manoeuvre.

Occasionally tissue may be out of reach of one of the instruments. If this situation occurs, grasp the tissue with an instrument that can reach the tissue and pass it to the instrument that could not.

Clashing of robot arms can be avoided by deployment of the various techniques already discussed. In general, robot arm clashing while operating in the midline suggests that port placement and robot arm positioning is suboptimal. It is only when operating at the extremes of the abdomen that clashing can occur. If access to an area of the abdomen is not possible due to robot arms clashing with each other, it can help if the surgeon performs a review of the position of the robot arms by leaving the console and looking directly at the patient. This should facilitate readjustment of the robot arms and allow surgery to proceed.

Regardless of how the robot is set up, if two robot arms are placed on the same side of the patient's abdomen, they will be at risk of clashing externally or limiting the range of the operating space of the other instrument. An example of this occurs during reflection of the bladder in a situation where arm 1 and 3 are positioned on the right side of the patient. Grasping the bladder peritoneum with instrument 3 and articulating the instrument tip at right angles to its shaft pointing downwards will increase the area in which instrument 1 can move (Fig. 27.8).

We find in easy surgeries that the needle driver can be used throughout the surgery as the manipulation third instrument arm. This will mean that only three instruments are used during the surgery rather than four, which is more economical.

Clashing of robot arms
Space ports at least a handbreadth apart
'Burp' the ports if they are too close together
Get an external view of the patient to see where clashing is occurring
In a very thin patient, place the lateral upper ports cranial to the camera port
Operating at extreme locations increase the risk of clashing of instruments

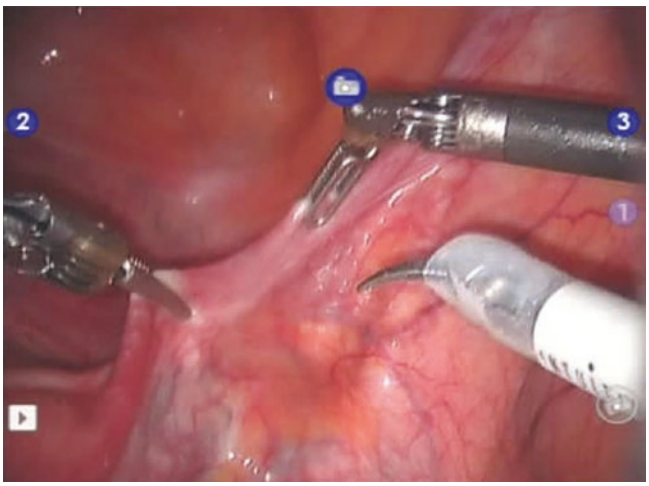

Fig. 27.8 The fenestrated grasper in arm 3 is grasping the round ligament while articulated to near 90° and pointing posteriorly. This allows increased space beneath this instrument in which the scissors in arm 1 can work

The Big Uterus

A large fibroid uterus imparts significant challenge when undergoing hysterectomy.

High placement of all trocars including the camera arm is essential to allow the surgery to be completed. A low camera port will limit overall view. If the lower trocars are placed too low, they will not allow the instruments to reach the opposite side of the uterus. An initial assessment may give the impression that the surgery is not possible. It is our experience that by dividing the round ligaments and ovarian vessels, the uterus begins to fall cranially allowing more access to the lower vessels and cervix, so it is important not to abandon the surgery too early. Classically, when performing the anterior colpotomy, we place the uterus in retroversion and the camera in the midline over the anterior surface of the uterus. This may not be possible with a large uterus as the sacral promontory may inhibit retroversion. Consequently, the camera may not reach over the uterus to visualise the anterior vagina in the midline. In this situation, we reflect the bladder from the cervix and reach the vagina by passing the camera down the side of the uterus. This approach is made possible by using arm 2 and 3 to reflect the uterus laterally.

If accessing the cervix is difficult, consider performing a subtotal hysterectomy after dividing the uterine arteries and then remove the cervix when the uterus has 'fallen' into the upper abdomen.

We would recommend that morcellation of the uterus is undertaken after undocking the robot and using a handheld camera.

Ultimately, the size of the uterus may preclude laparoscopic removal. We find a long thin uterus can be removed,

but a wide uterus impacted in the pelvis that restricts access to the pelvic sidewall presents the biggest challenge.

At the End of Surgery

We believe that all members of the team should have a role in preparing the operating room for the next patient after the surgery has finished, and this not only includes the nursing staff but also the medical staff. As the surgeon is not scrubbed, we recommend that they drive the robot cart back away from the patient after it has been released from the trocars. As the first assistant is already scrubbed, we recommend they should suture the port sites. The surgeon can undrape the robot by straightening each arm in turn, releasing the drape ties and then releasing the sterile adaptor. The drape can then be rolled around the sterile adaptor. This will collapse the drape and avoid air being trapped within it and allow it to be disposed of in a smaller container or bag (Fig. 27.9). Releasing the sticky tapes that hold the drapes in place is easier if they are not stuck to themselves but to the drape itself (Fig. 27.10).

