Minimally Invasive Urology

An Essential Clinical Guide to Endourology, Laparoscopy, LESS and Robotics

Sara L. Best
Stephen Y. Nakada
Editors

Second Edition

Springer

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ISBN 978-3-030-23992-3 ISBN 978-3-030-23993-0 (eBook)
https://doi.org/10.1007/978-3-030-23993-0

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

The first edition of *Minimally Invasive Urology* sought to provide an encompassing guide to all aspects of minimally invasive urology, from laparoscopic and robotic surgery on the urinary tract to endourologic procedures. With the second edition, we have added several new authors as well as new chapters about alternative minimally invasive techniques for the management of benign prostatic hyperplasia, as well as an in-depth review of instrumentation for stone surgery. The chapters contain revised "equipment lists" and tips and tricks for the practicing urologist, covering a broad spectrum of urologic disease.

We the editors are grateful to the contributing authors for sharing their expertise, and we hope you enjoy this second edition of *Minimally Invasive Urology*.

Madison, WI, USA

Sara L. Best
Stephen Y. Nakada

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Laparoscopic and Robotic Access

1

Andrew Bergersen and Benjamin R. Lee

Initial access into the peritoneal cavity is one of the most critical steps of any laparoscopic and robotic case. It is often overlooked in its importance within the overall success of the operation. If not performed correctly, laparoscopic access may be fraught with complications, adding to the potential morbidity and mortality of any case. In this chapter, we will review the various methods of laparoscopic and robotic access, as well as the potential complications. The technique is similar between the two minimally invasive modalities. Gaining access in laparoscopic and robotic surgery is the first step toward a successful surgery. With optimal placement of trocars and establishment of pneumoperitoneum, the subsequent execution of the procedure may be carried out in an ideal fashion, with the best possible chance of success.

There are two main types of laparoscopic and robotic access: open and closed. The closed approach is commonly referred to as the Veress technique, while the open approach is also known as the Hasson technique. Each has their associated advantages and disadvantages. Our preference is the Veress technique due to its efficiency, ease, and simplicity. There is also a technique known as direct trocar insertion, which is not commonly used. The major complications of any access are the potential risk for injury to the bowel and the great vessels in the retroperitoneum and the less threatening complication of damage to blood vessels in the abdominal wall, which rarely can create a source of troublesome bleeding, requiring transfusions and return to the operating room. Alternatively, the dissection of the preperitoneal space is of minor consequence and the gas is easily resorbed upon further insufflation in the correct cavity. Furthermore, some of these injuries may not be recognized until the postoperative period, thereby increasing the associated morbidity. In the early learning curve, a significant proportion of the complications related to laparoscopic surgery occur during access and port placement [1], which decreases with experience [2].

Prior to any of the techniques for trocar placement, one should make sure to decompress the stomach with a nasogastric or orogastric tube, and a Foley catheter should also be placed to drain the bladder. These steps reduce the chance of injury to the GI tract and bladder due to distension.

The closed technique employs a Veress needle to gain peritoneal access. The Veress needle is actually named after the Hungarian physician, Janos Veres, who died in 1979 at the age of 76. He was a pulmonologist who invented the Veress needle in 1932. At that time, there was a high inci-

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S. L. Best, S. Y. Nakada (eds.), *Minimally Invasive Urology*,
https://doi.org/10.1007/978-3-030-23993-0_1

dence of tuberculosis, and one of the accepted treatments at that time was creating an iatrogenic pneumothorax by puncturing the pleural cavity. This technique was fraught with complications, often with direct injury to the lung. Janos Veres invented a spring-loaded dual-needle system: one with a blunt tip that comprised the inner core and the other a sharp needle that made up the outer core (Fig. 1.1a). The blunt needle would retract when faced with the resistance of the skin and underlying costal muscles and would spring forward again once inside the pleural space, thereby protecting the viscera of the lung. In 1936, Veres published his experience of over 900 successful interventions. However, it was not until the 1970s, with the gaining popularity of endoscopy, that Veres's contributions were widely appreciated [3].

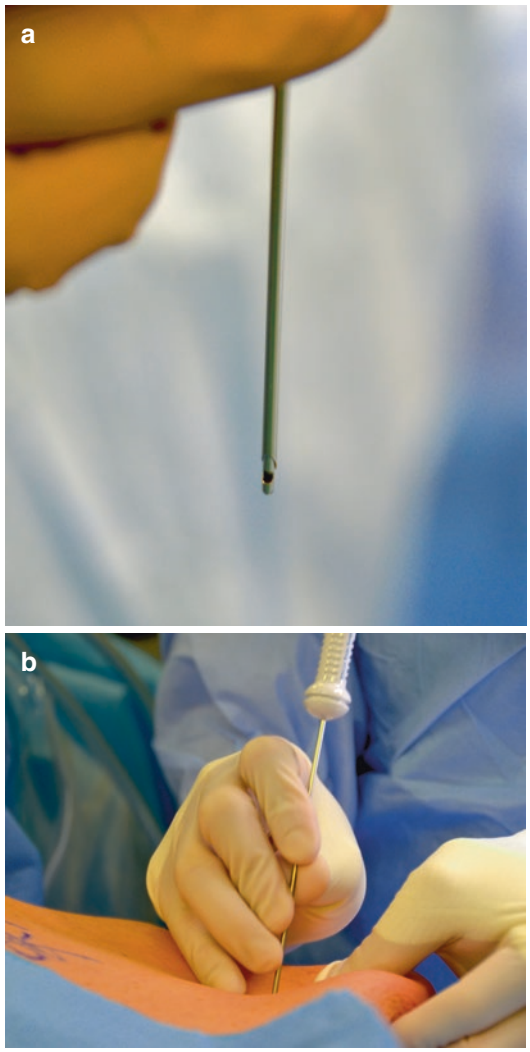

Fig. 1.1 (**a**) Veress tip—spring-loaded inner core retracts once the tip of the Veress needle traverses the muscle and enters the abdominal cavity. (**b**) Veress placement. Holding the Veress securely helps in accurate placement. Opening pressures of the pneumoperitoneum should be less than 10 mmHg

Today, the Veress needle has a bore of 2 mm and comes in lengths from 12 to 15 cm. It works on the exact same premise of an outer beveled needle with an inner spring-loaded stylet that springs forward again upon entry into space as described by Veres over 75 years ago. The Veress needle is the most common method used to gain peritoneal access. Out of 155,987 gynecological laparoscopic procedures, the Veress technique was used to gain access in 81%. Alternatively, out of 17,216 general surgery procedures, the Veress needle was used for access in 48%, whereas 46% employed the Hasson technique (the remaining 6% were accessed via the direct trocar insertion technique) [4].

The most common site of placement of the Veress needle is at the umbilicus. This is because this is the only location in the abdomen where there is no muscle or fat between the skin and peritoneum. Previous scars near this site, or a site on the abdomen, should dictate that the Veress needle be placed in another location—typically a minimum of 6 cm from the scar. Umbilical hernia is a contraindication to placement of the Veress needle in this location. Furthermore, the Veress needle may be introduced at any point throughout the abdomen and is usually based on surgeon preference and comfort level, as well as regard to the procedure being performed. It is always wise to study available imaging to check for anatomic abnormalities or variations, such as hepatomegaly or splenomegaly. Also, one should remember that if the patient is in the flank position, needle placement too far laterally can result in retroperitoneal insufflation. Selection for placement of the Veress needle should be away from subsequent first trocar location placement, since introduction of the trocar will push down on the abdominal wall, with consequent potential advancement of the tip of the Veress needle downward toward bowel.

The main advantage of using the Veress needle is quicker entry into the abdominal cavity, as well as a potentially reduced risk of a port-site hernia. The disadvantage of the Veress needle is a slightly increased risk of complications due to its blind placement, such as bowel insufflation or bleeding, albeit a rare occurrence.

It is important that the stopcock on the Veress needle be open during its passage; this allows for the entry of air through the needle so that the bowel and omentum drop away from the elevated anterior abdominal wall. There are several ways to determine successful placement of the Veress needle in the peritoneal cavity (Fig. 1.1b):

1. Two "clicks"—two clicks are usually heard upon successful passage into the peritoneal cavity. The first click is heard when the needle traverses the fascia of the abdominal wall and the second as it is passed through the parietal peritoneum.
2. Aspiration—a saline-filled syringe is attached to the Veress needle and aspirated to make sure there is no return of blood or succus. If either of these contents is aspirated, the Veress needle can be removed with plans for careful inspection of intra-abdominal contents once the peritoneal cavity is safely accessed.
3. Hang drop—it involves placing a drop of saline on the external surface of the Veress needle. If the saline drops quickly down the needle and disappears, then the needle is likely properly placed within the peritoneal cavity
4. Low opening insufflations pressures—once the needle is in place and the CO_2 insufflation is begun, opening pressures below 10 mmHg generally confirm correct placement. Starting with a low flow of gas, confirming opening pressures <10 mmHg, and then increasing the gas flow rate is the most common and preferred approach by the authors.

Some surgeons may use a combination of the above techniques. The two "clicks" and low opening pressures obviously should be experienced upon every successful placement. There are some physicians who choose to omit the aspiration and hang drop test. A retrospective study did report that the double click, aspiration, and hang drop test were not confirmatory for proper placement of the Veress within the peritoneum. The same study reported that low opening insufflations pressure, less than 8 mmHg, was the most reliable method for confirming intraperitoneal placement [5]. The hang drop test may prove to be additionally helpful in confirming proper placement in morbidly obese patients, when opening insufflations pressures may be borderline high or equivocal simply due to the higher resting pressures created by the compression of the abdominal cavity by a very large pannus.

Some surgeons perform the "waggle" test, in which the needle is moved from side to side. They believe that free movement of the needle tip indicates a properly placed needle. However, this maneuver should actually be condemned, as it can easily turn a small, 1.6 mm hole in a vessel or bowel into a considerably more problematic situation by lacerating the tissue within.

In morbidly obese patients, one can start with increasing insufflation pressures temporarily to 20 mmHg, in order to counter the weight of the abdominal pannus, and then after successful trocar placement, the pressure may be reduced to a working pressure of 15 mmHg. The increase in pneumoperitoneal pressure can be safely elevated to 20 mmHg in patients without significant cardiac or pulmonary comorbidities. This step increases the distance between anterior abdominal wall and peritoneal contents, as well as producing a more taught abdominal wall, which is important for controlling the amount of axial force necessary for trocar passage into the abdomen [2]. It has been shown that this maneuver can lengthen the distance between aortic bifurcation and the umbilicus from 0.6 cm at a pressure of 12 mmHg to 5.9 cm [6]. One should remember to return the insufflation pressure to 15 mmHg upon successful placement of trocars.

The open, or Hasson, technique is performed by making a small skin incision and bluntly dissecting down to fascia. Stay sutures are then passed through the fascia on opposite sides and tagged with a hemostat. The fascia is then incised, creating an opening just large enough to pass the

trocar. If this incision is larger than is needed, difficulty in maintaining pneumoperitoneum throughout the case may be encountered due to gas leaking out of the incision. Once the fascia is opened, blunt dissection may be used to dissect down to peritoneum. The peritoneum is then grasped with pickups or hemostats, brought out of the wound, and opened sharply. A finger is inserted into the peritoneal cavity to assess for any adhesions. The blunt-tipped trocar can then be safely passed into the peritoneal cavity under direct visualization. The fascial stay sutures are then used to secure the trocar to the fascia, thereby preventing dislodgement later in the case. Many ports designed for use with the Hasson technique offer a balloon on the distal end of the trocar that is inflated within the peritoneal cavity and then retracted upward to compress against the abdominal wall, thus minimizing accidental displacement and gas leaks. There may be a sponge on the proximal aspect of the trocar that may be compressed against the body wall to also help with securement of the port in addition to preventing gas leak. Disadvantages of the Hasson technique include increased time in placing this initial port, as well as an increased risk of gas leakage from the wound throughout the case, especially in obese patients. In cases of gas leaks from a port site, the leak can usually be minimized and pneumoperitoneum maintained by compressing Vaseline gauze around the leaking port site, by placing a sharp towel clamp around the skin edges, or by simply suturing the fascial opening closed so there is a better seal around the port.

Direct trocar placement by physical elevation of the abdominal wall, without creation of a pneumoperitoneum or absence of Hasson "open" technique, is not advised or recommended due to increased risk of injury.

Complications of Laparoscopic Access

Fortunately, injury rates during laparoscopic access are relatively low, with most sources reporting risks ranging from 0.05% to as high as 0.3% [7]. However, most feel that the rates of complications are vastly underreported. A survey of 407 Canadian gynecologists indicated that at least 25% of them had experienced access-related injuries [8]. It's been postulated that most studies come from surgeons and centers of high volume, whose complications rates would naturally be lower once they are past the learning curve. Studies have indicated that 13–50% of vascular injuries and approximately 40–50% of bowel injuries are unrecognized until later in the postoperative period [2, 7].

One of the leading causes of death from laparoscopic access is major vascular injury, which carries a mortality rate as high as 15%. It is second only to anesthesia as the leading cause of mortality in laparoscopy [9]. It can occur during passage of the Veress needle or with placement of the trocar itself. Typically, injuries made with the Veress needle are self-limiting, and the Veress needle may simply be removed if no manipulation of the needle has occurred. In thin patients, the distance from the anterior abdominal wall to the retroperitoneum and its associated vascular structures may be as little as two centimeters [2]. The most commonly injured retroperitoneal vessel injured is the right common iliac artery, given that it lies just posterior to the umbilicus. However, any of the great vessels or their branches may lie in harm's way.

Injury to the inferior epigastric vessels is the most common minor vascular injury. If the injury is recognized and bleeding is brisk, a Foley catheter may be inserted through the fascial opening, the balloon inflated, and traction held on the Foley so that the bleeding is temporarily tamponaded until further control can be obtained. Alternatively, some advocate nothing more than maintaining traction on the Foley balloon for 24 h with subsequent removal the next day. The same authors maintain that sutures may be placed full thickness through the abdominal wall above and below the bleeding site to gain immediate hemostasis, with removal of these sutures after 24 h [10]. This maneuver can be performed using a port closure device, such as the Carter-Thomason fascial closure device to pass suture above and below the site of bleeding in order gain hemostasis.

As stated previously, if a Veress needle is placed with immediate suspicion for vascular injury, it may be removed and placed in a different location, with vigilant subsequent inspection of the original site upon successful entry into the abdomen. Alternatively, the Hasson technique can also be employed at that time, depending on the surgeon's discretion. If a trocar is passed and blood is noted to be pooling or welling in the trocar upon removal of the obturator, the trocar should not be removed. Rather, a high suspicion of great vessel injury should exist, with potential consideration for conversion to exploratory laparotomy. One should also be aware that not all vascular injuries are immediately apparent; some retroperitoneal bleeds may not be diagnosed until the postoperative period.

Bowel injury is the third leading cause of death from laparoscopic procedures, behind anesthesia and vascular injury. Unfortunately, bowel injuries are often not recognized intraoperatively, and diagnosis may occur in a delayed fashion after the patient's condition has deteriorated significantly. A bowel injury carries a mortality rate of 2.5–5.0% [2, 7]. It has been found that delayed recognition and patient age greater than 59 were both independent predictors of death in cases of bowel injury. One complication that can be easily missed is through-and-through passage of a trocar through a loop of bowel. In other words, the trocar has passed through the lumen of the bowel and comes out of the other side, with no real visual evidence of an injury, unless the surgeon passes all secondary trocars under direct vision and then goes back and visualizes the initial port as well (if a closed technique was used). To decrease this risk of injury, keeping the instruments in the field of view is paramount, as well as not forcing instruments when passing them from the lateral assistant trocar. If resistance is felt, the advancement of the instrument should stop immediately and the camera panned back to visualize the insertion through the trocar.

Recognizing these bowel injuries as early as possible is extremely important in mitigating the risk of patient mortality and in reducing morbidity. The most common presentation is "severe single trocar site pain, abdominal distension, diarrhea, and leukopenia followed by acute cardiopulmonary collapse secondary to sepsis within 96 h of surgery" [11]. Bishoff et al. also reported that nausea and vomiting, ileus, and generalized abdominal pain were not common presentations. None of the patients had leukocytosis or peritoneal signs; only one had a fever greater than 38 °C. A high index of suspicion is paramount, and a CT scan with oral contrast can be obtained if concern exists in the postoperative period.

Bhoyrul et al. [12] studied 629 trocar injuries during a 3-year period using data obtained from the Food and Drug Administration (FDA). Manufacturers are legally required to report incidents involving medical devices as dictated by the Safe Medical Devices Act, passed by Congress in 1990. In turn, hospitals are obligated to report device-related deaths to both the FDA and the manufacturer. Serious injuries may be reported to the manufacturer or FDA; the manufacturer is then required to disclose these injuries to the FDA within 30 days in the prior scenario. In their study, out of 629 trocar injuries, there were 32 deaths, with 26 (81%) due to vascular injuries and the other 6 (19%) being due to visceral (mostly bowel) injuries. Of these vascular injuries resulting in patient death, 23% involved the aorta and 15% were a result of trauma to the inferior vena cava. The rest were attributable to injury to the iliacs or other vessels. Regarding deaths due to bowel injuries, none were recognized intraoperatively. It should also be noted that in four of these cases, one involved a bleeding disorder undiagnosed prior to surgery, one had an abdominal aortic aneurysm that was unknown before surgery, one involved a trocar reinsertion into the abdomen without reinsufflating the abdomen, and one was a surgeon's first case. In looking at all injuries in the series—not just those involving mortality—it should be noted that bowel and vascular injuries occurred concomitantly in 9% of cases.

One must keep in mind patient anatomy during laparoscopic port placement. The distance between the retroperitoneal vessels and the anterior abdominal wall is only 3–4 cm and can be as

little as 2 cm in thin patients. However, by inducing pneumoperitoneum or by manually raising the abdominal wall anteriorly with towel clips next to the area of planned trocar insertion, this distance may be increased to 8–14 cm [12]. One should also take extra care when placing trocars in those with abdominal wall laxity, such as those with atrophy of the muscle of the anterior abdominal wall and in females with a history of multiple pregnancies. This scenario will bring the anterior abdominal wall closer to the retroperitoneal vessels during port insertion if one is not careful. When inserting ports in the umbilicus, it is generally recommended that port insertion should occur at a 90° angle to the skin to gain direct entry into the abdomen instead of skiving the surface. Also, one should be aware that the bifurcation of the aorta is approximately at the level of the iliac crest. One of the most important tenets of laparoscopy is the need to control the axial force of entry during port placement; this may be the single most important step in preventing a catastrophic vascular injury. The axial force required for successful, safe trocar placement in each patient is different and is a learned motor and cognitive skill, with some reliance on muscle memory. It has been noted in studies that controlling the axial force is less difficult when the force needed is minimal in relation to the total upper body strength of the person passing the trocar [13]. Other factors that should be kept in mind as it relates to muscle memory and proprioception are the height of the table and the need to resist the urge to reach across the table to place a lateral port [7]. Trocars should be directed toward the organ of interest in order to avoid tearing of the fascia with subsequent placement of instruments and dissection.

Finally, laparoscopy and port placement do carry with it the small risks of a carbon dioxide gas embolism, which can potentially be fatal. The incidence has been reported to be 0.001% in a review of 489,335 closed laparoscopy cases. This complication has not been reported with open laparoscopic techniques [2, 14]. The patient may experience arrhythmias, tachycardia, cyanosis, and ultimately cardiovascular collapse. The anesthesiologist will see a sharp rise in the end-tidal CO_2 and a mill-wheel murmur may be auscultated. If this occurs, the surgeon should immediately desufflate the abdominal cavity and the patient should be placed in the left lateral decubitus position with the head down (Durant's maneuver). This results in a reduced amount of gas advancing from the right side of the heart into pulmonary circulation, allowing the gas to remain in the right heart until it is slowly absorbed [6]. Additional methods that may be utilized if this is unsuccessful include hyperventilation to increase carbon dioxide excretion, insertion of a central venous catheter or pulmonary artery catheter to aspirate the gas, or, in rare refractory cases, hyperbaric oxygen that has shown some success in treatment of gas embolism [15, 16].

Types of Trocars

There are several types of trocars currently available. The authors' preference is to use a bladeless dilating trocar for subsequent decreased risk of hernia (Fig. 1.2a). Other alternatives are disposable, shielded cutting trocars, visual entry trocars, and radially expanding trocars. All of these are placed after initial insufflation of the abdomen with a Veress needle and always under direct visualization. With placement of any trocar, it is important to remember to extend the index finger of the dominant hand that is advancing the trocar to serve as a limit to how deep the trocar may be inserted. Our preference as well is to use an optical access visualizing obturator, which allows the 5 or 10 mm laparoscope to be placed within the shaft of the trocar and allows direct visualization of the layers of muscle and subcutaneous fat as the tip of the trocar traverses the layers in order to identify entry into the abdomen (Fig. 1.2b).

Optical access laparoscopic trocars have an obturator that is hollow with a clear tip, allowing the laparoscope to be inserted into the obturator during passage into the peritoneal cavity. This displays each layer of the abdomen during placement of the trocar. The visual obturators come in both bladed (Visiport, US Surgical, Norwalk, CT) and non-bladed varieties (Optiview, Ethicon, Cincinnati, OH). Optical access trocars have a

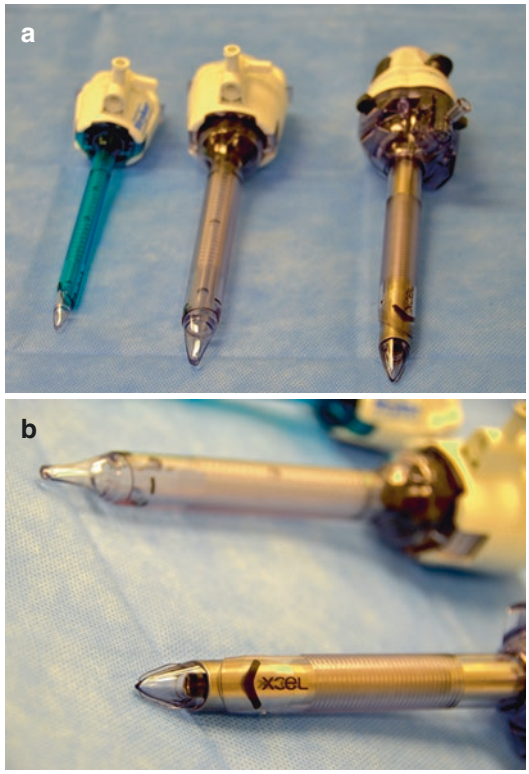

Fig. 1.2 (**a**) Bladeless, dilating trocars. (**b**) Note the ridges at lateral edge of trocar which separate and spread fascia rather than a blade which cuts tissue

great advantage of safely visualizing each layer of the abdominal wall during placement of the initial trocar and are highly recommended for all laparoscopic cases. Unfortunately, the robotic camera does not fit or seal within the obturator of currently available optical access trocars.

These trocars can be combined with bladeless, dilating trocars, which are similar to the bladed tips in overall appearance, except the tip of the obturator is conically shaped plastic with a ridge. This trocar has a lower risk of cutting vessels in the abdominal wall during trocar insertion, as well as a lower risk of port-site hernia due to the lack of cutting the fascia, which ultimately translates into a smaller fascial defect. In contrast to the VersaStep, there is no inherent counter traction mechanism (i.e., dispersion of axial force into radial force) involved in placing the trocar. Thus, some feel that there is at least higher theoretical risk of a vascular injury to the retroperitoneal vessels associated with placement compared to the VersaStep.

Disposable, shielded cutting trocars rely on the same principle as a Veress needle in its design and function. It has a bladed tip covered by a plastic sheath. The plastic sheath retracts when it meets resistance, thereby exposing the cutting tip as it passes through the abdominal wall, with subsequent retraction of the plastic sheath over the blade upon passage into the peritoneal cavity. Advocates of this trocar feel that there is less axial force needed to advance the trocar into the abdominal cavity, thereby lessening the likelihood of inadvertent passage of the trocar into the retroperitoneum, where the great vessels reside. However, others feel that there is more potential for harm during that very brief moment when the blade is still exposed immediately after passage into the peritoneal cavity, with subsequent increased risk of hernia.

The AirSeal Intelligent Flow System (ASIFS) is a laparoscopic carbon dioxide (CO_2) insufflation system that utilizes valveless trocars. The entire system consists of a valveless trocar and a semirigid filter tube set. The trocars maintain insufflation by creating a pressure barrier by directing CO_2 into the proximal end of the trocar housing. CO_2 escaping the abdomen is captured in the proximal end of the valve, filtered, and redirected into the trocar. The recirculation of the insufflated gas filters out surgical smoke to improve vision and reduce camera smudging [17]. The inner diameter of the trocar is 12 mm. Additionally, the valveless trocar enables easier passage of instruments and needles into the trocar, as well as facilitating intact specimen extraction through the trocar. Herati et al. reported decreased smudging of laparoscopes, automatic evacuation of smoke leading to improved visualization, stable pneumoperitoneum despite continuous suction, reduced insufflation gas consumption, and improved needle insertion and specimen extraction in their experience with the valveless trocar system [18]. They did note limitations of the system as well, including excessive noise production from the smoke evacuator and potential adverse clinical implications of stable, elevated intraperitoneal pressure [18]. An additional drawback with

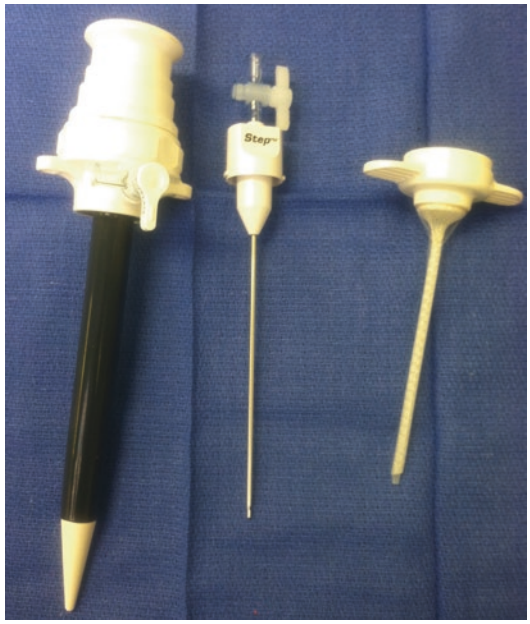

Fig. 1.3 VersaStep trocar. A sheath is placed over the Veress needle first during initial access. After withdrawing the Veress needle, the subsequent trocar is placed within the sheath, so that counterforce is applied during trocar placement

this system is the cost of trocars as specifically designed to work with this system.

Finally, the radially expanding trocar, often referred to as the VersaStep trocar, is a bladeless trocar (Fig. 1.3). There is a theoretical lower risk of injury to the vasculature of the abdominal wall (i.e., the inferior epigastric vessels) as the tip displaces vessels to the side rather than cutting through them. This type of trocar creates a smaller fascial defect, as it is just stretched rather than cut. As a result, these trocars typically have an extremely low leak rate compared to other trocars. More importantly, the counter traction provided by the webbed outer flange provides a counterforce to the axial force during placement. There is published data of almost 2600 patients where no major vascular injuries occurred and where bare needle punctures into the small bowel, liver, and small mesenteric vessels were the only intra-abdominal injuries [7]. One complaint is that the smooth sides of the trocar lack the grip on the abdominal wall of other trocars and thus may make it more prone to accidental dislodgement during surgery. However, the authors have not found this to be a common occurrence in our practice. Also, it is generally held that these port sites do not require fascial closure. In a series of bariatric patients in which port-site hernia rates with the VersaStep were reviewed, 741 consecutive bariatric patients undergoing laparoscopy for gastric bypass surgery were retrospectively reviewed. Each patient had an initial supraumbilical Hasson port placed, with the rest of the ports employing the VersaStep system: two 12 mm ports and three 5 mm ports. Only the Hasson port was closed. There were no hernias at any of the VersaStep sites; there were nine incisional hernias at the Hasson site [16]. Nevertheless, there is at least one case report of a port-site hernia occurring with the VersaStep trocar [19].

Port-Site Hernias

Port-site hernias are a relatively rare, yet serious complication of laparoscopic surgery. First reported in the literature in 1968 [20], it has an estimated prevalence of 0.5% [21]. Most of these port-site hernias are associated with trocars that are at least 10 mm in diameter. In one series from the gynecologic literature, out of 840 port-site hernias, 86.3% were associated with trocars that were ≥10 mm, 10.9% occurred with ports between 8 and 10 mm, and 2.7% occurred with trocars ≤8 mm [22, 23].

It is generally held that port-site hernias are more apt to occur in the midline, rather than at the site of laterally placed ports [23]. Given that the umbilicus is the weakest point in the abdominal wall and is a commonly used access point for port placement, this finding is not surprising. Many surgeons, depending on the type of case, may extract the specimen through the umbilical port, thereby stretching and weakening the fascia. The counterargument is that multiple muscle and fascial layers of the lateral abdominal wall provide additional layers of protection against port-site hernias which midline access points cannot offer [23, 24]. Another proposed reason for the smaller risks posed by laterally placed

ports is simply anatomic: the small bowel is in more direct and continuous contact with the abdominal midline than at points on the lateral abdominal wall [25].

Another risk factor for port-site hernias is obesity, due to the higher intra-abdominal pressures and a higher likelihood of improper closure of the wound as a result of the challenges posed by their body habitus [23].

The clinical presentation of a port-site hernia must be recognized quickly and clinicians should carry a low index of suspicion for those patients with GI complaints or tenderness at the port site, especially when occurring within 14 days from surgery. GI complaints usually consist of abdominal pain, nausea and vomiting, and often abdominal distension—often the classic signs of small bowel obstruction. The diagnosis can often be made clinically but is usually confirmed with a CT scan. Once realized, the patient should be taken to the operating room if signs and symptoms of an acute abdomen exist. The risk of nonoperative management delays surgical repair, with potential subsequent critical illness due to strangulation and necrosed bowel [23].

Ultimately, most of the literature supports closing those ports that are 10 mm in size or greater. Trocars less than 10 mm in size pose lower risk, though one should be aware that port-site hernias can still occur with these smaller ports. Moreover, port-site hernias can still occur in port sites that have been closed if the fascia tears. Thus, the physician's index of suspicion in the postoperative period should always remain high.

Fascial Closure

The Carter-Thomason fascial closure device is a simple yet effective way of closing port sites (Fig. 1.4a) and typically is necessary only for ports measuring 10 mm or larger. Due to difficulty in closing fascia using traditional open methods with a needle driver, the Carter-Thomason device is a time-efficient and safe means of closing fascia under direct visualization. Additionally, it makes closing the peritoneal defect easier in obese patients [26].

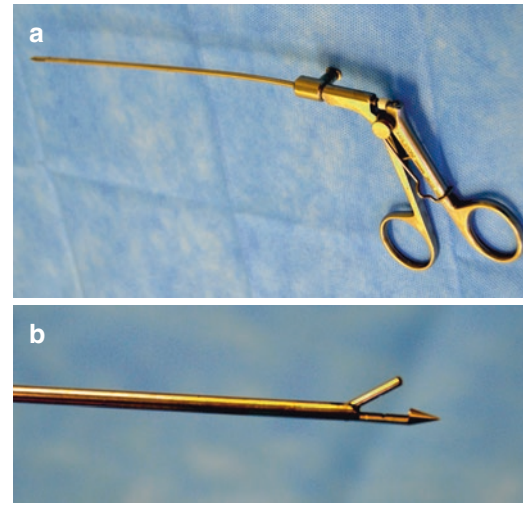

Fig. 1.4 (**a**) Carter-Thomason fascial closure device. (**b**) Tip of Carter-Thomason. A #1-Vicryl is placed through the abdominal wall and instrument is withdrawn. After subsequent second pass on the opposite side of the incision with the instrument, the suture is grasped and withdrawn from the incision

Application of the Carter-Thomason device starts with grasping a #1-Vicryl suture (with the needle cutoff) in the middle of the strand (Fig. 1.4b). A single hemostat holds both ends of the suture together to avoid inadvertent passage of the ends. Then, under direct laparoscopic vision through another port, the Carter-Thomason device is passed through the fascia on one side of the fascial defect into the abdominal cavity. The device is then withdrawn, leaving the free suture inside the abdominal cavity, and then passed a second time through the opposite side of the trocar incision back into the abdominal cavity, where the free suture is grasped again and withdrawn through the skin. It is helpful to use a laparoscopic needle driver through a separate port to grasp the free suture and direct it toward the jaws of the Carter-Thomason device if there is any difficulty in retrieval.

Exiting the Abdomen

Port removal is often an afterthought as it pertains to the remainder of the case. However, there is still the potential for complications dur-

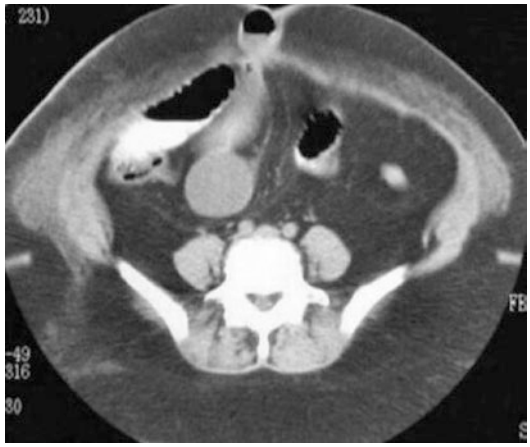

Fig. 1.5 Computed tomography scan of incisional hernia

ing this final step of the operation. At the very least, it should be viewed as a final opportunity to assess the abdomen before completing the procedure. One should visually inspect the surgical area again to confirm adequate hemostasis. Also, one should inspect the bowel to ensure there is no evidence of injury or entrapment in trocar closure. The extraction site can be reinspected a final time to confirm adequate airtight fascial closure and decrease risk of incisional hernia (Fig. 1.5). Finally, all of the ports, with the exception of the final one, should be withdrawn under direct vision. The surgeon should make sure that there is no bleeding from any of the port sites in the anterior abdominal wall that could signify a serious vascular injury, such as a laceration to the epigastric vessels which potentially could have been tamponaded by the trocar up to that point in the case. Prior to removing the last port, all remaining carbon dioxide should be evacuated from the abdomen. Otherwise, a partial vacuum is present and omentum and bowel may be drawn into the trocar upon its removal [25], thereby creating a port-site hernia or possibly referred shoulder pain due to irritation of the diaphragm.

Summary

In summary, the surgeon should maintain a high index of suspicion for injury on every single case. It can be easy to be lulled into a sense of complacency or to let one's vigilance decrease before the final closure is completed. One should always be mindful that a significant number of bowel injuries go undiagnosed until the postoperative period and a sizable number of vascular injuries, including those in the retroperitoneum, are not recognized intraoperatively. With a careful inspection at the end of the case and attention to detail, the risk of complication can be minimized.

References

1. Jansen FW, Kolkman W, Bakkum EA, de Kroon CD, Trimbos-Kemper TC, Trimbos JG. Complications of laparoscopy: an inquiry about closed versus open-entry technique. Am J Obstet Gynecol. 2004;190(3):634–8.
2. Krishnakumar S, Tambe P. Entry complications in laparoscopic surgery. J Gynecol Endosc Surg. 2009;1(1):4–11.
3. Szabo I, Laszlo A. Veres needle: in memoriam of the 100th birthday anniversary of Dr. Janos Veres, the inventor. Am J Obstet Gynecol. 2004;191(1):352–3.
4. Molloy D, Kaloo PD, Cooper M, Nguyen TV. Laparoscopic entry: a literature review and analysis of techniques and complications of primary port entry. Aust N Z J Obstet Gynaecol. 2002;42(3):246–53.
5. Teoh B, Sen R, Abbott J. An evaluation of four tests used to ascertain Veres needle placement at closed laparoscopy. J Minim Invasive Gynecol. 2005;12(2):153–8.
6. Zikry AA, DeSousa K, Alanezi KH. Carbon dioxide embolism during laparoscopic sleeve gastrectomy. J Anaesthesiol Clin Pharmacol. 2011;27(2):262–5.
7. Chandler JG, Corson SL, Way LW. Three spectra of laparoscopic entry access injuries. J Am Coll Surg. 2001;192(4):478–91.
8. Yuzpe AA. Pneumoperitoneum needle and trocar injuries in laparoscopy, a survey on possible contributing factors and prevention. J Reprod Med. 1990;35(5):485–90.
9. Nordestgaard AG, Bodily KC, Osborne RW Jr, Buttorff JD. Major vascular injuries during laparoscopic procedures. Am J Surg. 1995;169(5):543–5.
10. Philips P, Amaral J. Abdominal access complications in laparoscopic surgery. J Am Coll Surg. 2001;192(4):525–36.
11. Patel MS. Laparoscopic port site hernia at a 12 mm non-bladed Ethicon Endopath Excel VersaStep trocar site. World J Colorectal Surg. 2010;2(1):3.
12. Bhoyrul S, Vierra M, Nezhat C, Krummel TM, Way LW. Trocar injuries in laparoscopic surgery. J Am Coll Surg. 2001;192(6):677–83.
13. Corson SL, Batzer FR, Gocial B, Maislin G. Measurement of the force necessary for laparoscopic trocar entry. J Reprod Med. 1989;34(4):282–4.

14. Neudecker J, Sauerland S, Neugebauer E, Bergamaschi R, Bonjer HJ, Cuschieri A, et al. The European Association for Surgery Clinical Practice Guideline on the pneumoperitoneum for laparoscopic surgery. Surg Endosc. 2002;16(7):1121–43.
15. McGrath BJ, Zimmerman LE, Williams JF. Carbon dioxide embolism treated with hyperbaric oxygen. Can J Anesth. 1989;36(5):586–91.
16. Morgan GE Jr, Mikhail MS, Murray MJ. Carbon dioxide is cheap, does not support combustion. Clinical anesthesiology. 4th ed. New York: McGraw-Hill; 2006. p. 582–4.
17. Miyano G, Morita K, Kaneshiro M, Miyake H, Nouso H, Yamoto M, et al. Laparoscopic Toupet fundoplication using an air seal intelligent flow system and anchor port in a 1.8-kg infant: a technical report. Asian J Endosc Surg. 2015;8(3):357–60.
18. Herati AS, Atalla MA, Rais-Bahrami S, Andonian S, Vira MA, Kavoussi LR. A new valve-less trocar for urologic laparoscopy: initial evaluation. J Endourol. 2009;23(9):1535–9.
19. Johnson WH, Fecher AM, McMahon RL, Grant JP, Pryor AD. Versastep trocar hernia rate in unclosed fascial defects in bariatric patients. Surg Endosc. 2006;20(10):1584–6.
20. Bishoff JT, Allaf ME, Kirkels W, Moore RG, Kavoussi LR, Schroder F. Laparoscopic bowel injury: incidence and clinical presentation. J Urol. 1999;161(3):887–90. Review.
21. Fear RE. Laparoscopy: a valuable aid in gynecologic diagnosis. Obstet Gynecol. 1968;31(3):297–309.
22. Swank HA, Mulder IM, la Chapelle CF, Reitsma JB, Lange JF, Bemelman WA. Systematic review of trocar-site hernia. Br J Surg. 2012;99(3):315–23.
23. Montz FJ, Folschneider CH, Munro MG. Incisional hernia following laparoscopy: a survey of the American Association of Gynecologic Laparoscopists. Obstet Gynecol. 1994;84(5):881–4.
24. Tonouchi H, Ohmori Y, Kobayashi M. Trocar site hernia. Arch Surg. 2004;139(1):1248–56. Review.
25. Plaus WJ. Laparoscopic trocar site hernias. J Laparoendosc Surg. 1993;3(6):567–70.
26. Duron JJ, Hay JM, Msika S, Gaschard D, Domergue J, Gainant A, Fingerhut A. Prevalence and mechanisms of small intestinal obstruction following laparoscopic abdominal surgery: a retrospective multicenter study. French Association for Surgical Research. Arch Surg. 2000;135(2):208–12.

2 Laparoscopic Renal Extirpative Surgery

David Mikhail, Jessica Kreshover, and Lee Richstone

Introduction

Laparoscopic approaches have become the gold standard for most renal extirpative surgery in the twenty-first century. They pose a unique set of challenges over traditional open surgery. Here we discuss presurgical considerations including the extent of renal resection planned and preoperative imaging. We then describe in detail our approach for laparoscopic renal extirpative surgeries for both benign and malignant processes. We have included our equipment list (below); however this varies significantly based on the institution and surgeon preferences. We first describe transabdominal approaches and include the imperative details such as patient positioning, equipment, and port placement. General surgical steps as well as intraoperative considerations such as adrenal management, renal preservation, and tumor identification are then reviewed. We summarize commonly encountered complications of laparoscopic renal surgery, their diagnosis, and management. Finally, we also describe modifications for a retroperitoneal approach and nephroureterectomy.

Equipment List

- Operating room table (slider and kidney rest preferred)
- Small long gel rolls (×2)
- Pillow
- Small flat gel pad
- Towels
- 3-inch silk tape
- Thompson scope holder (optional)
- Laparoscopic argon beam coagulator and delivery system
- Laparoscopic LigaSure® (Covidien, Mansfield, MA)
- Intraoperative ultrasound
- Veress needle 14 gauge
- 12 mm AirSeal® trocar and insufflation system (SurgiQuest, Milford, CT)
- 10 mm camera port
- 5 mm suction port
- 12 mm additional working port (optional)
- Laparoscopic specimen entrapment bag (12 or 15 mm)

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S. L. Best, S. Y. Nakada (eds.), *Minimally Invasive Urology*,
https://doi.org/10.1007/978-3-030-23993-0_2

- Multi-fire Endo GIA stapler® (for radical nephrectomy, available during partial nephrectomy) (Covidien, Mansfield, MA)
- Laparoscopic retractor, e.g., Endo Paddle 12 mm (available) (Covidien)
- 2–0 barbed, e.g., V-Loc® (Covidien, Mansfield, MA) or Vicryl suture ×2 (more available if needed, for partial nephrectomy)
- Laparoscopic Weck® Hem-o-lok® clip applier with clips (Teleflex, Research Triangle Park, NC)
- Lapra-Ty® applier (Ethicon, Blue Ash, OH) (for partial nephrectomy)

Surgical Planning

Multiple factors must be considered before proceeding with laparoscopic renal surgery. Based on the pathology, the decision must be made to perform a simple nephrectomy, radical nephrectomy, partial nephrectomy, or nephroureterectomy. The techniques described in this chapter are generally applicable to standard laparoscopic renal extirpative surgery, while laparo-endoscopic single site (LESS) approaches will be discussed later in this textbook.

One important consideration when consenting the patient for laparoscopic renal surgery is the risk of significant complications that might require conversion to an open procedure. These include complications such as significant intraperitoneal organ injury, vascular injury, and failure to progress. Thus, patients should always be consented for a possible conversion to open procedure.

Simple nephrectomy is indicated in benign renal conditions often involving nonfunctioning or symptomatic kidneys. Indications include refractory renovascular hypertension, chronic pain related to polycystic kidney disease, chronic hydronephrosis not amenable to repair, loin pain hematuria syndrome, or chronic infectious processes such as XGP (xanthogranulomatous pyelonephritis), renal tuberculosis, or chronic pyelonephritis. Infectious processes often have significant fibrosis in the perirenal space and thus are more difficult to perform laparoscopically; thus these patients should be counseled on possibility of conversion to an open procedure. When performed laparoscopically, a transperitoneal rather than retroperitoneal approach should be used for this reason [1].

Radical nephrectomy is generally accepted for T1 to T3a tumors and cytoreductive nephrectomies. They have been performed laparoscopically for renal masses up to 25 cm [2] and some have reported laparoscopic nephrectomy with caval thrombectomy [3].

Radical nephroureterectomy with excision of bladder cuff remains the standard of care for upper tract urothelial carcinoma that is high risk (high grade and/or invasive) and involves the renal pelvis or proximal ureter [4]. It is also used for noninvasive and low-grade tumors that are large, multifocal, or refractory to conservative treatments. We will briefly discuss modifications to the radical nephrectomy when the ureter is also to be removed.

Partial nephrectomy is the most technically challenging of these procedures and has the potential for unique complications such as urine leak (Table 2.1) [5]. The frequency of partial nephrectomies continues to rise based on the international urologic community's acceptance of nephron-sparing surgery as standard of care for localized renal cell carcinoma whenever technically feasible [6–8]. Much of the literature is now focused on optimizing the technicalities and outcomes of this operation. Many have adopted a robotic-assisted laparoscopic approach to partial nephrectomy, which is discussed in detail in Chap. 6 of this textbook.

Preoperative Imaging

Adequate cross-sectional imaging is essential before proceeding with any laparoscopic renal surgery, especially oncologic and nephron-sparing procedures. The accepted standard imaging is a biphasic or triphasic contrast-enhanced computed tomography (CT) scan with slices 5 mm or less to allow for adequate identification of renal vasculature, anatomy, and clinical staging and reveals characteristics of the renal mass (i.e., solid/cystic/fat containing or vascular). For

Table 2.1 Complications of laparoscopic renal surgery [5]

Complication		Prevention	Management
Positioning injury	Brachial plexus injury	Axillary roll for lateral positioning; axillary roll for obese patients in modified lateral position; prevent abduction of contralateral arm >90°	Physical therapy
	Sciatic injury	Support ipsilateral leg with pillows to prevent adduction of hip particularly in flank position	Physical therapy
	Rhabdomyolysis	Keep all pressure points padded; minimize operative time	Aggressive hydration, consider urine alkalization
Veress needle injury	To bowel	Appropriate selection of insertion site away from scars, use of OG/NG tube to decrease gastric distension; use of Hasson technique for complicated access	Do NOT insufflate; remove needle, examine, gross spillage requires evaluation and unlikely to be managed conservatively
	To liver/spleen	Appropriate selection of insertion site away from scars; use of Hasson technique for complicated access	Do NOT insufflate; remove needle, examine, hemostatic agents, or coagulation (argon beam); surgical consultation for large bleeds
	To gallbladder	Appropriate selection of insertion site away from scars; use of Hasson technique for complicated access	Do NOT insufflate; remove needle, examine, surgery consult, likely requires cholecystectomy
	To vasculature	Appropriate selection of insertion site away from scars; use of Hasson technique for complicated access	Do NOT insufflate; remove needle, examine, repair if necessary, open if necessary
Vascular injury		Review and refer to CT/MRI imaging	Exposure, turn up pneumo; add trocars or open if necessary; repair vs. ligate; for epigastric injuries (usually trocar related), full-thickness suture ligation should be used to control bleeding
Bowel injury		Avoid cauterization near the bowel; take extra care during duodenal dissection	Intra-op repair, general surgery consults; exploration, general surgery consult (delayed)
Liver/splenic injury		Avoid unnecessary traction on liver or spleen; care during Veress needle insertion	Hemostatic agents or coagulation (argon beam); surgical consultation for large bleeds
Diaphragmatic injury		Avoid monopolar cautery use during lateral/apical dissection	Suture repair +/− chest tube placement
Ureteral injury		Identification of the ureter early in dissection	Mobilization, debridement if necessary (cautery injury), tensionless suture repair, stent placement (intra-op); ureteral stent vs. percutaneous nephrostomy with possible delayed repair (delayed)
Urine leak		Closure of collecting system in separate layer	Placement of ureteral stent, percutaneous drainage of urinoma if necessary
Wound infection		Sterile prep	Antibiotics; opening wound and packing may be needed if abscess is suspected
Incarcerated hernia		Close all trocar sites 12 mm or larger or any port placed with cutting trocar	Exploration if clinical suspicion

OG/NG orogastric/nasogastric

complex cases, consider three-dimensional CT reconstruction to better depict vascular and renal mass anatomy [9, 10]. Magnetic resonance imaging is an alternative in those who cannot tolerate the contrast medium or to better classify indeterminate renal masses on CT scans [11]. Renal ultrasound, including contrast-enhanced ultrasound (CEUS), can help characterize renal masses but is limited in its utility for preoperative surgical planning given its limitations [12].

Based on cross-sectional imaging, surgical approach and extent of resection can be planned. Classifying the difficulty of a nephron-sparing procedure can be determined by validated scoring systems such as the RENAL nephrometry score [13], PADUA (Preoperative Aspects and Dimensions Used for an Anatomical) classification [14], the Centrality Index (CI) [15], and Contact Surface Area (CSA) [16]. Multiple studies have compared and validated these scoring systems in their ability to quantify difficulty of a partial nephrectomy.

When imaging of a small renal mass ≤4 cm is indeterminate, a renal mass biopsy can be performed but should only be performed if it could alter the management plan of the patient [17]; however they are still nondiagnostic in roughly 10–20% of biopsies depending on the center's experience [18, 19].

Renal Function

This remains one of the primary drivers in deciding to pursue partial nephrectomy or radical nephrectomy in oncologic cases. Those with solitary functioning kidney, multiple tumors, bilateral tumors, significant chronic kidney disease, or risk factors such as hypertension and diabetes mellitus should have nephron-sparing surgery for localized renal tumors when safe and technically feasible.

Multiple factors impact renal functional outcomes. When simple or radical nephrectomies are planned or likely, a differential renal function can be established using a nuclear medicine renogram to predict effect on overall renal function. For partial nephrectomies, predicting postoperative renal function is more complex. Multiple factors should be considered, including preoperative renal function, comorbidities, age, gender, tumor size, percentage volume preservation, and ischemic time. Of these, the two relevant surgical principles are preservation of renal parenchyma volume and minimizing ischemia time [20].

Transperitoneal Approach

Patient Positioning

The patient is brought into the operating room and positioned supine on the table. After induction of anesthesia, the patient is placed in a modified lateral decubitus position at 30° with the ipsilateral side of the abdomen elevated. Gel rolls or pillows may be placed behind the back to aide in positioning. The contralateral arm is placed out on armrest at less than 90°. The ipsilateral arm is bent and placed across the chest. At this degree of rotation, the legs may remain in anatomic position and should not require bent knee positioning and/or elevation of the ipsilateral leg as there should not be a significant degree of hip adduction and thus no strain on the sciatic nerve. At this degree of rotation, there is also generally no need for an axillary roll. However, for obese patients, an axillary roll may be necessary to relieve any pressure on the brachial plexus. The patient is secured to the surgical table with tape or straps placed across the hips and across the chest (underneath the ipsilateral arm). The authors prefer wide silk tape placed over gel pads and surgical towels. All pressure points should be padded to prevent soft tissue injury and rhabdomyolysis (refer to Table 2.1 for further description regarding positioning injuries [5]). The ipsilateral arm is loosely secured to prevent movement during the case. Bilateral legs are also loosely secured to the surgical table to prevent significant movement during the case. See Fig. 2.1.