Fig. 27.9 Once the stickers on the drapes are released, the drape can be rolled up easily which expels the air from the drape which enables easier disposal

When the arm is fully extended, it is exposed and very vulnerable. It can easily be banged by a person or an object, e.g. the opening of a door, so it should not be left in position for any length of time. To increase the turnaround of the theatre, we recommend that no member of the medical staff is allowed to leave the theatre until the patient has departed the theatre. This will encourage them to help to tidy the theatre.

Care should be taken to document the numbers of uses for each instrument to allow timely ordering of replacements and the unnecessary sterilisation of expired instruments.

At the end of surgery
Console surgeon drives the cart and undrapes
First assistant stays with patient and sutures
Second assistant checks vagina for bleeding and retained swabs and completes pathology forms
Scrubbed nurse assists suturing
Runner nurse removes instruments for cleaning and checks lives remaining

Robot Malfunction

A recent survey of urologists on intraoperative robot malfunction found that breakdown intraoperatively is uncommon. However, it does occasionally occur highlighting the need to counsel patients and to have a contingency plan. Studies recommend conventional laparoscopic suturing skills should be maintained as a requirement on the curriculum, thus allowing the surgery to continue using minimally invasive approach if required [10]. All surgeons performing robotic surgery must become familiar with troubleshooting robotic technology and associated equipment. Failure to do so may add time and technical difficulty to robotic cases [11]. Of note, the failure rate decreases with increased operator and team experience [12]. Checklists have been used as an intervention to

Fig. 27.10 If the drape stickers are applied to the drape and not attached to their opposite ends, this enables them to be removed more easily

prevent these failures by promoting a teamworking culture, standardising practice, allowing the detection of potential errors and improving patient safety as a whole. This further substantiates the point that surgeons need problem-solving training. Common malfunctions occurring when instruments are inserted and fail to be recognised are shown in the following table.

Malfunctioning instrument checklist
Instrument expired
Trocar not fully attached to robot
Sterile adaptor not fully attached to robot arm
Master controls too close to each other
Robot arm clashing with another robot arm or the patient
Instrument not fully cleaned with dried blood clot inhibiting movement
Monopolar insulator cover not applied correctly
Use a known functioning instrument in the malfunctioning arm to determine whether the malfunction is due to the instrument or the arm/trocar

Conclusions

As with any new piece of equipment, experience will increase the familiarity and efficiency of its use, and nothing can replace console time. Keep the same team for the first few cases including both nursing and medical staff. Only attempt difficult cases when proficient with the use of the robot and enjoy your surgery.

Acknowledgement We would like to thank all the nursing, anaesthetic and junior staff in the Cork University Maternity Hospital that have made our robotic programme possible.

References

1. Bokhari MB, et al. Learning curve for robotic-assisted laparoscopic colorectal surgery. Surg Endosc. 2011;25(3):855–60.
2. Seamon LG, et al. A detailed analysis of the learning curve: robotic hysterectomy and pelvic-aortic lymphadenectomy for endometrial cancer. Gynecol Oncol. 2009;114(2):162–7.
3. Lenihan JP Jr, Kovanda C, Seshadri-Kreaden U. What is the learning curve for robotic assisted gynecologic surgery? J Minim Invasive Gynecol. 2008;15(5):589–94.
4. Akl MN, et al. Robotic-assisted sacrocolpopexy: technique and learning curve. Surg Endosc. 2009;23(10):2390–4.
5. Pulliam SJ, Weinstein MM, Wakamatsu MM. Minimally invasive apical sacropexy: a retrospective review of laparoscopic and robotic operating room experiences. Female Pelvic Med Reconstr Surg. 2012;18(2):122–6.
6. Ng JS, et al. Gynaecologic robot-assisted cancer and endoscopic surgery (GRACES) in a tertiary referral centre. Ann Acad Med Singapore. 2011;40(5):208–12.
7. O'Sullivan OE, et al. Da Vinci robot emergency undocking protocol. J Robot Surg. 2016;10(3):251–3.
8. Mills JT, et al. Positioning injuries associated with robotic assisted urological surgery. J Urol. 2013;190(2):580–4.
9. Lawson EC, Curet MJ, Sanchez BR, Schuster R, Berguer R. Postural ergonomics during robotic and laparoscopic gastric bypass surgery: a pilot project. J Robot Surg. 2007;1(1):61–8.
10. Kaushik D, et al. Malfunction of the Da Vinci robotic system during robot-assisted laparoscopic prostatectomy: an international survey. J Endourol. 2010;24(4):571–5.
11. Finan MA, Rocconi RP. Overcoming technical challenges with robotic surgery in gynecologic oncology. Surg Endosc. 2010;24(6):1256–60.
12. Nicolas C. Buchs, François Pugin, Francesco Volonté, Philippe Morel, (2014) Reliability of robotic system during general surgical procedures in a university hospital. The American Journal of Surgery 207 (1):84–88.

Index

A. El-Ghobashy et al. (eds.), *Textbook of Gynecologic Robotic Surgery*, https://doi.org/10.1007/978-3-319-63429-6