When positioned in this manner, there should be no need to flex the bed or to use kidney bar. Unlike open surgery, these maneuvers are unlikely to aide in exposure and have known potential associated morbidity. Once in position,

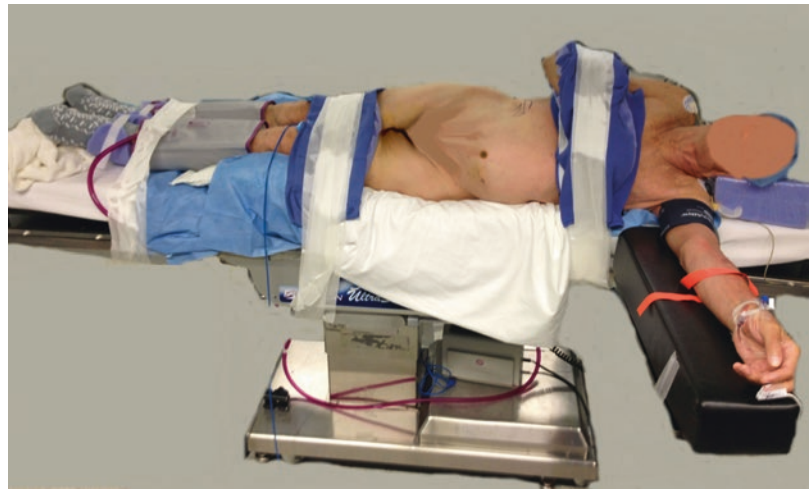

Fig. 2.1 Modified lateral decubitus positioning

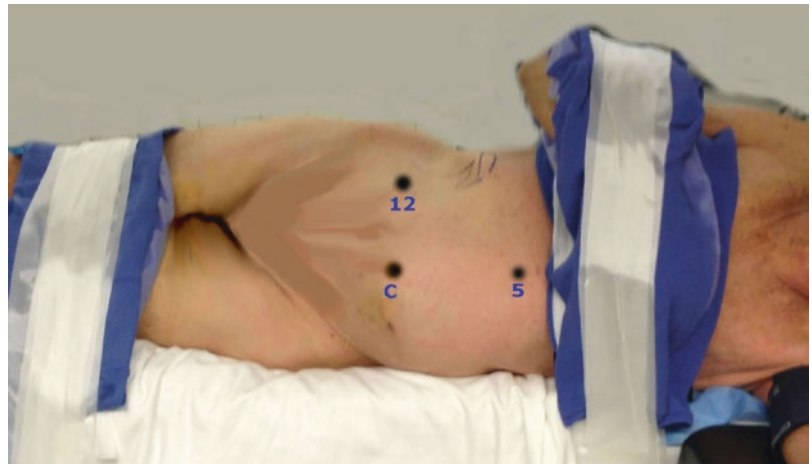

Fig. 2.2 Laparoscopic port positioning. C = camera port, 12 = 12 mm port, 5 = 5 mm port

the surgical bed should be lowered and then rotated toward the operating surgeon to ensure the patient remains secure and immobile.

Trocar Positioning

The surgeon stands on the contralateral side of the surgical bed. Access and pneumoperitoneum can be achieved via closed (Veress needle) or open (Hasson) techniques. The Veress needle may typically be inserted via the umbilicus. In cases of prior midline abdominal surgery, hernias, or obesity (body mass index >30), the Veress may be introduced at Palmer's point, which is located 3 cm below the left costal margin in the midclavicular line [21]. Two "clicking" sounds should be heard as the needle passes through fascia and peritoneum. Aspiration and saline "drop test" are used to help confirm intraperitoneal location. Opening pressures should be ≤5–10 mmHg and were shown to be the most reliable in avoiding iatrogenic injury [22]. Refer to Table 2.1 for further discussion regarding Veress needle injuries. Once insufflation pressure has reached 15 mmHg, trocar placement can take place.

Generally, the camera port (10 mm) is placed at the level of the umbilicus, a 5 mm port is placed in the subxiphoid position, and a 12 mm working port is placed in the lateral position of the ipsilateral side of the abdomen cephalad to the anterior superior iliac spine. Please refer to Fig. 2.2 for diagram of placement.

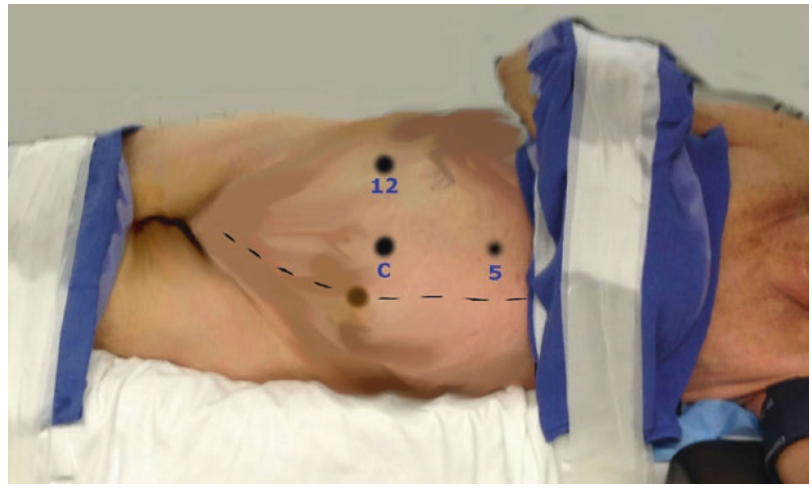

Fig. 2.3 Laparoscopic port shift for obese patients. C = camera port, 12 = 12 mm port, 5 = 5 mm port

For right-sided procedures, there may be a need for an additional port for liver retraction. This port (5 mm) may be placed just superior and/or medial to the upper 5 mm trocar. A ratcheting grasper can then be placed from this medial port underneath the liver and then grasping the side wall to displace the liver cephalad and out of the surgical field. It is important that the grasper is placed cephalad enough through the abdominal wall to allow for adequate superior retraction of the liver and prevent clashing with the right-hand port. Liver retraction can also take place from an inferior approach by placing an additional 5 mm port lateral and cephalad to the lateral 12 mm port. A laparoscopic liver retractor can then be used to superiorly displace the liver without obstructing the left- and right-hand working ports.

There are additional considerations for trocar placement in specific patient populations. For obese patients, trocars should be shifted laterally secondary to habitus (Fig. 2.3). In patients with prior surgeries, initial trocar placement should take place away from prior surgical incisions. In patients with multiple prior surgeries and complicated abdomens, the surgeon must take great care with access to avoid complications. In select cases, after successful initial insufflation with a Veress needle, one can employ a second Veress needle in a proposed site for the initial trocar. If the surgeon hears a stream of air when that location is probed with the second Veress needle, this suggests few if any adhesions in that area and raises confidence of this being a safe location for trocar placement[1]. For very complex abdomens, one should strongly consider the open Hasson technique for access or a retroperitoneal approach. For the open Hasson approach, a 10–12 mm incision is made through the skin, and blunt dissection is performed down to the fascia which is incised sharply. The peritoneum is grasped between two clamps and cut with Metzenbaum scissors. A Hasson trocar is then placed after a "360° sweep" with a finger to ensure proper entry into the peritoneal cavity and assess the abdomen for adhesions. Subsequent trocars can then be placed under direct visualization and with incisions hidden within prior scars after it is ensured that there are no intra-abdominal adhesions that may prevent safe trocar placement.

Once trocars are placed, the surgical bed is lowered and rotated to the contralateral side to allow for medial displacement of intra-abdominal contents and to promote exposure of the retroperitoneum as in Fig. 2.4.

Simple/Radical Nephrectomy

The camera is placed via the umbilical 10 or 12 mm port. The 30° downward deflecting lens is the most common lens used. The camera may then be held and manipulated by a surgical assis-

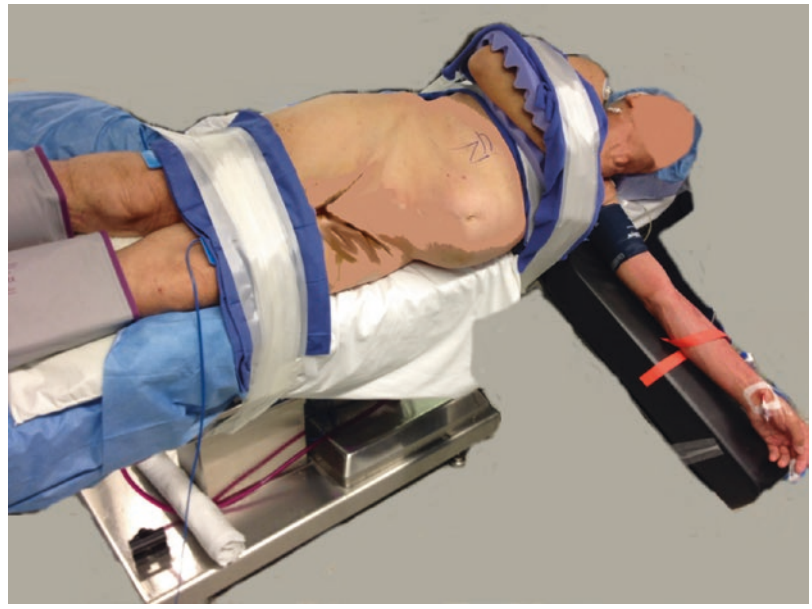

Fig. 2.4 Oblique final patient positioning

tant or by the Thompson laparoscopic camera holder (Thompson Surgical Instruments Inc., Traverse City, MI).

Exposing the Kidney

Begin by reflecting the colon medially to expose the retroperitoneum. An incision is made along the white line of Toldt from the splenorenal (left) or hepatorenal (right) flexure inferiorly to below the level of the lower pole of the kidney. The colon is then reflected medially. Care should be taken to avoid entrance into Gerota fascia. There is a distinction in the color of the retroperitoneal fat and perinephric fat which is contained within Gerota fascia, with the latter being a more "golden" shade. Recognizing this slight difference in color aids in dissection. With appropriate dissection, the anterior surface of Gerota fascia remains intact as the posterior aspect of the mesocolon is dissected free. Holes within the mesentery may be made during this dissection and should be closed once identified to avoid internal hernia. If the hole is small, laparoscopic metal clips may be used for closure. Larger holes may require reapproximating with sutures.

During right-sided procedures, care must be taken to identify and prevent injury to both the duodenum and gallbladder. Dissection should not take place on the duodenum itself. Kocher maneuver is typically needed to medially reflect the duodenum and expose the renal hilum and should be performed in a sharp, athermal manner. Attachments to Gerota fascia should be taken down sharply and at an adequate distance from the duodenum so that if bleeding is encountered, cautery can be safely used without risking injury to the duodenum.

Identification of the Renal Hilum

Once the colonic reflection is complete, the anterior surface of the psoas muscle should be easily identified. If the muscle is not directly visualized, care should be taken to identify the gonadal vessel and/or ureter just inferior to the lower pole of the kidney. Dissection posterior to the gonadal vessels and ureter will allow for identification of the anterior surface of the psoas muscle. In obese patients, the field of vision is altered by lateralization of the ports, and thus the anatomy may appear aberrant. Dissection tends to be more medial than it appears, and hence clear identification of the

vena cava (for right-sided procedures) and the aorta (for left-sided procedures) should take place to ensure dissection within the appropriate planes.

With the psoas muscle identified, the overlying gonadal vein and ureter can be traced superiorly toward the renal hilum with a combination of sharp and blunt dissection. Generally, the ureter is retracted anteriorly, and the gonadal vessels may be retracted with it or left down in its anatomic position. The posterolateral aspect of the kidney can be dissected free bluntly. This allows for strong anterior retraction of the kidney to best expose the renal hilum.

Careful dissection should take place around the renal hilum to identify the primary renal vein and renal artery, which generally lies posterior to the vein. Dissection takes place primarily in a blunt fashion with the suction/irrigator. Generally, there is thin connective tissue both inferior to and overlying the renal vein that needs to be transected to allow for complete identification. Preoperative imaging can be reviewed to check for aberrant renal vasculature so that these vessels can additionally be identified and controlled. Gonadal vessels, aberrant venous vasculature, and lumbar vessels may be clipped and transected as needed to aide in isolation of the hilum.

Renal Vasculature Control and Transection

Once identified and safely dissected freely, control of the renal hilum is the next step. Options for renal artery and vein control include endovascular stapler (Endo-TA-type device, US Surgical, Norwalk, CT), nonlocking titanium clips and locking polymer clips (Hem-o-lok, Weck Closure Systems, Research Triangle Park, NC), or a combination of these. Weck Hem-o-lok clips for renal artery control have been contraindicated by the FDA since 2005 for laparoscopic donor nephrectomy secondary to potential for dislodgement with resultant profuse bleeding which could lead to reoperation or death (https://www.accessdata.fda.gov/cdrh_docs/pdf13/K133202.pdf) [23]. However, they continue to be used for renal vascular control by many urologists [24, 25], with an emphasis on appropriate practice of safe application techniques [25]. In a 2015 survey, about 10% of transplant surgeons still used them for one or both vessels during donor nephrectomies and most consider them safe if multiple locking clips are used [26]. A review of the FDA database for mechanisms of failure of renal hilum control during laparoscopic donor nephrectomy found that of the 92 failures reported between 1992 and 2007, more cases were reported from staplers and titanium clips (64% and 23%) compared to just 13% from locking clips [23]. The data emphasizes the importance of surgeon's experience, knowledge of various options available, and ability to troubleshoot quickly for safe management of the renal hilum.

The renal artery should be controlled first. In our practice, we use a laparoscopic endovascular stapler for its benefit of transfixion and transection. Careful use and knowledge of the stapler is important. Failures most often occur in the form of missing/malformed staple lines (51%) or failure to release (25%) [23]. If the renal vein is obstructing appropriate visualization of the artery, we place a single Weck Hem-o-lok on the artery to allow for venous transection with endovascular stapler prior to arterial transection. This should only be done when adequate safe exposure of both vessels has been achieved.

Adrenal Management and Final Dissection

Once the hilar vessels are transected, dissection can continue superiorly. The adrenal gland should be spared when possible during most radical nephrectomies, including large upper pole tumors, as it has been linked to negatively affect overall patient survival [27]. Adrenal involvement can often be ruled out preoperatively, with the negative predictive value almost 100% with modern cross-sectional imaging [28, 29]. Tumors larger than 7 cm (T2) have been shown to have a higher rate of adrenal involvement than smaller (T1) tumors, but this remains still very low at only 3% [30]. Contemporary indications for concomitant ipsilateral adrenal-

ectomy are evidence of adrenal metastasis on imaging, macroscopic evidence of disease at the time of surgery, or direct extension of tumor into the adrenal gland [31].

In adrenal sparing surgery, dissection should take place in the plane between the adrenal gland and the upper pole of the kidney. The adrenal has a rich blood supply such that small adrenal branches may be encountered, and therefore meticulous hemostasis should be ensured. This portion of the dissection is aided by use of an electrothermal tissue/vessel sealing instrument, of which we prefer the bipolar LigaSure™ (Medtronic, Minneapolis, MN).

Once complete, the only remaining attachments should be the lateral attachments of the kidney, which can be taken down with a combination of blunt and sharp dissection, and the ureter, which can be transected after placement of clips or with an additional reload of endovascular GIA stapler.

Specimen Extraction and Closure

The kidney is then placed within a laparoscopic specimen bag. The site of extraction can be determined on an individual basis. A prospective comparison between extending a port site and a Pfannenstiel incision found the Pfannenstiel group had less early postoperative pain, slightly shorter hospital stay, and trends toward better patient satisfaction, however no statistically significant differences in complications at 6 months [32]. Based on the size of the specimen, we generally remove via an umbilical site extension if amenable. The incision is extended through the skin and then down through the fascia with care taken to avoid injury to intra-abdominal contents. For simple nephrectomies when malignancy is not suspected, intra-abdominal morcellation can be performed. The specimen bag can then be removed and the incision closed. The abdomen should be re-insufflated and the surgical bed inspected to ensure adequate hemostasis after a period of desufflation. Hemostasis can also be assessed before specimen extraction by lowering the intra-abdominal pressure of the pneumoperitoneum down to 5–10 mmHg. The area should also be inspected for any evidence of injury to other intra-abdominal contents. Table 2.1 discusses management of these injuries as well as potential means of preventing other organ injuries.

The fascia at the sites of 12 mm ports, cutting trocars, and 10 mm trocar sites should be closed to prevent hernia (see Table 2.1). Any smaller ports do not require fascial closure. A suture passer system may be employed with a 0 Vicryl or a doubled over 2-0 Vicryl suture that is placed under direct visualization through the fascia on either side of the trocar defect while the abdomen remains insufflated. Skin incisions can then be closed in a subcutaneous fashion with your choice of absorbable sutures, such as a 4-0 Monocryl.

Partial Nephrectomy

Trocar placement, colonic reflection, and isolation of the renal hilum take place in a manner the same as that previously described for laparoscopic radical nephrectomy. The next steps of the procedure are dependent on tumor location. For anterior tumors, some lateral mobilization of the kidney may be necessary to be able to outline the entirety of the tumor. For posterior tumors, the entire kidney must be mobilized to allow for flipping and/or twisting of the kidney to expose the area of interest. Complete mobilization involves freeing the upper pole of the kidney from the inferior border of the adrenal gland (as described in a radical nephrectomy procedure). Mobilization of the lower pole can easily take place after the ureter and gonadal vessels are identified and isolated, and the remainder of the attachments can be taken quickly without fear of injury to adjacent structures.

Intraoperative Localization

Following mobilization, the next step is localization of the renal mass. Preoperative imaging should be reviewed thoroughly prior the procedure and available for review intraoperatively.

Intraoperative ultrasound is used to identify the renal mass, its characteristics (e.g., solid/cystic), exact borders, and relationship to renal structures (e.g., vessels, collecting system). If available, it should be used for partial nephrectomies as it has been found to reveal findings additional to preoperative imaging in about 10% of cases – which could significantly impact surgical approach [33].

With emphasis on nephron-sparing surgery, intraoperative imaging and augmented reality technologies continue to be developed, although intraoperative ultrasound continues to be most commonly used. One emerging method is the use of near-infrared fluorescence imaging (NIRF) using intravenous indocyanine green (ICG) minutes before clamping. This has been shown to aid in tumor localization, pathology prediction, super-selective clamping, and adequate clamping [34–36]. However, it does require specific endoscopic systems for laparoscopic use (SPY® Imaging System, Novadaq Inc., Mississauga, ON, Canada).

Renal Mass Resection

Once the lesion is localized, the kidney should be positioned to allow for adequate exposure during resection. In rare occasions, the surgeon may place an additional 5 mm port for use as an assistant port to aide in retraction and/or exposure. Gerota fascia is then incised away from the border of the tumor. The perinephric fat is dissected off the renal capsule around the area of the tumor with care taken to neither cut into the tumor nor remove the fat overlying the tumor. An outline of the line of incision can then be made into the renal capsule using shears (hot or cold) or monopolar hook. This incision should be made just lateral to the previously identified extent of the tumor to provide an adequate margin and prevent entering the tumor. A marked sponge may be placed in the abdomen at this time to prevent any blood loss that does occur from tracking into the contralateral side of the abdomen.

Next, a decision is made as to extent/type of vascular control needed for the procedure. There are many series reporting an off-clamp technique for excision of renal mass [37]. This method is associated with increased blood loss but has the ultimate goal of decreased (zero) ischemia and thus potential preservation of renal function. Other approaches to decrease ischemia time include early unclamping [38], segmental clamping, and tumor-specific clamping [20]. Patient factors, intraoperative feasibility, and surgeon preference should determine the method of vascular control to be used.

When a clamp technique is used, laparoscopic bulldog clamps can be placed on the main renal artery for complete occlusion or on segmental vessels for selective ischemia. We generally employ a method of early unclamping such that hilar clamp time should be limited to reduce the detrimental impact of warm ischemia on renal function [38, 39]; however, the amount of kidney removed and underlying renal function are of greater consequence to postoperative renal function [40].

The renal capsule is then incised at the previously marked position. A combination of blunt and sharp athermal dissection is used to excise the renal mass. Vessels that are directly visualized during this dissection may be clipped prior to transection to aide in hemostasis. Extreme care should be taken to prevent violation of the tumor that could lead to tumor spillage. Gentle manipulation with the suction/irrigator or with a laparoscopic DeBakey forceps may be employed to handle the tumor. Often, the overlying perinephric fat may be used to aide in tumor retraction with decreased risk of injury to mass. Once the tumor is completely excised, the specimen should be placed directly into an entrapment sac. The resection bed should then be examined. Cold cup or excisional biopsies may be taken and sent for permanent or frozen section.

Hemostasis is then obtained using a variety of techniques. The tumor resection bed may be cauterized using argon beam coagulator. Hemostatic matrix, such as Floseal (Baxter, Deerfield, IL), may be placed into the tumor bed. Additionally, some surgeons may employ a multilayered closure with initial placement of suture (3-0 Vicryl interrupted or running) along the floor

of the defect to aide in both hemostasis and/or closure of the collecting system (refer to Table 2.1 for discussion of urine leaks). Renal parenchymal edges are then reapproximated. Absorbable suture (0, 2-0, or 3-0 Vicryl) with Lapra-Ty and/or barbed suture may be used to reapproximate the parenchymal edges. Suture must be placed at an adequate distance (approximately 1 cm) to the edge of the defect to prevent the suture from tearing through the renal parenchyma. Sutures should be pulled in the direction of placement to also prevent tissue tearing. This can be performed in an interrupted or running fashion. Sutures should be placed until the renal edges appear well approximated and hemostasis is obtained. At this point, bulldog clamps can be removed from the renal hilum, and warm ischemia time can be calculated. Early clamp removal, prior to completion of the renorrhaphy, can be performed to limit ischemic time [38]. Mannitol administration can also be considered prior to hilar clamping with the theoretical potential for reduction of postoperative renal dysfunction. The data to support the use of mannitol is in animal models and transplant literature, which lead to routine use traditionally [41, 42]. Recent studies, including a randomized trial comparing mannitol vs. hydration in minimally invasive partial nephrectomies in a population with normal preoperative renal function, found no clinically or statistically significant difference in renal function between their cohorts at 6 months postoperatively [43]. Other retrospective and prospective trials had similar findings and thus contemporary data does not support mannitol use in this population [42, 44].

Once reperfusion has occurred, the kidney should be reexamined. Additional sutures may need to be placed to aide in hemostasis. The specimen is then extracted, and port sites can be closed as previously described in the nephrectomy section above. As the specimen is often much smaller, these can almost always be removed through a minor extension of a port site. A closed suction drain should be left if there is known or suspected collecting system involvement. The drain is used as an aide to diagnose and manage urine leak after partial nephrectomy, which occurs in about 4–5% of cases [45].

Considerations for Radical Nephroureterectomy

Most of the principles and techniques above apply to laparoscopic nephroureterectomy. Given the need for access to the distal ureter, positioning modifications are required. Generally, a modified flank position is amenable. Port placement should also be mindful of the need for distal ureteric dissection and might require an extra port.

The main decision to consider is approach the distal ureter and bladder cuff. If a complete laparoscopic approach is planned, the transurethral excision of the ureteric orifice should be performed first. Another approach is to do most of the resection laparoscopically with a small Gibson incision at the end of the case to excise the distal ureter.

Equivalent oncologic outcomes are seen with direct bladder cuff excision, pluck technique, and transurethral resection of intramural ureter, although intussusception (stripping) has been shown to be inferior [4]. Thus, it is based on surgeon preference and training. In general, T3/T4 tumors should not be approached laparoscopically.

Given the nature and high risk of seeding with urothelial carcinoma compared to renal cell carcinoma, careful oncologic principles should be followed when performing laparoscopic nephroureterectomy. These include avoiding entry into the urinary tract, avoiding direct contact with the tumor, maintaining a closed system, and attempting en bloc resection of kidney, ureter, and bladder cuff whenever possible [4].

Retroperitoneal Approach

Choosing between transperitoneal and retroperitoneal approaches is a function of surgeon comfort as well as tumor location with posterior and/or apical tumors potentially being more easily accessed via the retroperitoneum. The retroperitoneal approach may also offer advantages in those patients with multiple intra-abdominal surgeries in which dissection down into the retroperitoneum may be difficult secondary to adhesions.

Patient Positioning

Unlike in the transperitoneal approach, the retroperitoneal approach requires full flank patient positioning. After induction of general anesthesia, the patient is positioned at 90° to the bed with the ipsilateral side up. Gel rolls or pillows may be placed behind the back to aide in positioning. It is necessary to place an axillary roll to prevent brachial plexus injury with this position. The contralateral arm is placed out on armrest at less than 90°. The ipsilateral arm is draped over the chest in a neutral position and placed onto arm rest secured to the surgical table. At this degree of rotation, it is necessary to place contralateral leg in a bent position and then place pillows between the legs to elevate the ipsilateral leg and thus prevent a significant degree of hip adduction and/or strain on sciatic nerve (refer to Table 2.1 for further description regarding positioning injuries). The patient is secured to the surgical table with tape or straps placed across the hips and across the chest (underneath the ipsilateral arm). The authors prefer wide silk tape placed over gel pads and surgical towels. All pressure points should be padded. The ipsilateral arm is loosely secured to prevent movement during the case. Bilateral legs are also loosely secured to the surgical table to prevent significant movement during the case.

Trocar Positioning

Once secured, the bed can be flexed and the kidney bar raised to increase the distance between the ribs and hips and hence maximize access to the retroperitoneum. An incision is then made approximately two fingerbreadths below the tip of the 12th rib along the posterior axillary line. Dissection is taken down through the lumbodorsal space until the retroperitoneum is entered. Blunt dissection or a trocar-mounted dissecting balloon is used to develop the retroperitoneal working space. A blunt 12 mm trocar can be placed within newly developed space and retroperitoneum. The trocar balloon is inflated, placed on tension at the level of the skin, and then insufflated to 15 mmHg (Fig. 2.5). Working space is significantly diminished with this approach.

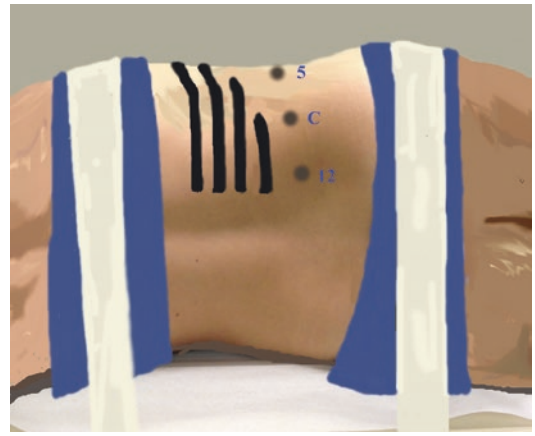

Fig. 2.5 Trocar positioning for retroperitoneal approach. C = camera port, 12 = 12 mm port, 5 = 5 mm port

Retroperitoneoscopic Partial Nephrectomy

It is necessary to obtain vascular control as the preliminary step. Dissection takes place in the plane between the anterior belly of the psoas muscle and the posterior aspect of the kidney. Lateral and anterior renal attachments should not be released until the hilum is identified as this will disrupt the natural retraction and hence make hilar identification more difficult. The artery is encountered first. Partial nephrectomy proceeds as described previously.

References

1. On M, Landman J. Laparoscopic nephrectomy. In: Smith Jr JA, Howards SS, Preminger GM, Dmochowski RR, editors. Hinman's atlas of urologic surgery. 4th ed. Philadelphia: Elsevier; 2018. p. 112–21.
2. Schwartz MJ, Rais-Barhami S, Kavoussi LR. Laparoscopic and robotic surgery of the kidney. In: Wein AJ, Kavoussi LR, Partin AW, Peters CA, editors. Campbell-Walsh urology. 11th ed. Philadelphia: Elsevier; 2016. p. 1446–82.
3. Bansal RK, Tu HY, Drachenberg D, Shayegan B, Matsumoto E, Whelan J, Kapoor A. Laparoscopic

management of advanced renal cell carcinoma with renal vein and inferior vena cava thrombus. Urology. 2014;83(4):812–6.
4. Rouuprêt M, Babjuk M, Compérat E, Zigeuner R, Sylvester RJ, Burger M, et al. European association of urology guidelines on upper urinary tract urothelial carcinoma: 2017 update. Eur Urol. 2018;73(1):111–22.
5. Elsamra S, Pareek G. Complications of laparoscopic renal surgery. Int J Urol. 2010;17(3):206–14.
6. Campbell S, Uzzo RG, Allaf ME, Bass EB, Cadeddu JA, Chang A, et al. Renal mass and localized renal cancer: AUA guideline. J Urol. 2017;198(3):520–9.
7. Finelli A, Ismaila N, Bro B, Durack J, Eggener S, Evans A, et al. Management of small renal masses: American Society of Clinical Oncology Clinical Practice Guideline. J Clin Oncol. 2017;35(6):668–80.
8. Ljungberg B, Bensalah K, Canfield S, Dabestani S, Hofmann F, Hora M, et al. EAU guidelines on renal cell carcinoma: 2014 update. Eur Urol. 2015;67(5):913–24.
9. Coll DM, Uzzo RG, Herts BR, Davros WJ, Wirth SL, Novick AC. 3-Dimensional volume rendered computerized tomography for preoperative evaluation and intraoperative treatment of patients undergoing nephron sparing surgery. J Urol. 1999;161(4):1097–102.
10. Wunderlich H, Reichelt O, Schubert R, Zermann DH, Schubert J. Preoperative simulation of partial nephrectomy with three-dimensional computed tomography. BJU Int. 2000;86(7):777–81.
11. Coll DM, Smith RC. Update on radiological imaging of renal cell carcinoma. BJU Int. 2007;99(5):1217–22.
12. Kang SK, Kim D, Chandarana H. Contemporary imaging of the renal mass. Curr Urol Rep. 2011;12(1):11–7.
13. Kutikov A, Uzzo RG. The R.E.N.A.L. nephrometry score: a comprehensive standardized system for quantitating renal tumor size, location and depth. J Urol. 2009;182(3):844–53.
14. Ficarra V, Novara G, Secco S, Macchi V, Porzionato A, Caro R, Artibani W. Preoperative aspects and dimensions used for an anatomical (PADUA) classification of renal tumours in patients who are candidates for nephron-sparing surgery. Eur Urol. 2009;56(5):786–93.
15. Simmons MN, Ching CB, Samplaski MK, Park CH, Gill IS. Kidney tumor location measurement using the C index method. J Urol. 2010;183(5):1708–13.
16. Leslie S, Gill IS, de Castro Abreu AL, Rahmanuddin S, Gill KS, et al. Renal tumor contact surface area: a novel parameter for predicting complexity and outcomes of partial nephrectomy. Eur Urol. 2014;66(5):884–93.
17. Herrera-Caceres JO, Finelli A, Jewett MA. Renal tumor biopsy: indicators, technique, safety, accuracy results, and impact on treatment decision management. World J Urol. 2019;37:437–43. https://doi.org/10.1007/s00345-018-2373-9.
18. Richard P, Jewett M, Bhatt J, Kachura J, Evans A, Zlotta A, et al. Renal tumor biopsy for small renal masses: a single-center 13-year experience. Eur Urol. 2015;68(6):1007–13.
19. Leveridge MJ, Finelli A, Kachura JR, Evans A, Chung H, Shiff DA, et al. Outcomes of small renal mass needle core biopsy, nondiagnostic percutaneous biopsy, and the role of repeat biopsy. Eur Urol. 2011;60(3):578–84.
20. Klatte T, Ficarra V, Gratzke C, Kaouk J, Kutikov A, Macchi V, et al. A Literature review of renal surgical anatomy and surgical strategies for partial nephrectomy. Eur Urol. 2015;68(6):980–92.
21. Gaunay GS, Elsamra SE, Richstone L. Trocars: site selection, instrumentation, and overcoming complications. J Endourol. 2016;30(8):833–43.
22. Azevedo OC, Azevedo JL, Sorbello AA, Miguel GP, Wilson Junior JL, Godoy AC. [Evaluation of tests performed to confirm the position of the Veress needle for creation of pneumoperitoneum in selected patients: a prospective clinical trial.] Acta Cir Bras. 2006;21(6):385–91. *[Article in Portugese].*
23. Hsi RS, Ojogho ON, Baldwin DD. Analysis of techniques to secure the renal hilum during laparoscopic donor nephrectomy: review of the FDA Database. Urology. 2009;74(1):142–7.
24. Simforoosh N, Sarhangnejad R, Basiri A, Ziaee S, Sharifiaghdas F, Tabibi A, et al. Vascular clips are safe and a great cost-effective technique for arterial and venous control in laparoscopic nephrectomy: single-center experience with 1834 laparoscopic nephrectomies. J Endourol. 2012;26(8):1009–12.
25. Ponsky L, Cherullo E, Moinzadeh A, Desai M, Kaouk J, Haber GP, et al. The Hem-o-Lok clip is safe for laparoscopic nephrectomy: a multi-institutional review. Urology. 2008;79(4):593–6.
26. Janki S, Verver D, Klop K, Friedman A, Peters T, Ratner L, Ijzermans J, Dor F. Vascular management during live donor nephrectomy: an online survey among transplant surgeons. Am J Transplant. 2015;15(6):1701–7.
27. Yap SA, Alibhai SM, Abouassaly R, Timilshina N, Margel D, Finelli A. Ipsilateral adrenalectomy at the time of radical nephrectomy impacts overall survival. BJU Int. 2013;111(3 Pt B):E54–8.
28. Gill I, McClennan B, Kerbl K, Carbone J, Wick M, Clayman R. Adrenal involvement from renal cell carcinoma: predictive value of computerized tomography. J Urol. 1994;152(4):1082–5.
29. Nason GJ, Aslam A, Giri SK. Predictive ability of preoperative CT scan in determining whether the adrenal gland is spared at radical nephrectomy. Curr Urol. 2016;9:143–7.
30. Yap SA, Alibhai SM, Abouassaly R, Timilshina N, Finelli A. Do we continue to unnecessarily perform ipsilateral adrenalectomy at the time of radical nephrectomy? A population based study. J Urol. 2012;187(2):398–404.
31. Gabr AH, Steinberg Z, Eggener SE, Wolf J Jr. Indications for adrenalectomy during radical nephrectomy for renal cancer. Arab J Urol. 2014;12(4):304–8.
32. Binsaleh S, Madbouly K, Matsumoto ED, Kapoor A. A prospective randomized study of pfannenstiel

versus expanded port site incision for intact specimen extraction in laparoscopic radical nephrectomy. J Endourol. 2015;29(8):913–8.
33. Bhosale PR, Wei W, Ernst RD, Bathala TK, Reading RM, Wood CG, Bedi DG. Intraoperative sonography during open partial nephrectomy for renal cell cancer: does it alter surgical management? Am J Roentgenol. 2014;203(4):822–7.
34. Tobis S, Knopf JK, Silvers C, Messing E, Yao J, Rashid H, Wu G, Golijanin D. Robot-assisted and laparoscopic partial nephrectomy with near infrared fluorescence imaging. J Endourol. 2012;26(7):797–802.
35. Borofsky MS, Gill IS, Hemal AK, Marien TP, Jayaratna I, Krane LS, Stifelman MD. Near-infrared fluorescence imaging to facilitate super-selective arterial clamping during zero-ischaemia robotic partial nephrectomy. BJU Int. 2013;111(4):604–10.
36. Angell JE, Khemees TA, Abaza R. Optimization of near infrared fluorescence tumor localization during robotic partial nephrectomy. J Urol. 2013;190(5):1668–73.
37. Rais-Bahrami S, George AK, Herati AS, nivasan AK, Richstone L, Kavoussi LR. Off-clamp versus complete hilar control laparoscopic partial nephrectomy: comparison by clinical stage. BJU Int. 2013;109(9):1376–81.
38. Nguyen MM, Gill IS. Halving ischemia time during laparoscopic partial nephrectomy. J Urol. 2008;179(2):627–32; discussion 632.
39. Desai MM, Gill IS, Ramani AP, Spaliviero M, Rybicki L, Kaouk JH. The impact of warm ischaemia on renal function after laparoscopic partial nephrectomy. BJU Int. 2005;95(3):377–83.
40. Mir MC, Campbell RA, Sharma N, Remer EM, Simmons MN, Li J, et al. Parenchymal volume preservation and ischemia during partial nephrectomy: functional and volumetric analysis. Urology. 2013;82(2):263–8.
41. Cooper CA, Shum CF, Bahler CD, Sundaram CP. Intraoperative mannitol not essential during partial nephrectomy. J Endourol. 2018;32:354–8.
42. Power NE, Maschino AC, Savage C, Silberstein JL, Thorner D, Tarin T, Wong A, Touijer KA, Russo P, Coleman JA. Intraoperative mannitol use does not improve long-term renal function outcomes after minimally invasive partial nephrectomy. Urology. 2012;79:821–6.
43. Spaliviero M, Power NE, Murray KS, Sjoberg DD, Benfante NE, Bernstein ML, Wren J, Russo P, Coleman JA. Intravenous mannitol versus placebo during partial nephrectomy in patients with normal kidney function: a double-blind, clinically-integrated, randomized trial. Eur Urol. 2018;73:53–9.
44. Choi K, Hill S, Hale N, Phillips S, Deem S. Intraoperative mannitol during robotic-assisted-laparoscopic partial nephrectomy. J Robot Surg. 2019;13(3):401–5.
45. Van Poppel H, Da Pozzo L, Albrecht W, Matveev V, Bono A, Borkowski A, et al. European Organization for Research and Treatment of Cancer (EORTC); National Cancer Institute of Canada Clinical Trials Group (NCIC CTG); Southwest Oncology Group (SWOG); Eastern Cooperative Oncology Group (ECOG). A prospective randomized EORTC intergroup phase 3 study comparing the complications of elective nephron-sparing surgery and radical nephrectomy for low-stage renal cell carcinoma. Eur Urol. 2007;51(6):1606–15.

3 Laparoscopic and Robotic Reconstruction of the Upper Genitourinary Tract

Ryan L. Steinberg and Jeffrey C. Gahan

Introduction

The first laparoscopic nephrectomy performed in 1991 revolutionized urology by demonstrating that extirpative surgery could be performed in a minimally invasive manner [1]. However, it wasn't until 3 years after Clayman performed the first laparoscopic nephrectomy that minimally invasive techniques for reconstruction were attempted. Schuessler performed the first laparoscopic pyeloplasty in 1993 [2, 3], which was followed shortly by Reddy and Evans and the first laparoscopic ureteroneocystostomy. Even after these publications, urologic reconstructive surgery was still largely performed in an open fashion, with only highly selected cases utilizing a minimally invasive approach. This delayed adoption was likely due to a combination of lagging technology and the requirement of a new and challenging skill set (e.g., intracorporal suturing). However, as laparoscopic technology advanced, along with the incorporation of robotic assistance, adoption of minimally invasive approaches to urologic reconstructive surgery has gained popularity. Currently, even uncommon and challenging reconstructive cases are being performed in a minimally invasive manner. This chapter aims to review some of the less common minimally invasive reconstructive surgeries being performed by providing detailed descriptions of each in conjunction with a brief review of the literature. Topics addressed in this chapter include distal ureteral reconstruction (ureteroneocystostomy, psoas hitch, Boari flap), retrocaval ureter, nephropexy, substitution ureteroplasty, and ureteral replacement. Table 3.1 gives a summary of the common instruments used for these cases.

Distal Ureter

Defects of the distal ureter may be the result of multiple etiologies, including ischemia, trauma, periureteral fibrosis, malignancy, congenital disorders, and iatrogenic injuries. Currently, iatrogenic injuries account for 2–10% of ureteral strictures and are commonly the result of gynecologic [4–6], endoscopic, or colorectal surgery. Distal ureteral stones and their treatment are also associated with an increased risk of stricture. Tas et al. reported that distal stones may cause ureteral stricture in up to 5.8% of cases and found that larger stones (>1.0 cm) and impacted stones have higher stricture rates [7]. Roberts et al. similarly showed that stones impacted for prolonged periods (greater than 2 months) had a 24% incidence of stricture formation [8]. Currently, with improved endoscopic equipment, the rate of long-term complications from stone treatment in

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S. L. Best, S. Y. Nakada (eds.), *Minimally Invasive Urology*,
https://doi.org/10.1007/978-3-030-23993-0_3

Table 3.1 Common instruments used in laparoscopic or robotic reconstruction of the upper genitourinary tract

Laparoscopic	Robotic (Intuitive Surgical, Sunnyvale, CA)
5 mm monopolar scissors	8 mm monopolar curved scissors
5 mm Maryland/atraumatic graspers	8 mm Maryland bipolar forceps
5 mm right angle graspers	8 mm Cadiere or Prograsp forceps (optional)
5 mm laparoscopic needle driver × 2	8 mm needle driver × 2
High-definition laparoscopic camera	High-definition 3D camera
10 mm 0° lens	12 mm 0° endoscope
10 mm 30° lens	12 mm 30° endoscope
5 mm trocar	8 mm robotic cannula (2 for DaVinci Si robot; 3 for DaVinci Xi robot
12 mm laparoscopic trocar	12 mm laparoscopic trocar (2 for DaVinci Si robot, camera and assistant ports; 1 for DaVinci Xi robot, assistant port)
5 mm Ligasure (optional)	
General equipment Veress needle 12 mm Visiport laparoscopic trocar (Medtronic, Minneapolis, MN) Hem-o-lok clip applier (small, medium, large) Angiographic 5 Fr 100 cm 0.038 in catheter Amplatz Super Stiff J tip guidewire 0.035 in Flexible cystoscope Vessel loop 6 Fr double J stent (length as appropriate) 19 Fr full-flute 4-channel drain 3–0 Vicryl 12 cm SH needle × 3 4–0 Vicryl 12 cm SH needle 3–0 V-Loc V-20 12 cm absorbable suture (optional)	*For bowel reconstruction:* Endo-GIA stapler 3.5 mm × 45 cm Endo-GIA staple loads × 4 2–0 Vicryl sutures (dyed and undyed)

the ureter is now <1% [9]. Urothelial carcinoma in the distal ureter is a relatively uncommon cause of distal ureteral obstruction which may be treated with segmental ureterectomy and ureteral reimplant. Several reports in the urologic literature report this as a safe and effective method in select patients while preserving renal function [10, 11]. In the pediatric population, congenital defects of the distal ureter are the most common etiology requiring surgical correction, but this remains outside the topic of this chapter. In general, most distal ureteral defects may be managed by ureteroureterostomy given that the defect is short and uncomplicated. If the segment of damaged or involved ureter is sufficiently long, additional methods may be incorporated to bridge the gap including a psoas hitch and Boari flap. Table 3.2 outlines the approximate defect lengths that may be bridged with each reconstruction technique.

Table 3.2 Approximate length of involved or damaged distal ureter that may be bridged given each method of reconstruction

Reconstruction technique	Defect lengths (cm)
Ureteroureterostomy	<2
Ureteroneocystostomy	2–5
Psoas hitch	6–10
Boari flap	12–15

Workup of Distal Ureteral Strictures

When evaluating a ureteral stricture, proper imaging is essential to ensure correct treatment planning. A retrograde pyelogram (RPG) and now less commonly an intravenous pyelogram (IVP) accurately define the length and location of a distal stricture. However, antegrade and retrograde studies both may be needed to elucidate the true extent of ureteral involvement (Fig. 3.1). Cross-sectional imaging such as magnetic resonance imaging

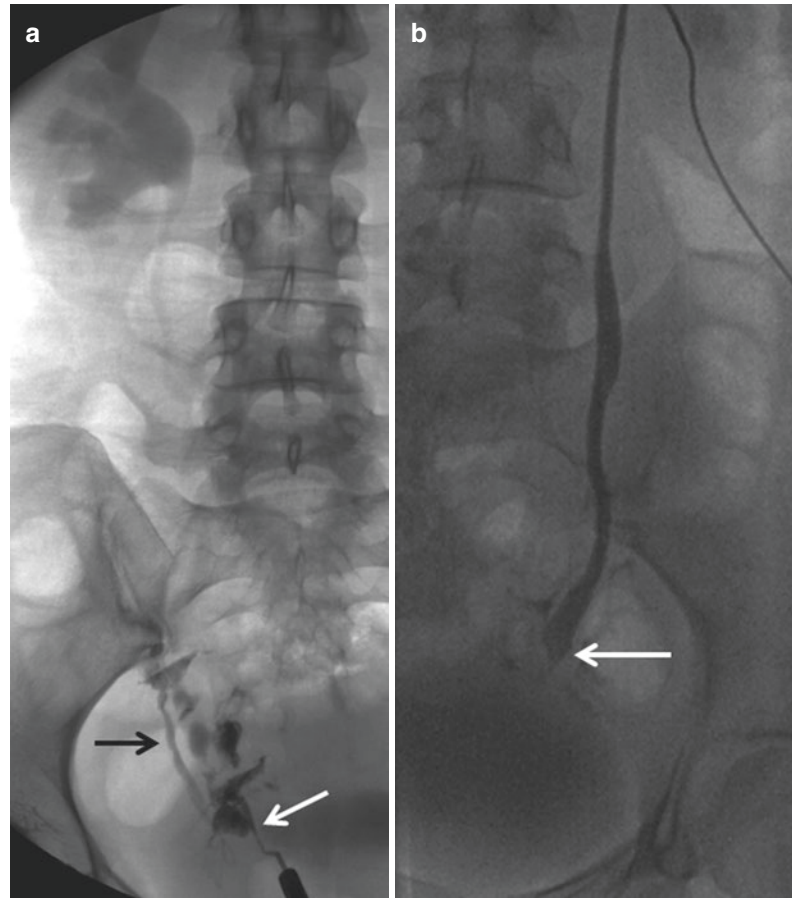

Fig. 3.1 Iatrogenic distal ureteral injury during laparoscopic ablation of endometriosis. (**a**) The distal extent of ureteral injury (*white arrow*) and the apparent normal proximal ureter (*black arrow*) are seen on retrograde pyelogram (RPG) along with moderate hydronephrosis. (**b**) An antegrade nephrostogram performed on the same patient shows a greater extent of proximal ureter (*white arrow*) involved than indicated by the RPG

(MRI) or computed tomography (CT) scan is also useful when evaluating ureteral strictures (Fig. 3.2) and may provide additional information to an IVP or RPG, especially when evaluating extrinsic causes of ureteral obstruction (non-urologic malignancy or fibrosis). In addition, despite their benign appearance, some strictures may be the result of malignancy and may not show the classical filling defect that is customarily seen. If there is any question as to the etiology of the stricture, a workup for malignancy should be undertaken. This should include cytology, ureteroscopy with biopsy if possible, or brushing if biopsy is not feasible. Another critical consideration is the functional status of the ipsilateral renal unit, which can be evaluated using a diuretic renal scan. Impaired function on renal scan <25% has been linked to worse success rates after endoscopic intervention [12], while renal function less than 20% may be an indication for nephrectomy. Indications for ureteral reconstruction include compromised renal function, recurrent pyelonephritis, and pain due to obstruction.

Ureteroneocystostomy

Although the literature is mainly limited to case series for ureteroneocystostomy [13–18], these series have shown good overall success with laparoscopic and robotic approaches (Table 3.3). A 3–5 cm segment of distal ureter can be excised and the defect bridged without performing a psoas hitch or Boari flap. This is possible given

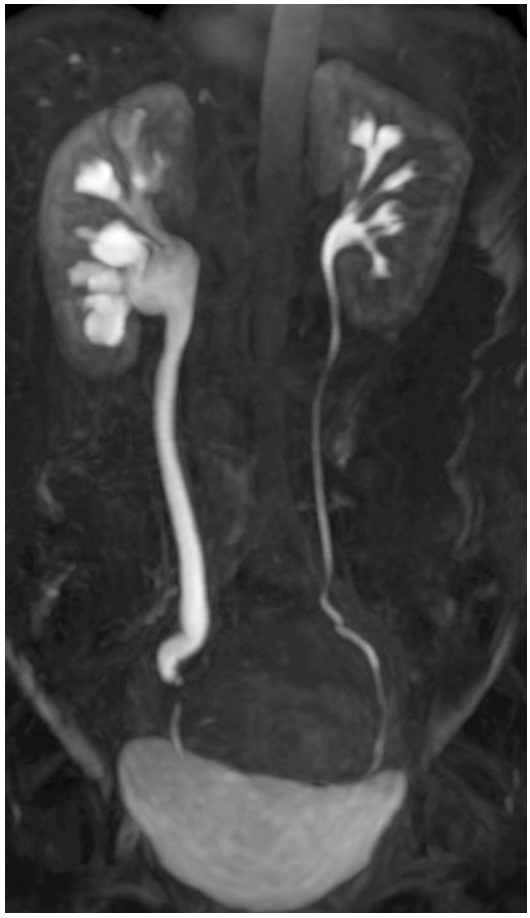

Fig. 3.2 Reconstructed MRI urogram demonstrating a distal right ureteral stricture with associated hydronephrosis due to an iatrogenic surgical injury

the posterior trajectory of the ureter upon entering the pelvis, which can be brought anteriorly with ureteral mobilization and mobilization of the bladder if there is sufficient capacity and compliance.

Typically, this procedure is performed via a transperitoneal approach when performed laparoscopically or robotically. The patient is placed in the supine position on the OR table with their legs in spreader bars or in low lithotomy. This allows access to the patient's urethra and easy docking of the robot. Patient positioning and trocar placement are shown in Fig. 3.3. Insufflation is typically achieved using a Veress needle, of which the exact method of placement will be discussed in other chapters. If performed robotically (Fig. 3.4), the trocar placement is similar to that of a radical prostatectomy, although the robotic trocar contralateral to the involved ureter is moved slightly caudal and medial. Once pneumoperitoneum is established, the colon is reflected medially, and the ureter is identified as it crosses over the iliac vessels. The OR table can be rotated slightly, allowing gravity to help with colon retraction. Once circumferential access is gained to the ureter, a vessel loop is placed around it to allow for atraumatic manipulation. The ureter is then dissected distally to the strictured segment and divided (see Fig. 3.4a). At this time, an evaluation of the ureteral length should be made by extending the ureter to the bladder.

Table 3.3 Robotic and laparoscopic series published for open, laparoscopic, and robotic ureteral reimplant

	N	Reimplant only (no.)	Psoas hitch (no.)	Boari flap (no.)	Follow-up (mo)	Surgical success[a] (%)	Etiology	Approach
Wenske et al. [13]	100	24	58	18	49	97	39% TCC	Open
Kozinn[b] et al. [14]	24	4	4	2	24	100	40% calculus	Robot
Hemal[b] et al. [15]	18	7	1	0	14	100	44% megaureter	Robot
Ogan et al. [16]	6	5	1	0	13	100	66 % iatrogenic	Lap
Soares et al. [17]	11	7	1	2	18	100	40% calculus	Lap
Rassweiler et al. [18]	10	0	6	4	–	100	30 % iatrogenic	Lap

[a]Operative success defined by imaging and symptom resolution
[b]These studies did not report the type of reconstruction for all cases

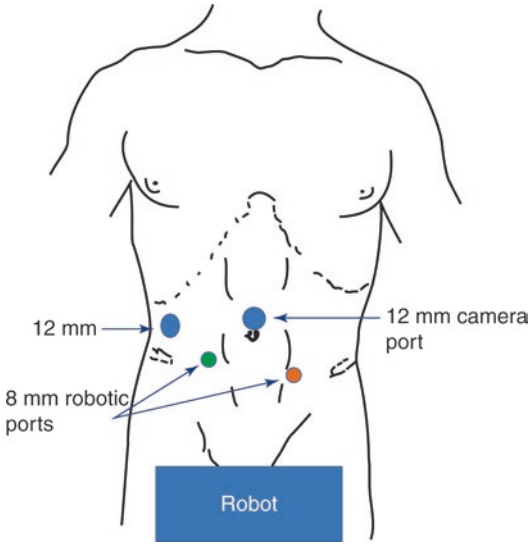

Fig. 3.3 Patient position and trocar placement for right robotic ureteroneocystostomy. Note the left robotic trocar (*orange*) is brought medial and caudal compared to the right (*green*). 12 mm trocars (*blue*) are used as the camera port and the right as a lateral assistant port. A similar port placement is used if performed laparoscopically

In most instances, the bladder will need to be mobilized to accommodate a tension-free anastomosis. This is accomplished by releasing the bladder from the anterior abdominal wall and incising the contralateral medial umbilical ligament. In some circumstances, the contralateral superior vesical artery may need to be ligated and transected. Once accomplished, the bladder is then filled with 150–200 mL of saline, and the insertion point of the ureter determined. Our method of ureteroneocystostomy involves using a flexible cystoscope passed through the urethra to identify the new ureteral insertion point from inside the bladder. The back or rigid end of a wire is pushed through the detrusor muscle and secured with a laparoscopic grasper (see Fig. 3.4b). An angiographic catheter is advanced over the wire (Amplatz Super Stiff, Boston Scientific, Marlborough, MA), and the wire is exchanged so the floppy end is advanced through the angiographic catheter and threaded up the ureter. This allows for easy subsequent stent placement. The cystotomy is slightly enlarged, and the ureter is spatulated on its posterior aspect. A spatulation of 1–2 cm may be required. Our preference is to perform a running anastomosis using two 3-0 Vicryl (Ethicon, Somerville, NJ) sutures, one for the lateral wall and one for the medial wall. A drain should be left in place through the lateral assistant port. Complications other than those associated with laparoscopy/robotics in general (e.g., port site hernia) or ureteral reconstruction (recurrent stricture) are uncommon. Though, as the ureter is often identified as it transverses over the bifurcation of the iliac artery, care must be taken to avoid an arterial injury. Table 3.4 provides a brief summary of complications specific to this and each procedure detailed in this chapter.

Psoas Hitch

The psoas hitch is an effective method to bridge larger defects in the distal 1/3 of the ureter and can effectively accommodate defects 6–10 cm from the bladder. However, as a general rule, the psoas hitch is not sufficient on its own to bridge defects that extend cephalad to the pelvis. In addition to the standard workup for ureteral strictures, when a psoas hitch is being considered, information about the bladder must be obtained. At minimum, a cystoscopy or cystogram documenting adequate bladder volume should be acquired. If there is concern for a neurogenic pathology, urodynamics may be indicated to document adequate bladder compliance.

If performing the psoas hitch laparoscopically or robotically, the patient position and trocar placement are the same as for ureteroneocystostomy (see Fig. 3.3). The steps for performing a psoas hitch are depicted in Fig. 3.5. The procedure is started with colon mobilization followed by identification and dissection of the ureter. The bladder is mobilized and attachments are divided as needed, which may include the vas deferens or round ligament. In addition, the contralateral superior vesical artery may be divided to increase mobilization. Lastly, an anterior cystotomy made perpendicular to the plane of ureteral insertion and closed

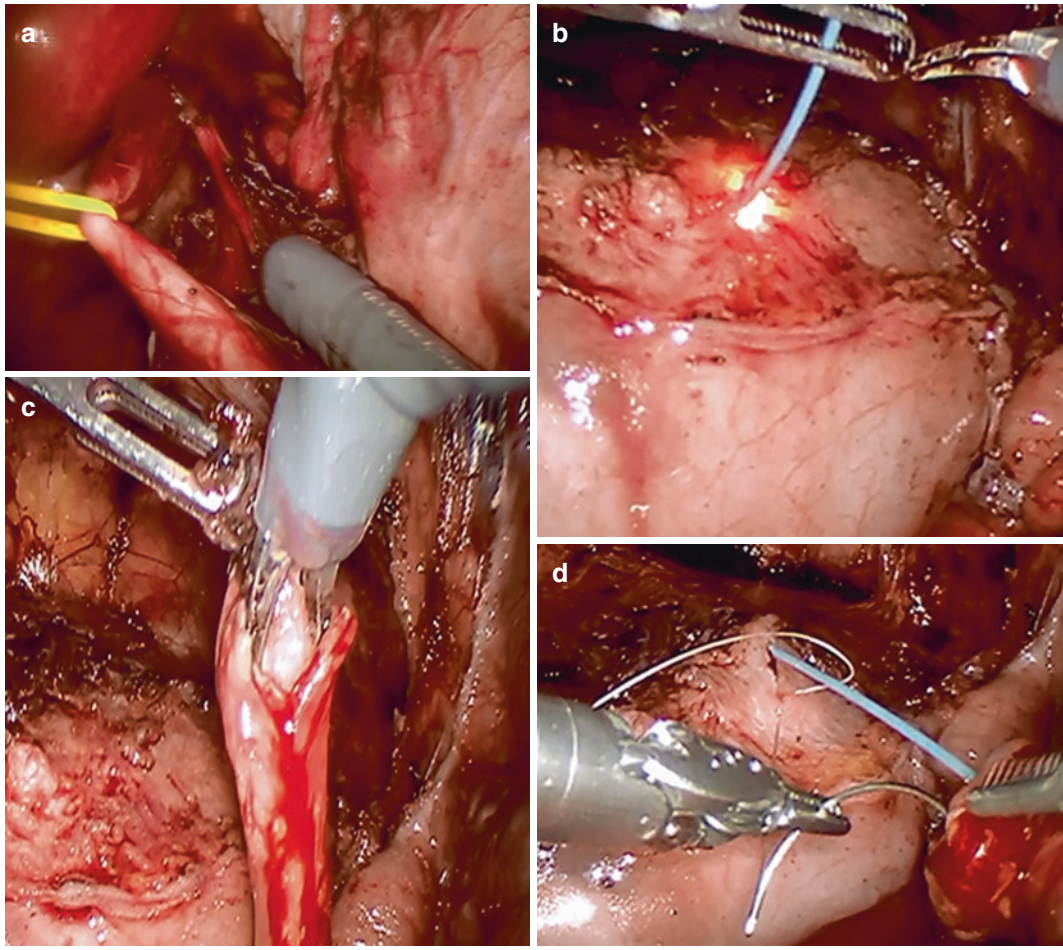

Fig. 3.4 Steps in a robotic ureteroneocystostomy. (**a**) The ureter is dissected to the level of the stricture and divided. A vessel loop aids in atraumatic manipulation. (**b**) A cystoscope is guided to the insertion point of the ureter and a wire is passed through the detrusor. (**c**) The ureter is spatulated on its posterior aspect, and the scissors are used to calibrate the inner lumen to ensure no stricture. (**d**) The anastomosis is completed using a 3-0 Vicryl suture over the wire. A double J stent is placed prior to completing the anastomosis

Table 3.4 Complications unique to laparoscopic and robotic reconstructive procedures of the upper genitourinary tract

Procedure	Complications
Ureteroneocystostomy	Iliac artery injury
Psoas hitch	Genitofemoral nerve entrapment
Boari flap	Limited bladder capacity/compliance
Ureteroureterostomy	Gonadal vessel injury
Retrocaval ureter	Caval injury, duodenal injury
Substitution ureteroplasty	Stensen duct injury, oral infection/abscess
Ureteral Substitution	Bowel leak, metabolic derangements
Nephropexy	Renal parenchymal bleeding

parallel can help advance the dome of the bladder to the ureter. This can be done either with a 3-0 Vicryl or an absorbable 3-0 V-Loc (Medtronic, Minneapolis, MN) suture. The bladder dome is then brought to the ipsilateral psoas muscle. This is secured to the psoas fascia using several absorbable (e.g., 2-0 PDS) or nonabsorbable (e.g., silk, Ethibond, or nylon) sutures. Care must be taken to avoid entrapping the genitofemoral nerve which can be avoided by placing the stitches parallel to the psoas muscle fibers and only incorporating the psoas fascia. The ureteroneocystostomy is then performed as previously described with stent placement either at the time of ureteroneocystostomy or at the

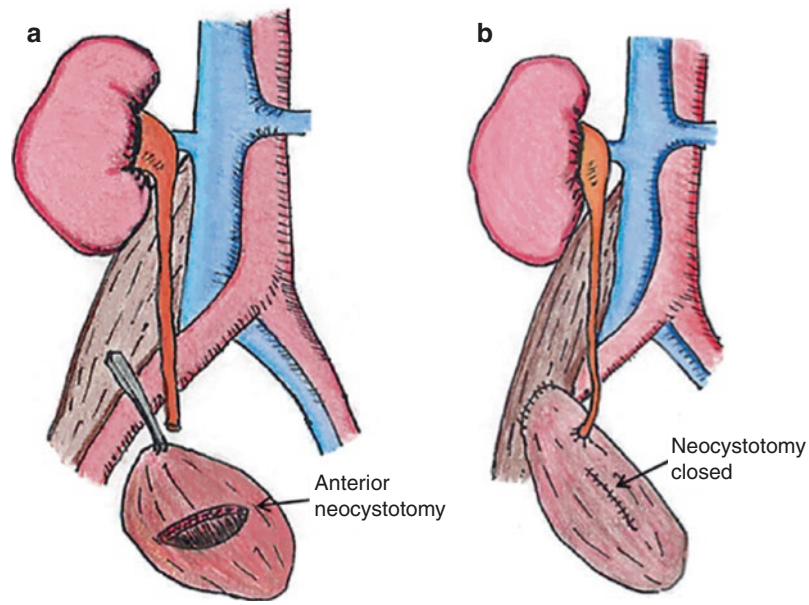

Fig. 3.5 (**a**) The bladder is brought to the psoas fascia after mobilization and an anterior neocystostomy is made if additional length is needed. (**b**) The bladder is tacked to the psoas fascia using a 3-0 Vicryl suture and the neocystostomy is closed

beginning of the case. Alternatively, some groups report performing the ureteroneocystostomy prior to the psoas hitch.

Although limited, reports indicate this to be a successful procedure with a greater than 85% success in adults and children. Advantages to this procedure include its relative simplicity and low complication rate.

Boari Flap

The Boari flap is an additional surgical technique that allows longer segments of damage to the distal ureteral to be bridged. Using this method, segmental defects up to 12–15 cm may be safely managed. As with the psoas hitch, the workup must include a thorough evaluation of the bladder to ensure that it has sufficient capacity and compliance to provide a flap of correct length and not result in a small capacity bladder.

The patient positioning, trocar placement, and dissection of the ureter are the same as for a ureteroneocystostomy (see Fig. 3.3). The bladder is completely dissected off the anterior abdominal wall, and the contralateral bladder attachments are divided as needed. The Boari flap is created by making an incision 2–3 cm from the bladder neck which is extended in an oblique fashion to the dome. The base of the flap should be at minimum 4 cm wide, with the apex being approximately 3 cm wide (Fig. 3.6a). The ratio of flap length to width should not exceed 3:1 to limit ischemia. Once the flap is created, the ureter is passed through a small opening in the distal flap, and a mucosa-to-mucosa anastomosis is performed using 4-0 Monocryl suture (Fig. 3.6b). The distal end of the flap is secured to the psoas muscle. The remainder of the flap is tubularized over a double J stent (Fig. 3.6c). Because of the extensive sewing, a 3-0 V-Loc may be considered for this step. Creating a spiral flap may allow even longer segments of damaged ureter to be bridged (Fig. 3.7). It should be noted that the bladder capacity will be diminished, in some cases greatly, depending on the length of the Boari flap generated. A drain is left through the lateral assistant port.

Mid- and Proximal Ureteral Stricture

A short defect in the mid- or proximal ureter (see Table 3.2) is appropriate for repair in the form of a laparoscopic or robotic ureteroureterostomy. When encountered in a trauma situation, this type of repair will be most often performed through an open approach, although there are rare instances when a minimally invasive ure-

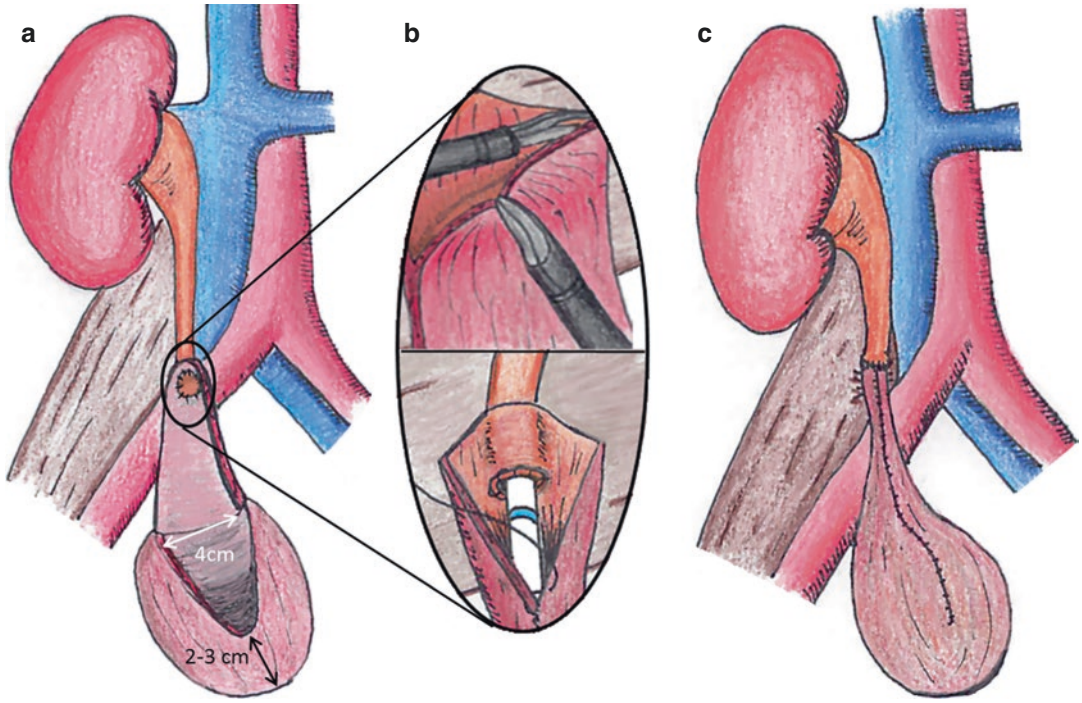

Fig. 3.6 (**a**) The Boari flap is created by incising approximately 2–3 cm from the bladder neck and the incision is carried to the bladder dome, with the base being at least 4 cm wide. (**b**) A mucosa-to-mucosa anastomosis is performed by raising a mucosal flap and tunneling the ureter through this portion of the bladder flap. (**c**) The Boari flap is secured to the psoas muscle and the flap is tubularized over a double J stent

teroureterostomy may be indicated. More distal ureteral strictures of similar length, however, may be managed best by ureteroneocystostomy. If a ureteroureterostomy is to be attempted, the defect must be short enough so that ureteral mobilization gives a tension-free anastomosis, as the rate of postoperative stricture formation is high if this criteria is not met. Trocar placement is dependent on the level of the stricture. For proximal and mid-ureteral strictures (those most appropriate for a ureteroureterostomy), we find it best to use a trocar configuration similar to that of a nephrectomy with the patient rotated into a 45° position with the diseased side up which allows the mobilized bowel to fall medially. Trocar adjustments may be made cranially or caudally depending on the stricture location during preoperative fluoroscopic evaluation (e.g., retrograde pyeloureterogram) (Fig. 3.8). The procedure is begun by incising lateral to the colon along the line of Toldt and mobilizing this medially so that the retroperitoneum is exposed. The ureter can be identified as it crosses the iliac vessels or just caudal to the lower pole of the kidney posterior and lateral to the gonadal vein. Circumferential access should be gained, and a vessel loop passed around the ureter and secured with a Hem-o-lok clip (Teleflex, Morrisville, NC). Again, this allows for atraumatic manipulation of the ureter. Once the ureter is completely mobilized, the damaged segment should be identified and excised to bleeding tissue. The exact site of the stricture can be identified in a number of ways. In patients with preoperative renal drainage, cystoscopic placement of a 5 Fr ureteral catheter or wire up to the distal aspect of the stricture prior to positioning for the ureteral repair can help identify the distal end. This can be left off the surgical field and removed by a nurse under the drapes after identification of the stricture by direct visualization. If a 5 Fr catheter is placed and prepped into the surgical field, indocyanine green (ICG) can be injected through it for stricture identification. If a nephrostomy

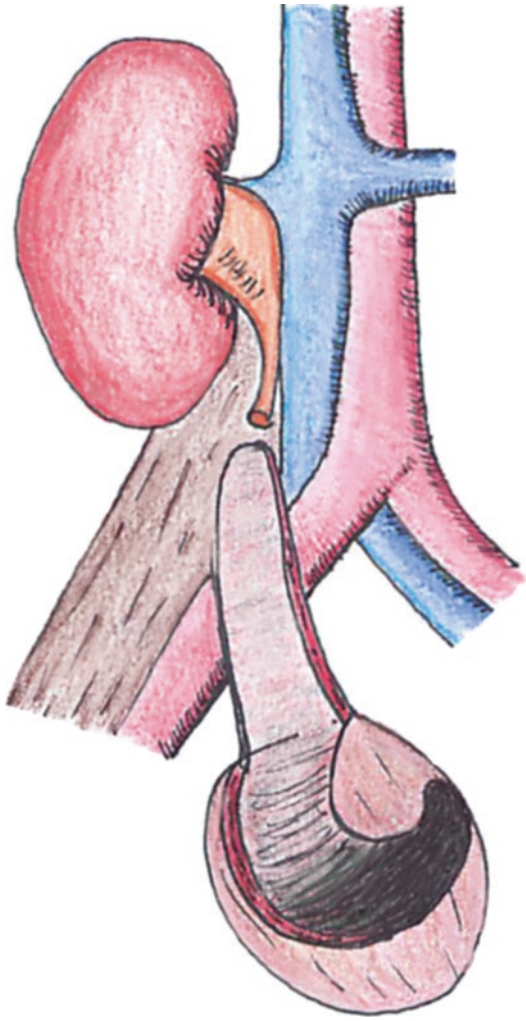

Fig. 3.7 A spiral flap can provide additional length when performing a Boari flap; however, this may result in significant loss of bladder volume

tube is in place, injection of ICG can be performed to identify the proximal end of the stricture [19]. Alternatively, if prepped into the field, a ureteral catheter can be exchanged for a guidewire, over which a ureteroscope can be passed to the level of the stricture. The robotic or laparoscopic light can be dimmed to allow visualization of the light of the ureteroscope, indicating the distal location of the stricture. Both ends should be calibrated with a laparoscopic instrument (see Fig. 3.4c) to ensure there is no remaining stricture. The ends are then spatulated 1–1.5 cm in length 180° from one another. A small, absorbable suture (we prefer 4-0 Vicryl) should be used. The suture is initially placed out-to-in on the ureter so the knot remains outside the lumen. The back wall is then completed first and a ureteral stent is placed over a wire into the bladder. If the ureteroscope had been used, as previously described, a wire can be replaced through the ureteroscope and the stent placed over the wire. The bladder can also be filled with methylene blue, which will reflux after the stent is in the bladder, confirming proper positioning.

Retrocaval Ureter

Retrocaval ureter (RCU) is a rare congenital urologic anomaly where the ureter is forced to travel posterior to the IVC due to a persistent, posterior cardinal vein before emerging on the medial aspect and crossing anterior to the vein (Fig. 3.9). This is an uncommon abnormality with 1/1000 births being affected. The persistent vein often causes a partial obstruction which leads to proximal ureteral dilation. An S-shaped deformity on intravenous pyelogram or retrograde pyelogram with proximal ureteral dilation should alert the physician to the possibility of a retrocaval ureter (see Fig. 3.9). A CT scan with IV contrast can provide a definitive diagnosis by demonstrating the persistent cardinal vein and obstructed ureter.

Surgical Intervention for RCU

Intervention for RCU is indicated if functional loss or persistent pain is experienced. Several case reports have demonstrated that a laparoscopic approach is feasible when attempting reconstruction of RCU [20, 21]. A ureteral stent can be placed at the beginning of the case in a retrograde fashion. Alternatively, intraoperative antegrade or retrograde placement can be performed, though retrograde placement may be more cumbersome laparoscopically. Both transperitoneal and retroperitoneal approaches have been described [22–24], as well as preservation and excision of the retrocaval section [25, 26].

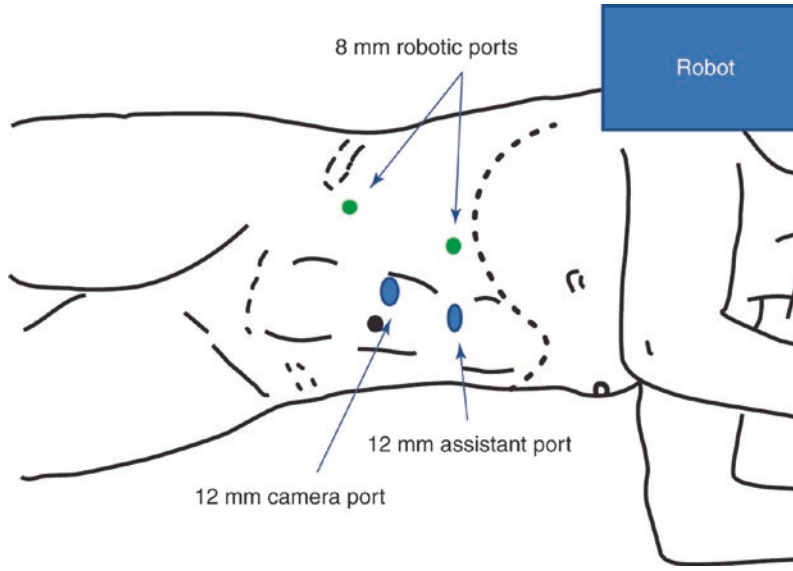

Fig. 3.8 Patient position and trocar placement for a left robotic ureteroureterostomy. The use of the fourth robotic arm is general not necessary. A 12 mm assistant is placed cranial to the camera port near the midline. If performed laparoscopically, the 8 mm ports can be substituted for 5 and 10 mm trocar and the assistant port is optional

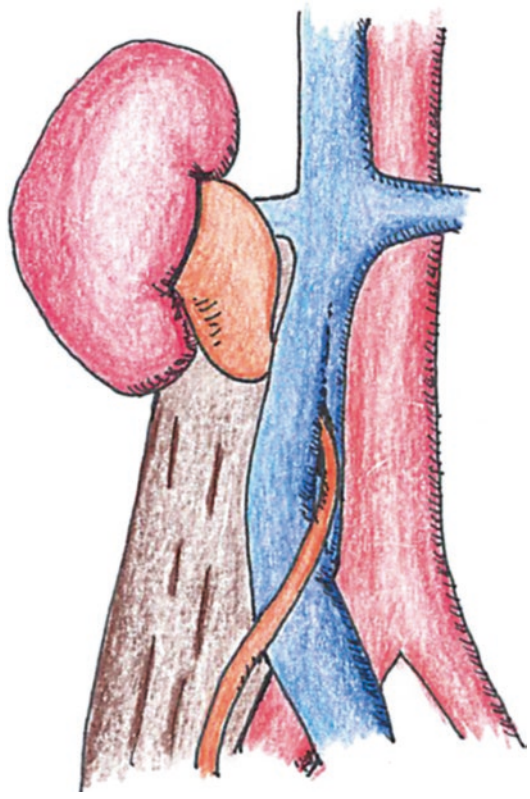

Fig. 3.9 Drawing depicting a retrocaval ureter. Note the dilation of the ureter proximal to the portion posterior to the vein

For a transperitoneal approach, the ureter is first mobilized completely away from the vena cava proximally and distally. The proximal ureter is divided at the dilated, most distal portion of the upper segment. The ureter should be calibrated with the laparoscopic or robotic instrument (as previously shown) to ensure there is no area of stenosis. If such an area exists, this should be excised. The proximal ureter is then brought anterior to the vena cava to the lower segment, which should be incised from the retrocaval segment. In general, ample ureteral length should be available for repair. The ureteral ends are then spatulated 1.5–2 cm at opposite ends. The anastomosis is performed over the stent using two absorbable sutures (4-0 Vicryl), with the posterior wall first, followed by the anterior wall. This anastomosis should be watertight and tension-free. A drain is then placed through either a lateral stab incision or through one of the laparoscopic trocars.

Although limited, the results of this repair have been favorable. In one of the largest series published, Chen et al. describe their series of 12 patients, all with significant improvement of hydronephrosis and all remaining symptom-free on follow-up. Of note, only 2 of 12 patients in

this series required resection of the retrocaval segment. In general, case series describing RCU repair show the laparoscopic or robotic approach to be safe, with minimal postoperative pain, short convalescence, and excellent short-term success [22–24].

Substitution Ureteroplasty

Surgical repair of long proximal ureteral strictures has historically been limited to ureteral substitution or autotransplant. The use of buccal mucosa in the urinary tract was first reported by Humby et al. for use in hypospadias repair [27]. The first report of buccal graft as a substitute for the ureter was shown in an animal model by Sommerville et al. [28] in 1984. It was not until 15 years later that Naude et al. [29] published the first report in humans, using the buccal as a patch graft or tubularized graft along with an omental wrap. Since that time, there have been multiple reports [30–35] on the use of buccal mucosa for ureteral repairs in both an open and robotic fashion with good overall success. Table 3.5 details those reports. Complications reported are consistent with those of any robotic procedure (e.g., port site hernia, postoperative ileus) and ureteral stricture repair (e.g., stricture recurrence requiring intervention). Other potential complications specific to this procedure include oral infection/abscess or damage to Stensen's duct during buccal harvest.

Intervention utilizing a buccal graft typically is reserved for patients who have either failed a prior repair or a sufficiently long stricture not amenable to ureteroureterostomy. Patients are placed in a lateral decubitus position and the genitalia is prepped into the field (modified lithotomy for women). The endotracheal tube should be taped to the nondependent side of the mouth to help facilitate future graft harvest. Port placement mirrors that of a pyeloplasty. After mobilization of the colon medially, the ureter is identified. The distal end of the stricture is then identified. There are a number of ways this has been reported including placement of a double J stent to the level of the stricture, intraoperative ureteroscopy (light identified using near-infrared fluorescence), or injection of intraureteral indocyanine green. The length of the stricture is this incised sharply. The decision to proceed with an onlay repair versus augmented anastomotic repair depends on surgeon preference, the length of the stricture, and whether a lumen is present so that an onlay may be performed. An onlay repair is performed by making a longitudinal incision along the anterior portion of the ureter until

Table 3.5 Reported series of ureteroplasty using buccal mucosa for proximal ureteral strictures

	No. of pts. (ureters)	Mean stricture length (cm)	Stricture location	Type of repair	Type of surgery	Mean follow-up (mo)	Success rate (%)
Naude [29]	6 (6)	–	Prox–6	Onlay–5 Tubular–1	Open	3	100
Badawy et al. [30]	5 (5)	4.4	Prox–3 Mid–2	Tubular	Open	24	100
Kroepfl et al. [31]	6 (7)	6.9	Prox–2 Mid–4	Onlay	Open	34	71
Pandey et al. [32]	3 (3)	5.7	UPJ–2 Prox–1	Onlay	Open	36	100
Arora et al. [33]	1 (1)	6	Prox–1	Onlay	Robotic	6	100
Lee et al. [34]	12 (12)	Median 3	UPJ–4 Prox–4 Mid–4	Onlay–10 AA–2	Robotic	Median 13	82
Zhao et al. [35]	19 (19)	4	UPJ–5 Prox–9 Mid–5	Onlay–15 AA–4	Robotic	26	89

UPJ ureterpelvic junction, *Prox* proximal ureter, *Mid* ureter, *AA* augmented anastomosis

healthy tissue is encountered on each end and suturing the buccal graft onto the ureterotomy. This technique mirrors the maintenance of the urethral plate when performing lower tract reconstructions with buccal mucosa. An augmented anastomotic repair involves the complete excision of the scarred ureteral segment, ureteral spatulation performed on the same side of the proximal and distal ureteral segments, and a running reapproximation of the posterior half of the ureter. This essentially recreates the posterior ureteral wall to which the buccal graft can be sewn to. The buccal graft can be harvested concomitantly with ureterotomy and prepared on the back table (removal of all submucosal tissue). The graft is then sewn to the host ureter using a fine, dissolvable suture (e.g., 4-0 Vicryl or 5-0 Monocryl). A pedicled omental flap can then be created and sutured around the repair to provide a vascular supply for the graft. A ureteral stent is then placed and left for 4 weeks.

Ureteral Replacement

First reported in 1909 for the treatment of genitourinary tuberculosis [36], the use of ileum as a ureteral replacement has become an accepted alternative in complex reconstruction cases. Over the years, multiple variations on the technique have been reported including distal tapering, a nonrefluxing anastomosis, and segmental, rather than complete, ureteral replacement. Though, there has been insufficient data to date to confirm these adjustments as superior to standard ileal ureter creation [37]. Laparoscopic ileal ureter creation was first reported by Gill et al. using a standard transperitoneal approach [38]. Since that time, other centers have also reported successful outcomes utilizing both laparoscopic [39] and robotic approaches [40, 41].

While minimally invasive techniques have improved postoperative patient convalescence, long-term complications of the procedure remain a real concern. As with other ileal-based urinary diversion, hyperchloremic hypokalemic metabolic acidosis and worsening renal dysfunction/uremia pose a significant risk. Though, in one of the largest series using ileal ureters, Roth et al. reported an incidence of metabolic acidosis in only 1.8% but worsening renal dysfunction in 17.6% [42]. These metabolic changes can be driven by urinary stagnation related to bladder outlet obstruction or incomplete emptying. Thus, late development of metabolic changes or hydronephrosis/ileal ureteral dilation should prompt further evaluation. Other potential complications include fistula, anastomotic stricture, and malignancy arising from the ileal segment [43]. Thus, long-term postoperative surveillance of these patients is required. Contraindications to ileal ureter creation include baseline CKD (Cr >2.0 mg/dL), prior small bowel radiation exposure, inflammatory bowel disease, and bladder outlet obstruction.

Prior to proceeding with surgical intervention, all patients should undergo a mechanical bowel prep. A robotic approach to intracorporeal ileal ureter requires multiple positioning changes. The patient is begun in a modified flank position and port placement proceeds as for a pyeloplasty. The white line of Toldt is incised and the colon reflected medially. The ureter is identified and mobilized from surrounding structures from the renal pelvis to the pelvic brim. The ureteral length to bridge this gap is then measured to determine the length of ileum required for reconstruction. Once completed, the robot is undocked, the patient moved into the supine position, and further ports placed in a configuration similar to a robotic prostatectomy. The bladder is then dropped from the anterior abdominal wall and a psoas hitch is performed as detailed above. The ileocecal valve is then identified and at least 15 cm proximal to this, a segment of ileum of appropriate length is chosen. Using an Endo-GIA stapler (Medtronic, Minneapolis, MN), the ileal segment is divided and each end is tagged with undyed 2-0 Vicryl suture. The ends of gastrointestinal ileum are tagged using dyed 2-0 Vicryl sutures for traction. Gastrointestinal continuity can then be re-established using two further staple loads in a side-to-side fashion. The diversion is then anastomosed to the bladder using 3-0 Vicryl sutures in an end-on fashion after excising the staple line. If the ureter to be reconstructed is

on the left, the segment of ileum is tunneled under the sigmoid colon to allow the ileal ureter to move to the left side. The robot is again undocked, the patient placed back into the modified flank position, and the robot redocked. The proximal aspect of the ileal segment can then be anastomosed to the renal pelvis in a side-to-side fashion using a 3-0 Vicryl. A ureteral stent is placed prior to completing the anastomosis.

Nephroptosis

Symptomatic nephroptosis is a rare disease requiring surgical intervention in the form of nephropexy in select cases. Nephroptosis is characterized by the descent of the kidney by more than 5 cm (or two vertebral columns) when shifting from the supine to upright position. This condition affects females disproportionately and most commonly affects the right kidney (70% of cases). Symptomatic nephroptosis, however, only occurs in approximately 10–20% of the cases where nephroptosis is identified [44, 45]. The most common symptom is intermittent flank pain or pain in the lower abdominal quadrant that resolves when supine. Rarely, more severe symptoms are associated with nephroptosis including recurrent UTI, pyelonephritis, renal stones, and hypertension. Nephroptosis is most commonly diagnosed on IVP in a supine then upright position (Fig. 3.10). The descent of the kidney more than 5 cm in the upright position suggests nephroptosis. Pain will often be related to ureteral kinking due to descent of the kidney, leading to obstruction. Though, with no ureteral kinking or obstruction on diuretic renal scan, repeat renal scan in the supine and upright position may demonstrate reduced renal perfusion in the upright position due to kinking of the renal vasculature. There has been much debate as to who the proper operative candidate should be. Matsui et al. have argued that any patient with symptomatic nephroptosis is an operative candidate, while others have stated that functional impairment must be demonstrated prior to performing a nephropexy [46]. Because of this requirement, several authors have advocated concomitant Doppler US to document impaired blood flow or diuretic renal scan to demonstrate impaired perfusion or obstruction prior to nephropexy [47].

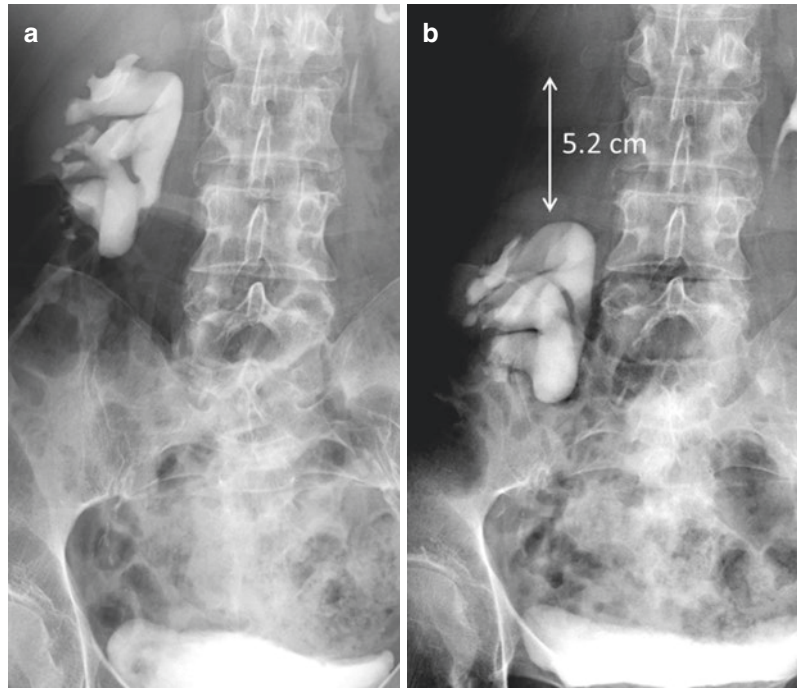

Fig. 3.10 (**a**) Intravenous pyelogram (IVP) when supine followed by (**b**) an upright IVP demonstrating a greater than 5 cm descent of the kidney

Surgical Intervention for Symptomatic Nephroptosis

Laparoscopic or robotic nephropexy may be performed through a transperitoneal or retroperitoneal approach [46, 48, 49]. The patient is positioned in a 45° lateral position as shown in Fig. 3.8. Once pneumoperitoneum has been established, a camera trocar is placed at the umbilicus. Two additional trocars are then placed, one 1/3 of the distance between the camera and xiphoid process just under the costal margin and the other approximately three fingerbreadths off the anterior iliac spine. The procedure is started with medial reflection of the colon. Gerota's fascia is then opened and the kidney is completely mobilized. The ureter is identified. Once freely mobile, the kidney is placed on upward traction to its ideal anatomic position. At this point, the exact method by which the kidney is best secured is subject to debate. We prefer a two- or three-point fixation method using an absorbable suture (2-0 Vicryl). This involves placing a suture through the posterior abdominal wall (Fig. 3.11a) and then through the renal capsule (Fig. 3.11b) carefully avoiding deep bite into the renal parenchyma leading to bleeding. The suture is then tied. This can be repeated until the kidney is sufficiently held in position. Once secured, Gerota's fascia is reapproximated using Hem-o-lok clips to provide additional support. A follow-up IVP is performed at 3 months to evaluate the success of the surgery based on radiographic criteria.

Several authors have reported using mesh [45, 50, 51]. In the series by Plas et al., absorbable mesh was reportedly used in the first six patients of the series, but due to early symptomatic recurrence, this was changed to nonabsorbable polypropylene mesh [45]. However, due to the intense fibrotic reaction that may be induced by mesh, concerns with its use have arisen, specifically that of fibrous encapsulation of the ureter. Multiple authors report a simpler approach using a two or three interrupted sutures to secure the upper portion of the kidney to the abdominal wall and have reported good success with this method [49, 52, 53]. Table 3.6 shows the outcomes for contemporary laparoscopic nephropexy series.

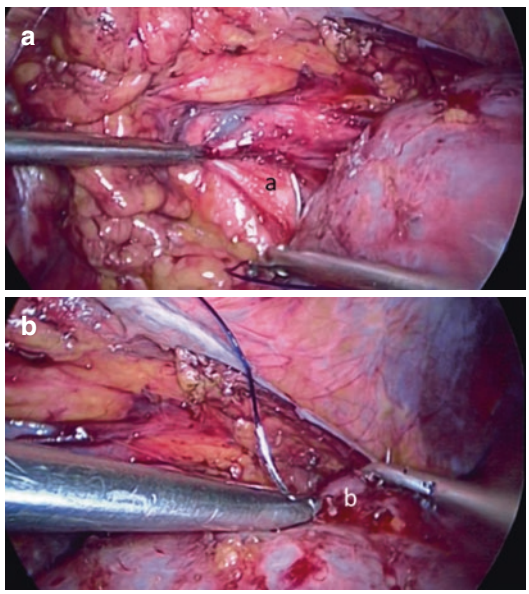

Fig. 3.11 Laparoscopic nephropexy. (**a**) The suture is first passed through the lumbar quadrate muscle or psoas muscle (**a**) then (**b**) passed through the renal capsule (**b**) and tied

Table 3.6 Contemporary laparoscopic nephropexy series for symptomatic nephroptosis. Outcome defined as percentage of patients with symptomatic resolution

	No.	Follow-up (months)	Method	Outcome (%)
Fornara et al. [54]	23	36	2-point fixation	91
Plas et al. [45]	13	60	Polypropylene mesh	92
Chueh et al. [48]	25	2–84	Running suture	84
Wyler et al. [49]	12	41	3-point fixation	84
Gozen et al. [52]	48	97	2-point fixation	95
Golab et al. [53]	21	3	2-point fixation	100

References

1. Clayman RV, Kavoussi LR, Soper NJ, Dierks SM, Merety KS, Darcy MD, et al. Laparoscopic nephrectomy. N Engl J Med. 1991;324(19):1370–1.
2. Schuessler WW, Grune MT, Tecuanhuey LV, Preminger GM. Laparoscopic dismembered pyeloplasty. J Urol. 1993;150(6):1795–9.
3. Reddy PK, Evans RM. Laparoscopic ureteroneocystostomy. J Urol. 1994;152(6 Pt 1):2057–9.
4. Ozdemir E, Ozturk U, Celen S, Sucak A, Gunel M, Guney G, et al. Urinary complications of gynecologic surgery: iatrogenic urinary tract system injuries in Obstet Gynecol operations. Clin Exp Obstet Gynecol. 2011;38(3):217–20.
5. Ibeanu OA, Chesson RR, Echols KT, Nieves M, Busangu F, Nolan TE. Urinary tract injury during hysterectomy based on universal cystoscopy. Obstet Gynecol. 2009;113(1):6–10.
6. Lee JS, Choe JH, Lee HS, Seo JT. Urologic complications following obstetric and gynecologic surgery. Korean J Urol. 2012;53(11):795–9.
7. Tas S, Tugcu V, Mutlu B, Karadag S, Bitkin A, Yucel M, et al. Incidence of ureteral stricture after ureterorenoscopic pneumatic lithotripsy for distal ureteral calculi. Arch Ital Urol Androl. 2011;83(3):141–6.
8. Roberts WW, Cadeddu JA, Micali S, Kavoussi LR, Moore RG. Ureteral stricture formation after removal of impacted calculi. J Urol. 1998;159(3):723–6.
9. Harmon WJ, Sershon PD, Blute ML, Patterson DE, Segura JW. Ureteroscopy: current practice and long-term complications. J Urol. 1997;157(1):28–32.
10. Dalpiaz O, Ehrlich G, Quehenberger F, Pummer K, Zigeuner R. Distal ureterectomy is a safe surgical option in patients with urothelial carcinoma of the distal ureter. Urol Oncol. 2014;32(1):34 e1–8.
11. Jeldres C, Lughezzani G, Sun M, Isbarn H, Shariat SF, Budaus L, et al. Segmental ureterectomy can safely be performed in patients with transitional cell carcinoma of the ureter. J Urol. 2010;183(4):1324–9.
12. Wolf JS Jr, Elashry OM, Clayman RV. Long-term results of endoureterotomy for benign ureteral and ureteroenteric strictures. J Urol. 1997;158(3. Pt 1):759–64.
13. Wenske S, Olsson CA, Benson MC. Outcomes of distal ureteral reconstruction through reimplantation with psoas hitch, Boari flap, or ureteroneocystostomy for benign or malignant ureteral obstruction or injury. Urology. 2013;82(1):231–6.
14. Kozinn SI, Canes D, Sorcini A, Moinzadeh A. Robotic versus open distal ureteral reconstruction and reimplantation for benign stricture disease. J Endourol. 2012;26(2):147–51.
15. Hemal AK, Nayyar R, Gupta NP, Dorairajan LN. Experience with robotic assisted laparoscopic surgery in upper tract urolithiasis. Can J Urol. 2010;17(4):5299–305.
16. Ogan K, Abbott JT, Wilmot C, Pattaras JG. Laparoscopic ureteral reimplant for distal ureteral strictures. JSLS. 2008;12(1):13–7.
17. Soares RS, de Abreu RA Jr, Tavora JE. Laparoscopic ureteral reimplant for ureteral stricture. Int Braz J Urol. 2010;36(1):38–43.
18. Rassweiler JJ, Gozen AS, Erdogru T, Sugiono M, Teber D. Ureteral reimplantation for management of ureteral strictures: a retrospective comparison of laparoscopic and open techniques. Eur Urol. 2007;51(2):512–22; discussion 22-3.
19. Lee Z, Simhan J, Parker DC, Reilly C, Llukani E, Lee DI, et al. Novel use of indocyanine green for intraoperative, real-time localization of ureteral stenosis during robot-assisted ureteroureterostomy. Urology. 2013;82(3):729–33.
20. Gupta NP, Hemal AK, Singh I, Khaitan A. Retroperitoneoscopic ureterolysis and reconstruction of retrocaval ureter. J Endourol. 2001;15(3):291–3.
21. Ramalingam M, Selvarajan K. Laparoscopic transperitoneal repair of retrocaval ureter: report of two cases. J Endourol. 2003;17(2):85–7.
22. Chen S, Xu B, Liu J, Ren Q, Hu X, Yang Y, et al. Retroperitoneal laparoscopic reconstruction for retrocaval ureter: experience and literature review. J Endourol. 2012;26(9):1147–52.
23. Chen Z, Chen X, Wu ZH, Luo YC, Li NN. Treatment of retrocaval ureter by retroperitoneal laparoscopic ureteroureterostomy: experience on 12 patients. J Laparoendosc Adv Surg Tech A. 2011;21(9):803–7.
24. Ding GQ, Xu LW, Li XD, Li GH, Yu YL, Yu DM, et al. Pure transperitoneal laparoscopic correction of retrocaval ureter. Chin Med J. 2012;125(13):2382–5.
25. Alkhudair WK, Seyam R, Al Zahrani HM, Al Otaibi MF, Al Taweel W. Robotic uretero-ureterostomy of the retrocaval ureter without excision of the retrocaval segment. Can Urol Assoc J. 2012;6(2):E38–41.
26. Simforoosh N, Nouri-Mahdavi K, Tabibi A. Laparoscopic pyelopyelostomy for retrocaval ureter without excision of the retrocaval segment: first report of 6 cases. J Urol. 2006;175(6):2166–9; discussion 9.
27. Humby G, Higgins TT. A one-stage operation for hypospadias. Br J Surg. 1941;29(113):84–92.
28. Somerville JJ, Naude JH. Segmental ureteric replacement: an animal study using a free non-pedicled graft. Urol Res. 1984;12(2):115–9.
29. Naude JH. Buccal mucosal grafts in the treatment of ureteric lesions. BJU Int. 1999;83(7):751–4.
30. Badawy AA, Abolyosr A, Saleem MD, Abuzeid AM. Buccal mucosa graft for ureteral stricture substitution: initial experience. Urology. 2010;76(4):971–5; discussion 5.
31. Kroepfl D, Loewen H, Klevecka V, Musch M. Treatment of long ureteric strictures with buccal mucosal grafts. BJU Int. 2010;105(10):1452–5.
32. Pandey A, Dican R, Beier J, Keller H. Buccal mucosal graft in reconstructive urology: uses beyond urethral stricture. Int J Urol. 2014;21(7):732–4.
33. Arora S, Campbell L, Tourojman M, Pucheril D, Jones LR, Rogers C. Robotic buccal mucosal graft ureteroplasty for complex ureteral stricture. Urology. 2017;110:257–8.

34. Lee Z, Waldorf BT, Cho EY, Liu JC, Metro MJ, Eun DD. Robotic ureteroplasty with buccal mucosa graft for the management of complex ureteral strictures. J Urol. 2017;198(6):1430–5.
35. Zhao LC, Weinberg AC, Lee Z, Ferretti MJ, Koo HP, Metro MJ, Eun DD, Stifelman MD. Robotic Ureteral Reconstruction Using Buccal Mucosa Grafts: A Multiinstitutional Experience. Eur Urol. 2017. pii: S0302–2838(17)31000-X. https://doi.org/10.1016/j.eururo.2017.11.015. [Epub ahead of print] PubMed PMID: 29239749.
36. Moore EV, Weber R, Woodward ER, Moore JG, Goodwin WE. Isolated ileal loops for ureteral repair. Surg Gynecol Obstet. 1956;102(1):87–97.
37. Waters WB, Whitmore WF 3rd, Lage AL, Gittes RF. Segmental replacement of the ureter using tapered and nontapered ileum. Investig Urol. 1981;18(4):258–61.
38. Gill IS, Savage SJ, Senagore AJ, Sung GT. Laparoscopic ileal ureter. J Urol. 2000;163(4):1199–202.
39. Stein RJ, Turna B, Patel NS, Weight CJ, Nguyen MM, Shah G, et al. Laparoscopic assisted ileal ureter: technique, outcomes and comparison to the open procedure. J Urol. 2009;182(3):1032–9.
40. Sim A, Todenhofer T, Mischinger J, Halalsheh O, Boettge J, Rausch S, et al. Totally intracorporeal replacement of the ureter using whole-mount ileum. J Endourol. 2014;28(10):1165–7.
41. Wagner JR, Schimpf MO, Cohen JL. Robot-assisted laparoscopic ileal ureter. JSLS. 2008;12(3):306–9.
42. Roth JD, Monn MF, Szymanski KM, Bihrle R, Mellon MJ. Ureteral reconstruction with ileum: long-term follow-up of renal function. Urology. 2017;104:225–9.
43. Austen M, Kalble T. Secondary malignancies in different forms of urinary diversion using isolated gut. J Urol. 2004;172(3):831–8.
44. Hubner WA, Schramek P, Pfluger H. Laparoscopic nephropexy. J Urol. 1994;152(4):1184–7.
45. Plas E, Daha K, Riedl CR, Hubner WA, Pfluger H. Long-term followup after laparoscopic nephropexy for symptomatic nephroptosis. J Urol. 2001;166(2):449–52.
46. Matsui Y, Matsuta Y, Okubo K, Yoshimura K, Terai A, Arai Y. Laparoscopic nephropexy: treatment outcome and quality of life. Int J Urol. 2004;11(1):1–6.
47. Barber NJ, Thompson PM. Nephroptosis and nephropexy--hung up on the past? Eur Urol. 2004;46(4):428–33.
48. Chueh SC, Hsieh JT, Chen J, Young YL, Chen SC, Tu YP. Retroperitoneoscopic nephropexy for symptomatic nephroptosis. Surg Endosc. 2002;16(11):1603–7.
49. Wyler SF, Sulser T, Casella R, Hauri D, Bachmann A. Retroperitoneoscopic nephropexy for symptomatic nephroptosis using a modified three-point fixation technique. Urology. 2005;66(3):644–8.
50. El-Shazly MA. Laparoscopic nephropexy using polyprolene mesh. Surg Laparosc Endosc Percutan Tech. 2011;21(3):188–90.
51. Baldassarre E, Marcangeli P, Vigano M, Vittoria I, Pone D, Gillo A, et al. Robotic nephropexy in case of symptomatic nephroptosis. Arch Ital Urol Androl. 2011;83(3):160–2.
52. Gozen AS, Rassweiler JJ, Neuwinger F, Bross S, Teber D, Alken P, et al. Long-term outcome of laparoscopic retroperitoneal nephropexy. J Endourol. 2008;22(10):2263–7.
53. Golab A, Slojewski M, Gliniewicz B, Sikorski A. Retroperitoneoscopic nephropexy in the treatment of symptomatic nephroptosis with 2-point renal fixation. Surg Laparosc Endosc Percutan Tech. 2009;19(4):356–9.
54. Fornara P, Doehn C, Jocham D. Laparoscopic nephropexy: 3-year experience. J Urol. 1997;158(5):1679–83.

4 Laparoscopic and Robot-Assisted Adrenalectomy

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Introduction

First described in 1992, laparoscopic adrenalectomy (LA) is performed for both benign and malignant conditions, including functional tumors, masses with radiographic findings suspicious for malignancy, solitary metastatic lesions, and nonfunctioning symptomatic lesions [1]. When compared to open adrenalectomy, LA offers shorter convalescence, improved cosmesis, and decreased postoperative pain [2–4]. In a recent review of the American College of Surgeons-National Surgery Quality Improvement Project database, LA was noted to have a significantly lower complication rate when compared with open adrenalectomy [5].

Patient selection is critical and a comprehensive preoperative evaluation in collaboration with an endocrinologist is important to identify metabolic aberrations caused by a functional adrenal mass. Preoperative optimization, including medical management of metabolic manifestations of the adrenal pathology, helps assure a successful outcome. Imaging studies may help prepare the surgeon, with attention paid to the size of the lesion, its vascular supply, and nearby structures that may pose a challenge (e.g., pancreas, hepatomegaly). Patients selected for LA must be evaluated on an individual basis, and surgeon experience and comfort level must be taken into consideration. While LA may be a feasible approach for many adrenal masses, a low threshold to convert to open surgery should be maintained.

As robot-assisted laparoscopic surgery continues to achieve greater penetration among all surgical specialties, evaluation of the safety and efficacy of robot-assisted adrenalectomy has been explored in greater detail as more adrenalectomies are performed using a robotic approach [6]. Interestingly, urologists are more likely than non-urologists to use laparoscopic or robotic approaches when performing adrenalectomy for benign or malignant tumors [7]. Although no high-quality randomized controlled trials exist comparing laparoscopic to robot-assisted adrenalectomy, numerous studies do not demonstrate any significant differences between the two approaches in terms of blood loss, conversion to laparotomy, intraoperative complications, postoperative complications, or mortality. Studies do note, however, that while patients treated with a robotic approach had a significantly shorter hospital stay compared to standard laparoscopy, they also had a significantly longer operating time and higher total charges [6, 8, 9]. Feasibility of robot-assisted adrenalectomy utilizing the transabdominal lateral approach or posterior retroperitoneal approach, and partial

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S. L. Best, S. Y. Nakada (eds.), *Minimally Invasive Urology*,
https://doi.org/10.1007/978-3-030-23993-0_4

adrenalectomy, has been demonstrated [10, 11]. In this chapter, the surgical approaches to laparoscopic and robot-assisted adrenalectomy, and partial adrenalectomy, are discussed.

Indications and Contraindications

The indications for laparoscopic adrenalectomy may be classified into several categories (Table 4.1). These include functional tumors, nonfunctional symptomatic tumors, indeterminate cysts, solitary metastatic lesions, malignant lesions, and incidental adrenal lesions with features such as large size, rapid growth rate, and indeterminate radiographic characteristics.

Functional adrenal adenomas that secrete hormones such as aldosterone and cortisol are among the most common indications for surgical excision of the adrenal gland. These benign lesions are optimal for laparoscopic excision due to their location and small size. While some controversy exists over the management of adrenal masses between 4 and 6 cm, guidelines from the American Association of Clinical Endocrinologists/American Association of Endocrine Surgeons recommend surgical excision of all masses larger than 4 cm [12]. Smaller lesions are commonly benign and thus are frequently followed radiographically.

Laparoscopic excision of adrenal lesions larger than 10 cm or of adrenal carcinomas is controversial. While some experienced surgeons have approached these lesions laparoscopically, many authorities consider these to be contraindications to laparoscopic adrenalectomy. These cases can be exceedingly complex, with high complication rates and more frequent conversions to an open procedure. Large lesions or those with potential for local invasion are recommended to be managed using an open approach.

Relative contraindications to laparoscopic adrenalectomy include significant adhesions from prior surgery, morbid obesity, uncorrected coagulopathy, and cardiopulmonary disease that precludes hypercapnea that is associated with pneumoperitoneum.

Table 4.1 Indications/contraindications for laparoscopic adrenalectomy

Indications
Aldosterone-producing adenoma
Cortisol-producing adenoma
Bilateral adrenal hyperplasia
Pheochromocytoma
Nonfunctioning adenoma >4 cm
Symptomatic cyst
Symptomatic myelolipoma
Solitary adrenal metastasis
Contraindications
Large tumor >10 cm (relative)
Morbid obesity (relative)
Uncorrected coagulopathy (relative)
Pyelonephritis (relative)
Adrenocortical carcinoma (relative)
Malignant pheochromocytoma (relative)
Significant abdominal adhesions (relative)
Severe cardiopulmonary disease (relative)
Local invasion (absolute)
Venous involvement (absolute)
Pregnancy (absolute)

Preoperative Evaluation

A complete history and physical examination is mandatory in the evaluation of a patient with an adrenal mass. While a complete discussion of the metabolic evaluation of adrenal lesions is beyond the scope of this chapter, a distinct effort to rule out the diagnosis a pheochromocytoma is crucial, as dire consequences may result from a misdiagnosis. This can be accomplished by evaluating the patient's plasma free metanephrines, along with confirmatory urinary catecholamine and metanephrine levels if necessary. A complete endocrinologic evaluation should also include measurement of serum electrolytes, serum hormone levels, and urine levels of steroid hormones and their metabolites. The exact tests ordered will depend on the observed clinical signs and symptoms as well as the patient's history and physical exam. In addition, stimulation studies such as the low- and high-dose dexamethasone suppression tests and measurement of plasma renin and aldosterone levels can be obtained if clinically warranted. It is also important to note that in the

setting of micronodularity or bilateral adrenal masses, adrenal vein sampling must be performed when assessing a patient for adrenalectomy for a functional adrenal mass.

Radiographic imaging is essential in the evaluation of an adrenal mass. While a pathologic evaluation can yield a definitive diagnosis, invaluable information can be obtained from a properly performed radiographic study. Computed tomography (CT) scans with and without intravenous contrast, with thin 1–3 mm cuts, are vital in assessing adrenal lesions. Lipid-rich adenomas are commonly homogeneous lesions with an attenuation less than 10 Hounsfield units on noncontrast CT, while lipid-poor adenomas may be differentiated by measuring levels of enhancement or percent contrast washout. Lymphadenopathy and local invasion are features that are more consistent with a malignant lesion.

Magnetic resonance imaging (MRI) scans are also commonly obtained in the evaluation of adrenal masses. This study can provide additional information such as identifying adipose tissue within lesions and can improve the identification of invasion into surrounding structures. Metaiodobenzylguanidine (MIBG) scans have poor spatial resolution and play a limited role in the evaluation of adrenal lesions. However, this study can be helpful in localizing small pheochromocytomas or extra-adrenal locations. This is especially true for those patients with multiple endocrine neoplasia (MEN) syndromes who are high risk for extra-adrenal pheochromocytomas. Additionally, MIBG scans are useful in suspected cases of malignant or bilateral pheochromocytomas.

Once an adrenal lesion is determined to require removal, standard preoperative evaluation and preparation are required. Patients diagnosed with a pheochromocytoma require a more thorough preoperative assessment and preparation. This includes alpha blockade for 2 weeks prior to surgery, along with the addition of beta blockers to treat tachycardia or arrhythmias if present. Beta blockers should only be given once complete alpha blockade is achieved. Furthermore, these patients also require cardiac consultation for the evaluation of occult cardiomyopathy.

Relevant Anatomy

The arterial supply to the adrenal gland is highly variable. The adrenal glands typically draw their blood supply from arterial cascades arising from the inferior phrenic artery, aorta, and renal artery. Adrenal venous drainage also displays great variability. On the right side, a short adrenal vein typically provides drainage into the posterolateral aspect of the vena cava. On the left side, the adrenal vein usually drains into the left renal vein. Not uncommonly, accessory adrenal veins are present near the superior and medial diaphragmatic attachments and provide additional drainage into the inferior phrenic vein. Meticulous dissection and appreciation of retroperitoneal anatomy is required in order to avoid inadvertent vascular injury.

Patient Preparation, Operating Room Setup, and Patient Positioning

Informed consent with explanation of pertinent risks is obtained prior to the procedure. Patients are instructed to maintain a clear liquid diet for 12–24 hours prior to surgery and administer a bowel preparation consisting of 300 ml of magnesium citrate on the prior day. Sequential compression devices are placed on the lower extremities and a single dose of intravenous antibiotics is given 60 minutes prior to surgical incision. After induction of general anesthesia, an orogastric tube and Foley catheter are placed to decompress the stomach and bladder, respectively. Bilateral intravenous access may be beneficial as upper extremity exposure is limited once positioning is completed. Administration of nitrous oxide can lead to bowel distention and should be avoided.

For cases of pheochromocytomas, invasive arterial monitoring, large bore intravenous access, or central line placement is recommended. These patients must be aggressively hydrated prior to surgery, as hypotension is frequently encountered after the induction of anesthesia or following excision of the tumor. Anesthetic agents such as propofol, ketamine, and halothane should be avoided.

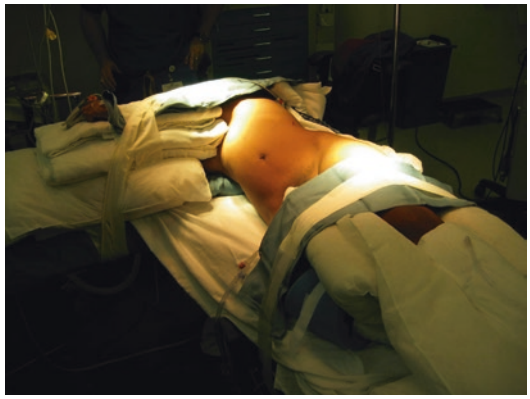

Fig. 4.1 Patient positioning for left laparoscopic adrenalectomy

The patient is placed in a modified lateral decubitus position (45°–60°) with the flank situated over the kidney rest. The table may be flexed to increase the area between the iliac crest and costal margin. A bean bag or large gel rolls are used to support the patient in this position. Pillows are placed between the legs and the dependent leg is flexed at the knee while the opposite leg is placed straight. The arms are placed parallel onto well-padded arm boards. The ankles, knees, dependent hip, shoulders, and brachial plexus are adequately padded. After verifying that all areas prone to pressure injury are well-padded, the patient is secured to the operating table using 3″ cloth tape across the shoulder and arm as well as across the hip. Figure 4.1 demonstrates proper patient positioning for left laparoscopic adrenalectomy. Positioning for right laparoscopic adrenalectomy is the mirror image of that for the left side. Furthermore, a needlescopic technique with 2–3 mm trocars can be employed.

Equipment

The instrumentation and setup for laparoscopic adrenalectomy is similar to that for laparoscopic renal surgery and consists of a video tower with a color monitor, video system, and CO_2 insufflator. Both 0°- and 30°-degree lenses are commonly used. A liver retractor is useful for right-sided procedures, and several types of retractors are commercially available. The liver retractor is held in place by an assistant or a self-retaining device that is attached to the operating table. The surgeon utilizes an atraumatic grasper, laparoscopic Kittner, or suction-irrigator in the nondominant hand and a dissecting instrument in the surgeon's dominant hand. A variety of laparoscopic thermal energy devices are available. Ultrasonic shears may be useful for colon mobilization and adrenal vein dissection. A bipolar device has excellent hemostatic properties and is may be used for performing the adrenal dissection. This device has been shown to significantly decrease blood loss and operative time during adrenal dissection compared to other devices. Furthermore, this device can be used to ligate and divide the adrenal vein, which obviates the need for hemostatic clips. Intraoperative ultrasound has shown to be helpful in localizing small adrenal lesions, especially in obese individuals with extensive amounts of retroperitoneal adipose tissue. The use of indocyanine green to help highlight adrenocortical tissue from surrounding retroperitoneal tissues may also be considered when attempting to localize small adrenal lesions [13]. A laparoscopic specimen retrieval bag is required. The robotic approach with the da Vinci™ Surgical System (Intuitive Surgical Inc., Sunnyvale, CA) utilizes a three- or four-arm robot which is controlled at the robotic console by the operating surgeon, while a bedside first assistant uses an accessory port for clip placement, suction, and additional maneuvers as needed. A variety of robotic instruments are available for robot-assisted adrenal surgery.

Equipment List for Laparoscopic Adrenalectomy

- Veress needle
- 5 mm or 10 mm laparoscope with 0°- and 30°-degree lenses
- 12 mm trocars
- 5 mm trocars
- Ultrasonic shears
- Bipolar vessel-sealing device
- Laparoscopic atraumatic grasping forceps

- Laparoscopic right angle
- Laparoscopic liver retractor and holder
- Laparoscopic Kittner
- Laparoscopic suction/irrigator
- Laparoscopic ultrasound probe
- Laparoscopic retrieval bag
- Laparoscopic stapling device (optional)
- Polymer or titanium hemostatic clips (5 mm or 10 mm)
- Oxidized cellulose polymer
- Other hemostatic agents (optional)
- Fascial closure device

Equipment List for Robot-Assisted Adrenalectomy

- Veress needle
- Robotic laparoscope with 0°- and 30°-degree lenses
- 5 mm or 10 mm laparoscope with 0°- and 30°-degree lenses (optional)
- 5 mm trocar
- 12 mm trocar
- 8 mm robotic trocars
- Robotic fenestrated bipolar forceps
- Robotic Maryland bipolar forceps
- Robotic curved monopolar scissors
- Laparoscopic liver retractor and holder
- Laparoscopic suction/irrigator
- Bipolar vessel-sealing device
- Laparoscopic ultrasound probe
- Laparoscopic retrieval bag
- Polymer or titanium hemostatic clips (5 mm or 10 mm)
- Oxidized cellulose polymer
- Other hemostatic agents (optional)
- Fascial closure device

Surgical Technique

Left Transperitoneal Laparoscopic Adrenalectomy

1. The patient is placed in the right lateral decubitus position. The patient should be positioned close to the abdominal edge of the bed to prevent laparoscopic instruments from colliding with the frame of the bed. The table may be flexed to increase the intra-abdominal working area if necessary, and the kidney rest can be partially elevated if desired. A bean bag or gel rolls are used to position the patient in the lateral decubitus position. An axillary roll is placed two fingerbreadths below the axilla. The lower arm is positioned on a well-padded armboard. The upper arm is supported either with a commercially available device or in another fashion such that it is parallel to the lower arm. The right scapula should be supported to prevent the arm from rotating posteriorly. The lower leg is gently bent, and the upper leg remains straight, with adequate pillows and padding. Once all of the areas prone to pressure are well-padded, the patient is secured using 3-inch tape or an alternative method of choice. A Foley catheter and orogastric tube should be placed before starting the procedure.
2. A skin incision is made 2 cm superior to the umbilicus and to the left of the midline. The location of the incision can be modified in patients with a large abdominal pannus, in which case the initial trocar can be placed slightly more lateral and cephalad. Insufflation with a Veress needle to 15 mm Hg or a Hasson technique is used to obtain pneumoperitoneum. A 5 mm or 12 mm trocar is placed at this site and a laparoscope is used to inspect the abdominal contents. A 5 mm or 12 mm trocar is placed 2 cm below the xiphoid process to the left of the midline and is used for the a 30°-degree laparoscope lens. A 12 mm trocar is placed 2 cm above the umbilicus in the midclavicular line (MCL). An accessory 5 mm trocar can be placed below the costal margin at the anterior axillary line (AAL) to assist in retraction of the kidney and other maneuvers. The periumbilical and MCL trocars are used for instrument passage, starting with atraumatic grasping forceps at the periumbilical trocar and ultrasonic shears or alternative energy device in the MCL trocar. Two options for

trocar placement during left transperitoneal laparoscopic adrenalectomy are illustrated in Fig. 4.2.

3. The descending colon is mobilized along the white line of Toldt, avoiding entry into the Gerota fascia (Fig. 4.3). The spleen is mobilized extensively to allow visualization of the upper pole of the kidney and adrenal gland. Careful mobilization of the tail of the pancreas is required to avoid injury to this organ during this maneuver.
4. Dissection and exposure of the adrenal gland can begin either at the inferomedial aspect or the superomedial aspect. Initial dissection of the inferomedial aspect of the adrenal gland is performed in order to identify the renal

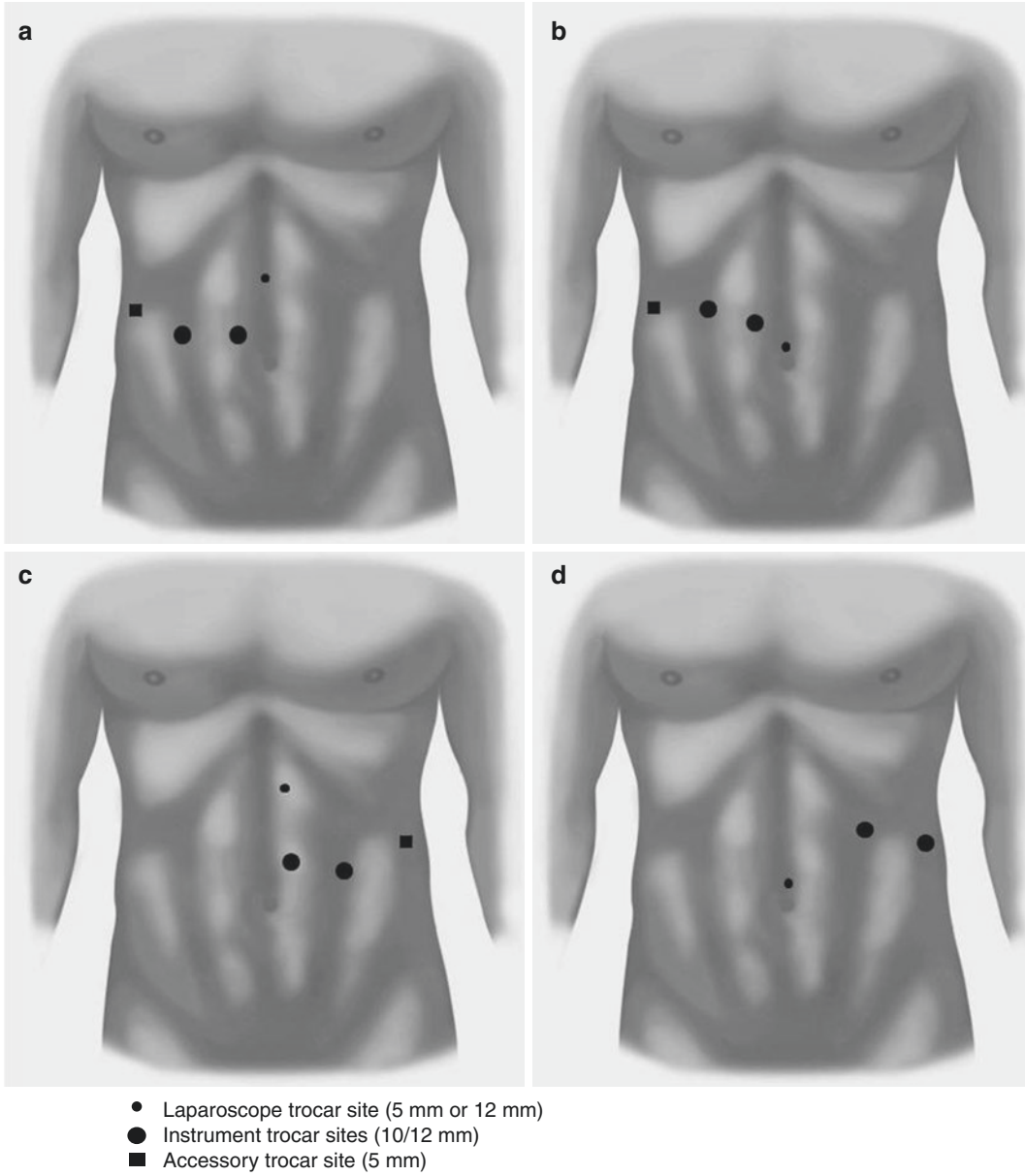

Fig. 4.2 (**a**, **b**) Right transperitoneal laparoscopic adrenalectomy trocar placement. (**c**, **d**) Left transperitoneal laparoscopic adrenalectomy trocar placement

hilum. In patients with a large amount of perinephric adipose tissue, an intraoperative ultrasound device may be useful to assist with localization of the adrenal gland.

5. The renal vein is identified and used as a landmark to identify the adrenal vein. A right-angle clamp is used to dissect the adrenal vein (Fig. 4.4). Once completely free from surrounding structures, the left adrenal vein can be divided between hemostatic polymer clips or with a bipolar vessel-sealing device. Figure 4.5 demonstrates use of a bipolar vessel-sealing device to ligate the vein. If a bipolar vessel-sealing device is used, the tissue should be sealed in several areas before transecting the vein in the middle of the sealed tissue.
6. After division of the adrenal vein, the adrenal gland can be retracted medially. The parenchyma of the kidney is identified as seen in Fig. 4.6. Lateral attachments of the adrenal gland are divided. Any remaining medial attachments are also divided. The ultrasonic shears or bipolar vessel-sealing device can be used as the adrenal attachments are often highly vascular. Small arterial branches from the inferior phrenic or renal arteries can be encountered and should be carefully divided with clips or the bipolar vessel-sealing device. The adipose tissue

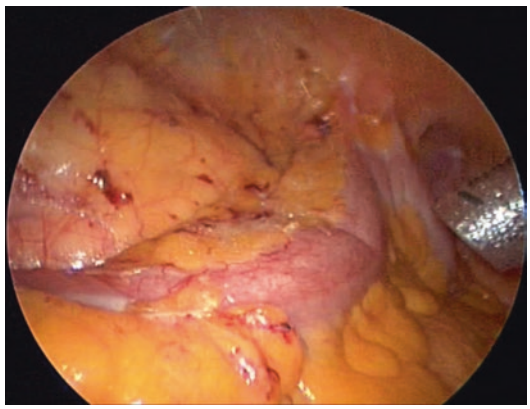

Fig. 4.3 The colon has been mobilized along the white line of Toldt to expose the kidney and left adrenal gland

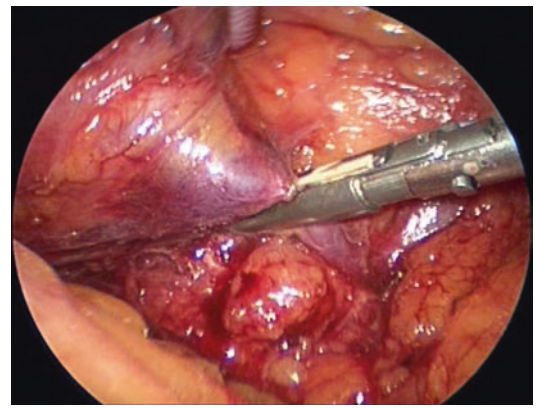

Fig. 4.5 The bipolar sealing device is used to seal the adrenal vein in several places before dividing the vein

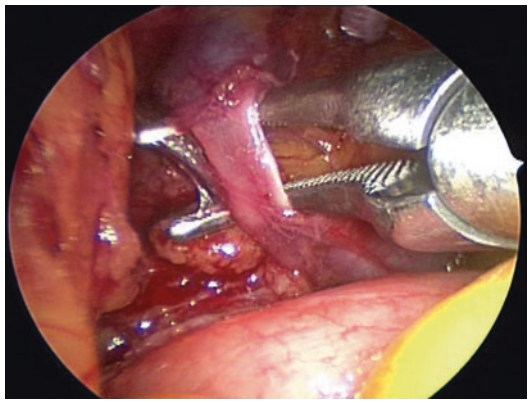

Fig. 4.4 A laparoscopic right-angle clamp is used to isolate the adrenal vein

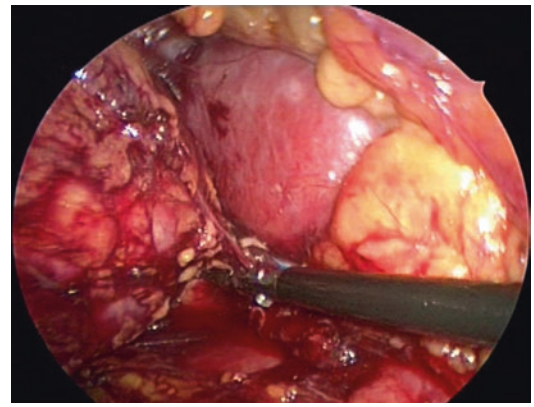

Fig. 4.6 After the left adrenal vein is divided, the adrenal can be retracted medially to expose the kidney parenchyma and attachments of the adrenal gland

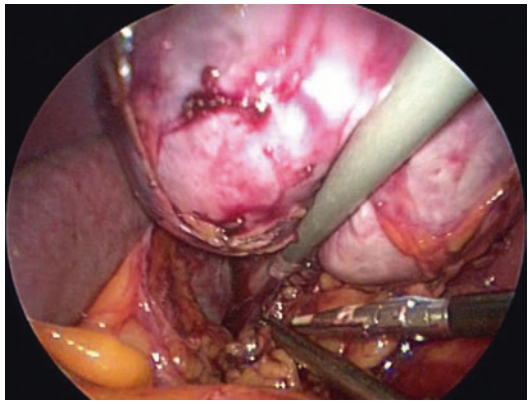

Fig. 4.7 The remaining medial attachments of the adrenal are divided. The adrenal mass can be seen at the top of the image

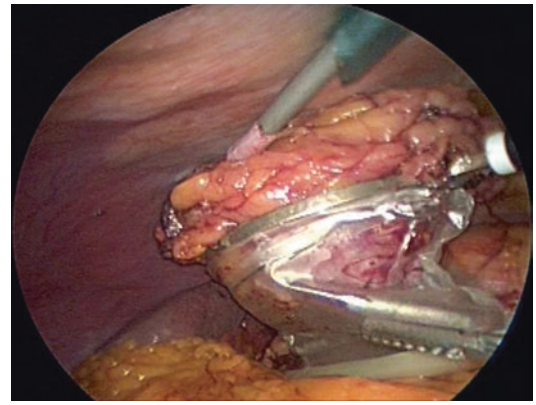

Fig. 4.8 The adrenal gland is placed in a laparoscopic retrieval bag

between the renal vein and the infero-lateral margin of the adrenal gland often contains segmental branches of the adrenal artery. Avoidance of these vessels is facilitated by carefully dissecting the tissue before dividing. Carrying the dissection closer to the margin of the adrenal gland can also assist in avoiding inadvertent vascular injury. Any additional superior attachments of the adrenal gland are divided. Figure 4.7 shows division of the remaining adrenal attachments using a bipolar vessel-sealing device.

7. The specimen is placed in a laparoscopic retrieval bag (Fig. 4.8).
8. The pneumoperitoneum is decreased to 5 mm Hg and the adrenal bed is inspected for bleeding. Hemostatic maneuvers, such as the use of oxidized cellulose polymer, can be used based on surgeon preference. Oxidized cellulose polymer can be used in the setting of minor bleeding. If indicated, a hemostatic matrix such as Floseal™ can be used as well.
9. The specimen may be extracted from any of the trocar sites. Often, the trocar site incision will require enlargement in order to accommodate the specimen.
10. After specimen extraction, all trocar sites 10 mm or larger are closed under direct vision using a fascial closure device or open closure. Inspection of the trocar sites after removal of the trocars should be performed to confirm the absence of bleeding. Skin incisions are closed using subcuticular sutures or skin staples.

Right Transperitoneal Laparoscopic Adrenalectomy

1. The patient is placed in the left lateral decubitus position. The patient should be positioned close to the abdominal edge of the bed to prevent laparoscopic instruments from colliding with the frame of the bed. The table may be flexed to increase the intra-abdominal working area if necessary, and the kidney rest can be partially elevated if desired. A bean bag or gel rolls are used to position the patient in the lateral decubitus position. An axillary roll is placed two fingerbreadths below the axilla. The lower arm is positioned on a well-padded armboard. The upper arm is supported either with a commercially available device or in another fashion such that it is parallel to the lower arm. The right scapula should be supported to prevent the arm from rotating posteriorly. The lower leg is gently bent, and the upper leg remains straight, with adequate pillows and padding. Once all of the areas prone to pressure are well-padded, the patient is secured using 3-inch tape or an alternative method of choice. A Foley catheter and oro-

gastric tube should be placed before starting the procedure.

2. An incision is made to the right of the midline, 2 cm above and 2 cm lateral to the umbilicus. The location of the incision can be modified in patients with a large abdominal pannus, in which case the initial trocar can be placed slightly more lateral and cephalad. A Veress needle is introduced into the abdominal cavity through the incision, or alternatively, a Hasson technique is used, and the abdomen is insufflated to 15 mm Hg. A 12 mm trocar is placed at this site, and a laparoscope is used to inspect the abdominal contents. A 5 mm or 12 mm trocar is placed 2 cm below the xiphoid process to the right of the midline and is used for a 30°-degree laparoscope lens. A 5 mm or 12 mm trocar is placed 2 cm above the umbilicus in the midclavicular line (MCL). An accessory 5 mm trocar is placed below the costal margin at the anterior axillary line (AAL). The instruments are advanced through the trocars, including ultrasonic shears or alternative energy device through the periumbilical trocar and atraumatic grasping forceps through the MCL trocar. The 5 mm accessory trocar is used for a liver retractor. This trocar configuration is shown in Fig. 4.2.
3. The liver is mobilized to expose the adrenal gland, starting with incision of the right triangular ligament. The posterior peritoneum is divided near the liver edge from the inferior vena cava to the abdominal side wall (Fig. 4.9). The liver must be mobilized extensively to provide adequate exposure to the inferior vena cava and the adrenal gland. A commercially available liver retractor is often useful to keep the liver out of the operative field, as shown in Fig. 4.10. A Kocher maneuver is performed to mobilize the duodenum and expose the inferior vena cava. The medial aspect of the inferior vena cava can then be traced cephalad to identify the adrenal vein. The renal hilum is often visible during this portion of the surgery, and care must be taken to avoid injury to the renal vein.

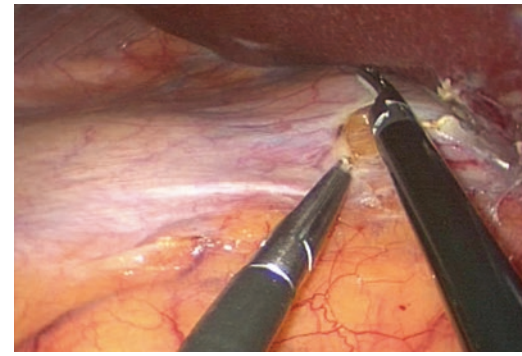

Fig. 4.9 Incision of the peritoneum overlying the right kidney and adrenal gland initiates mobilization of the liver

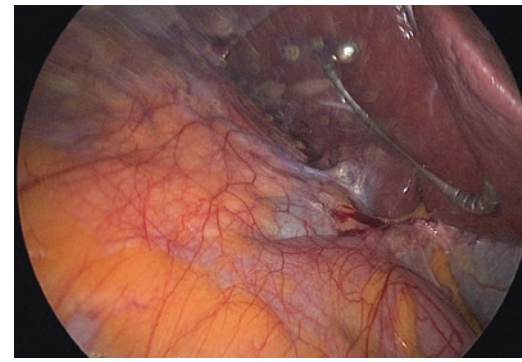

Fig. 4.10 A commercially available liver retractor is used to provide exposure to the right adrenal gland

4. To localize the adrenal gland, the superior border of the kidney is identified and the Gerota fascia is entered (Fig. 4.11). Ultrasonic shears or a bipolar vessel-sealing device for more vascular tissue can be used for this maneuver. The adrenal gland is identified along the superior-medial portion of the kidney. Care is taken to avoid injury to branches of the renal artery, which often can be found between the adrenal gland and the upper pole of the kidney. Minimal dissection of the adrenal gland is performed during this step as localization of the adrenal gland is the intention.
5. Once the upper pole of the kidney and the edge of the adrenal gland are located as landmarks, dissection is initiated lateral to the inferior vena cava, along the superomedial aspect of the adrenal gland. Branches of the

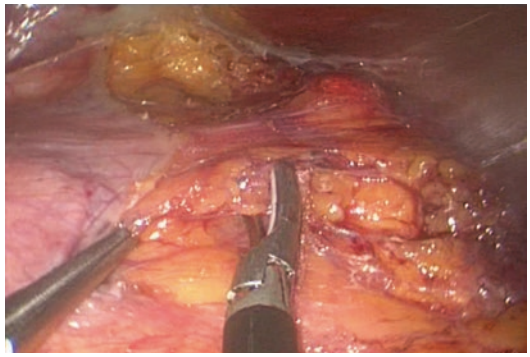

Fig. 4.11 Entry into the Gerota fascia, using ultrasonic shears to locate the adrenal gland

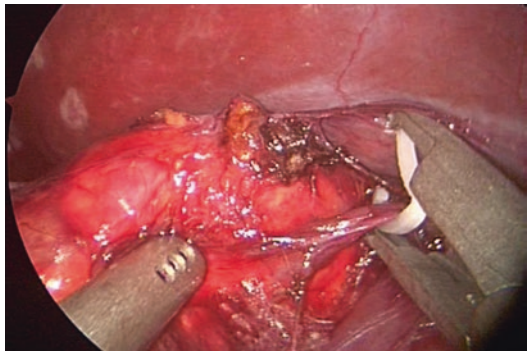

Fig. 4.12 Placement of a hemostatic polymer clip on the right adrenal vein. Note the short length and tangential course of the adrenal vein

renal artery and vein can be encountered here, and cautious dissection is warranted to avoid injury to these structures. The adrenal gland can be retracted laterally to expose the medial tissue with the assistance of a laparoscopic Kittner or a suction-irrigator device.

6. The right adrenal vein is identified during the course of the dissection. A right-angle clamp is used to dissect the adrenal vein which is then either clipped with hemostatic polymer clips and divided or sealed and divided with a bipolar vessel-sealing device. Figure 4.12 demonstrates placement of a hemostatic polymer clip on the adrenal vein. The right adrenal vein is short in length, and care must be taken when manipulating and dividing the vein to avoid injury to the vein or inferior vena cava. If possible, when using the vessel-sealing device, a short length of adrenal vein should be left on the inferior vena cava to allow for clip placement if bleeding is encountered. Many of the commercial vessel-sealing devices can seal tissue up to 7 mm in diameter, but each individual device's instruction manual should be reviewed in regard to limits of vessel-sealing capacity.

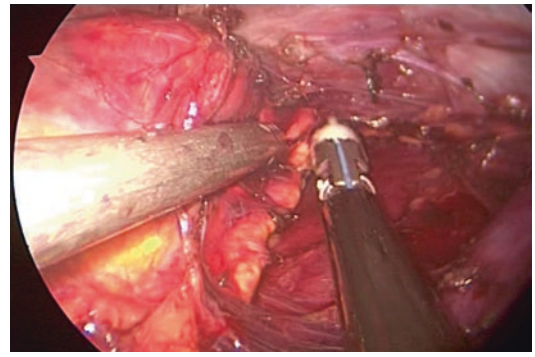

Fig. 4.13 After division of the adrenal vein, the adrenal gland is gently retracted away from the liver to allow division of the attachments to the liver and underlying psoas muscle. The bipolar vessel-sealing device is used to divide these attachments

7. After division of the adrenal vein, the adrenal is dissected from the upper pole of the kidney and the surrounding structures. Ultrasonic shears or a bipolar vessel-sealing device is useful for the dissection of the adrenal tissue as this tissue often contains small perforating blood vessels. During dissection of the medial and lateral attachments of the adrenal, the renal artery and vein, including branches of the renal artery, can be seen and should be preserved. The bipolar vessel-sealing device is used in Fig. 4.13 to divide adrenal attachments to the liver and psoas muscle.
8. To avoid the rotation of the adrenal gland during dissection of the vein and medial tissues, the lateral attachments of the adrenal gland are divided last. Once the adrenal gland has been completely dissected from the surrounding structures, it is placed into a laparoscopic retrieval bag.
9. The pneumoperitoneum is lowered to 5 mm Hg and the area is inspected for bleeding. Hemostatic maneuvers, including the use of

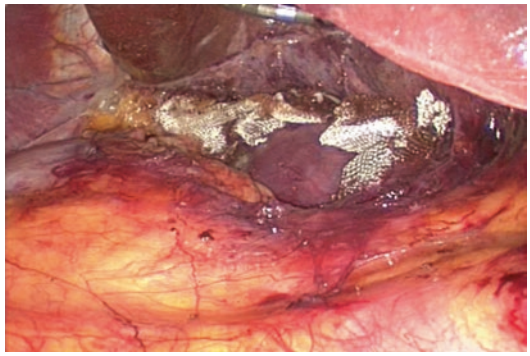

Fig. 4.14 After the adrenal gland has been placed in the laparoscopic specimen retrieval bag, the adrenal bed is inspected for any bleeding. Oxidized cellulose matrix is placed in the adrenal bed to aid with hemostasis

oxidized polymer matrix, can be used as needed, as shown in Fig. 4.14.

10. The specimen is removed through one of the 12 mm trocar sites, which can be enlarged as necessary. After specimen extraction, all trocar sites 10 mm or larger are closed under direct vision using a fascial closure device or open closure. Inspection of the trocar sites after removal of the trocars should be performed to confirm the absence of bleeding. Skin incisions are closed using subcuticular sutures or skin staples.

Right Retroperitoneal Laparoscopic Adrenalectomy

1. A skin incision is made 2 cm below the costal margin in the midaxillary line and the underlying muscles are bluntly divided to gain access to the retroperitoneum. The peritoneum is retracted medially to provide room for the access device. A commercially available dissecting balloon is inserted into the incision, directed laterally and posterior to the Gerota fascia, and the balloon is inflated. A 30°-degree lens can be placed through the balloon to assist in developing the retroperitoneal space. Once the retroperitoneal space is developed, a 10 mm or 12 mm trocar is placed, and the retroperitoneal space is insufflated to 15 mm Hg. A 30°-degree laparoscope lens is placed through the trocar. Additional trocars are placed under direct vision. A common configuration involves placement of two additional trocars (5 mm and 12 mm) 3–4 cm cephalad to the initial trocar in the anterior and posterior axillary lines. If desired, an additional 5 mm trocar may be placed for additional retraction or suction. For proper orientation, the psoas muscle should be identified posteriorly, and the kidney should be displaced anteriorly and medially. Proper trocar placement for right retroperitoneal laparoscopic adrenalectomy is depicted in Fig. 4.15.

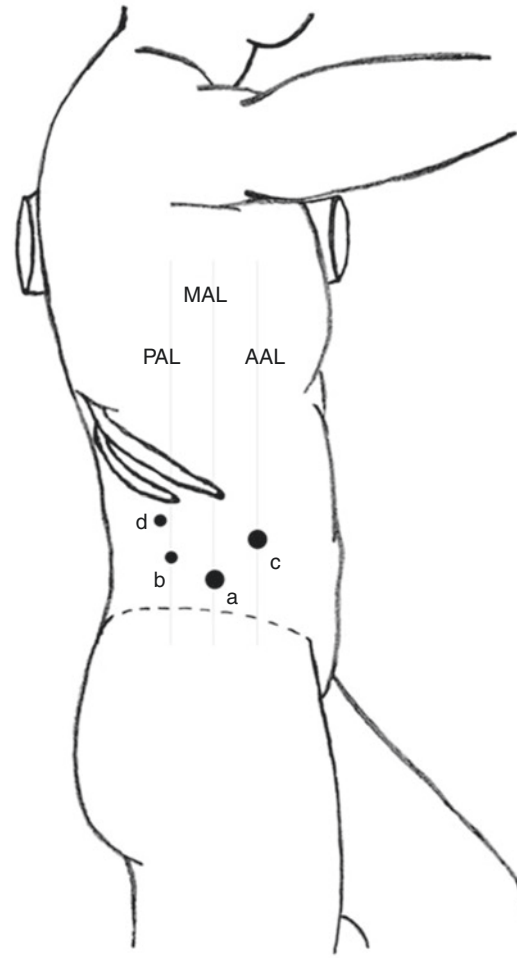

Fig. 4.15 Trocar configuration for retroperitoneal laparoscopic adrenalectomy: (**a**) 10 mm trocar (laparoscope); (**b**) 5 mm trocar (forceps or suction); (**c**) 12 mm trocar (thermal energy device); (**d**) 5 mm accessory trocar (retracting instrument or suction). MAL midaxillary line, AAL anterior axillary line, PAL posterior axillary line

2. The first step of the right-sided retroperitoneal approach is medial reflection of the peritoneum, which in turn reflects the liver and ascending colon. The renal hilum is located medial to the psoas muscle.
3. Right retroperitoneal laparoscopic adrenalectomy is initiated with identification of the inferior vena cava and the psoas muscle. The main adrenal vein is identified on the posterolateral aspect of the vena cava. The vein is isolated and divided.
4. Using ultrasonic shears, dissecting forceps, or a bipolar vessel-sealing device, the medial and inferior surfaces of the adrenal gland are dissected off the renal vein and vena cava. Small vessels, including branches from the inferior phrenic artery, are identified, clipped, and cut. The inferior surface of the adrenal gland is dissected off of the upper pole of the kidney. Finally, the lateral surface of the kidney is dissected free, and the specimen is placed in a laparoscopic retrieval bag.
5. The pneumoperitoneum is lowered to 5 mm Hg and the adrenal bed is inspected for bleeding. The 12 mm trocar site can be enlarged for specimen removal, and trocar sites 10 mm and larger are closed with a fascial closure device. The skin is closed with subcuticular sutures or skin staples.

Left Retroperitoneal Laparoscopic Adrenalectomy

1. The configuration for left retroperitoneal laparoscopic adrenalectomy is the mirror image of that used for the right side.
2. The first step of the left-sided retroperitoneal approach is medial reflection of the peritoneum, which in turn reflects the spleen and descending colon. The renal hilum is located medial to the psoas muscle.
3. The renal hilum is identified and the renal artery is retracted caudally and blunt dissection helps to identify the left adrenal vein. The vein is then carefully dissected, isolated, and divided.
4. Next, the superior aspect of the adrenal gland is dissected from the diaphragm, and inferior phrenic vessels, if encountered, are divided. The lateral surface of the adrenal gland is dissected from the kidney. Cephalad retraction of the adrenal gland assists in dissection of the inferior surface from the kidney, and the lateral surface of the adrenal gland is dissected free. The specimen is freed from its surrounding tissues and placed in a laparoscopic retrieval bag.
5. The pneumoperitoneum is lowered to 5 mm Hg and the adrenal bed is inspected for bleeding. The 12 mm trocar site can be enlarged to allow specimen removal, and trocar sites 10 mm and larger are closed with a fascial closure device. Skin incisions are closed with subcuticular sutures or skin staples.

Robot-Assisted Adrenalectomy

1. Robot-assisted adrenalectomy (RA) requires several modifications to the standard transperitoneal laparoscopic adrenalectomy. A three-arm approach, with rotation of the bed (the foot of the bed tilted away from the side of the surgery) is utilized to facilitate docking of the robot. This may be less of an issue with the da Vinci Xi robotic system platform. Trocar placement begins with placement of an 8 mm or 12 mm trocar lateral to the umbilicus, toward the side of the lesion. An 8 mm or 12 mm smooth, non-bladed trocar is placed in this location. If a Hasson technique is used to gain intra-abdominal access, a long, Hasson trocar can be utilized at this location. The exact location varies depending on the body habitus of the patient. This trocar can be placed more lateral in larger patients to optimize visualization. Once the robotic laparoscope trocar is placed, two 8 mm robotic trocars are placed under direct vision in a triangulated fashion, with a minimum distance of 8 cm between trocars to avoid robotic arm collision. A 12 mm assistant trocar is placed, usually caudad to the camera trocar, with 8 cm distance between the trocars. For right-sided procedures, a 5 mm trocar can be placed in the anterior axillary line for placement of a liver

retractor. Trocar placement for left and right RA is shown in Fig. 4.16.

2. Recommended instrumentation for RA is listed in the equipment section of this chapter. The fenestrated bipolar forceps are an ideal tool for both robot-assisted kidney and adrenal surgery. The broad surface area of the instrument and rounded tip are idea for gentle dissection and bipolar cautery when working with vascular tissue. Fenestrated bipolar forceps are used for the left robotic arm and a monopolar scissors for the right arm. Alternatively, a Maryland bipolar forceps can be used for the left arm to aid in dissection through more resilient tissue.
3. The steps for colon reflection and splenic mobilization when performing left-sided adrenalectomy (Fig. 4.17) and liver and duodenal mobilization for right-sided adrenal surgery (Fig. 4.18) are similar to those described for laparoscopic transperitoneal adrenal surgery. For right-sided surgery, the use of a commercially available liver retractor to keep the liver out of the operative field is once again recommended. Care should once again be taken to maintain meticulous dissection and hemostasis with bipolar cautery. Due to its blunt nature, the use of fenestrated bipolar forceps is recommended for dissection and exposure of the adrenal vein (Fig. 4.19). Additional assistance

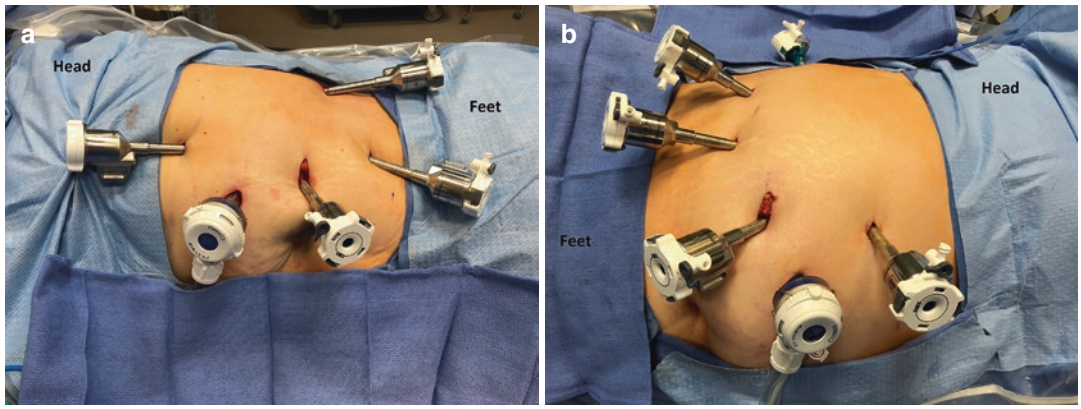

Fig. 4.16 (**a**) Trocar placement for left robot-assisted adrenalectomy and partial adrenalectomy. (**b**) Trocar placement for right robot-assisted laparoscopic adrenalectomy and partial adrenalectomy

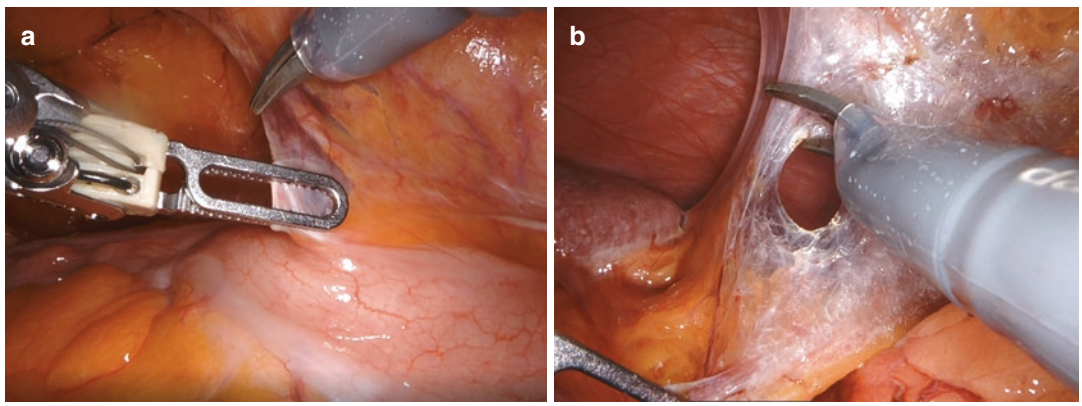

Fig. 4.17 (**a**) Mobilization of the colon along the white line of Toldt to expose the left kidney and left adrenal gland. (**b**) Splenic mobilization with the spleen visualized on the left to allow for adequate exposure of the left kidney and adrenal gland

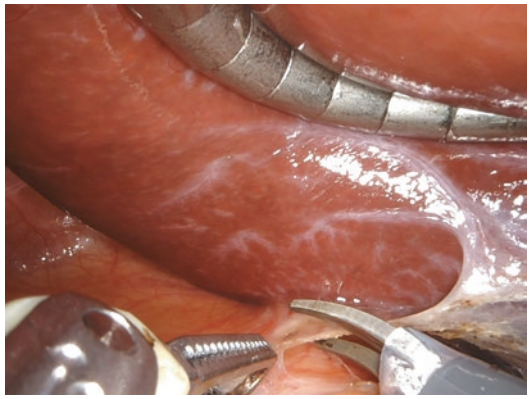

Fig. 4.18 Mobilization of the liver by incising the peritoneum overlying the right kidney and adrenal gland using the liver tractor to provide countertraction as visualized in the upper portion of the picture

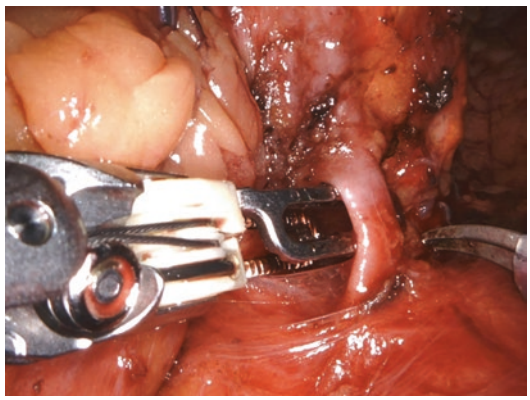

Fig. 4.19 Dissection and exposure of the left adrenal vein with the use of the bipolar fenestrated forceps to create adequate space for placement of hemostatic polymer clips

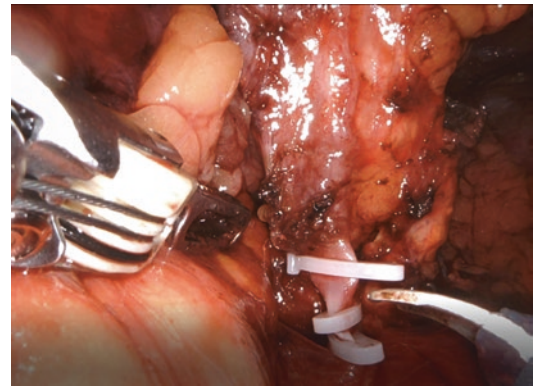

Fig. 4.20 The assistant has placed hemostatic polymer clips on the adrenal vein. The adrenal gland is located above the most cephalad clip

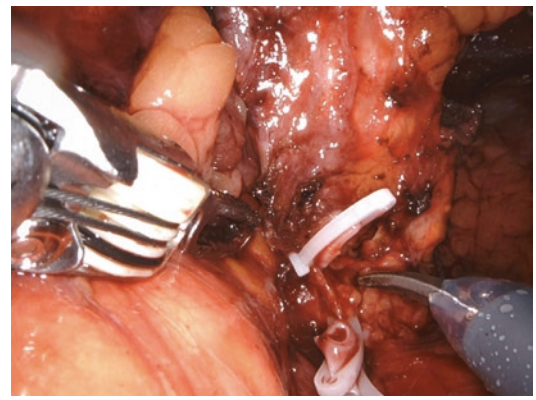

Fig. 4.21 The branch of the adrenal vein draining the adrenal mass is selectively divided

with exposure during dissection can be provided by the assistant though the 12 mm assistant trocar with the use of the suction-irrigator or a laparoscopic instrument. The assistant can also place hemostatic polymer clips on the adrenal vein as shown in Fig. 4.20, although a robotic clip applier is recommended as the articulating joint may provide a better angle of approach. When larger vessels are encountered, the robotic vessel-sealing instrument may be utilized.

4. Once the adrenal vein is adequately controlled and divided (Fig. 4.21), dissection of the adrenal gland from the surrounding tissue can be approached with several techniques, including as previously described in the laparoscopic approach. The primary goal is circumferential dissection of the adrenal gland. Hemostasis can be maintained throughout the dissection with the use of the fenestrated or Maryland bipolar forceps in combination with the monopolar scissors (Fig. 4.22). Circumferential mobilization can be initiated from the upper pole of the kidney (Fig. 4.23) progressing toward the medial aspect of the diaphragm and then along the medial aspect of the adrenal gland (Fig. 4.24) prior to creating a plane between the psoas and posterior aspect of the adrenal gland. The robotic vessel-sealing device can also be used to dissect and maintain hemostasis when mobilizing the adrenal. Additionally, an assis-

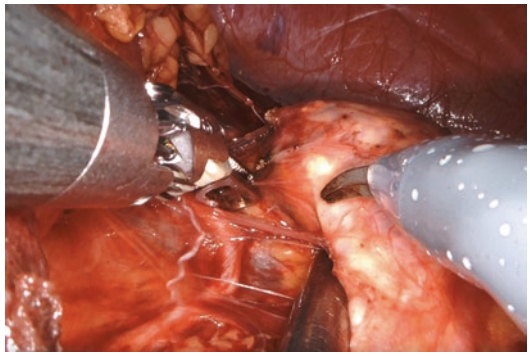

Fig. 4.22 A bipolar fenestrated grasper is used to dissect and divide the vascular tissue around the adrenal gland while maintaining hemostasis

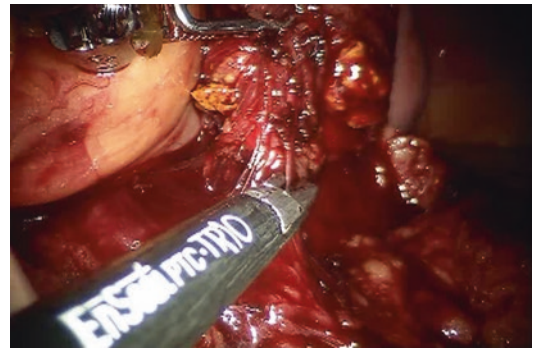

Fig. 4.25 A bipolar vessel-sealing device through the assistant trocar is used to divide the vascular tissue around the adrenal gland

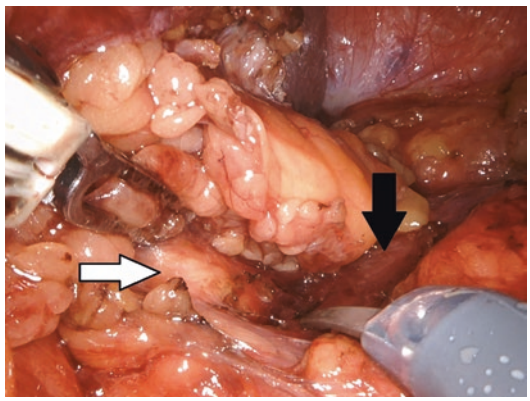

Fig. 4.23 Mobilization of the adrenal from the upper pole of the kidney with adrenal tissue located behind the adipose tissue indicated by the white arrow and the medial aspect of the kidney surface indicated by the black arrow. Note that the adipose tissues around the adrenal are grasped for retraction to prevent fracturing of the adrenal gland

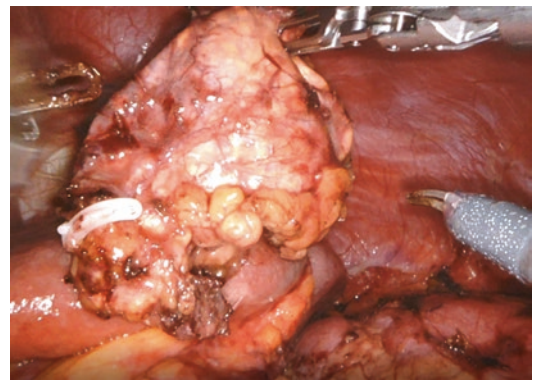

Fig. 4.26 The adrenal mass has been excised and is seen at the top of the image. The remaining adrenal tissue is inspected for bleeding

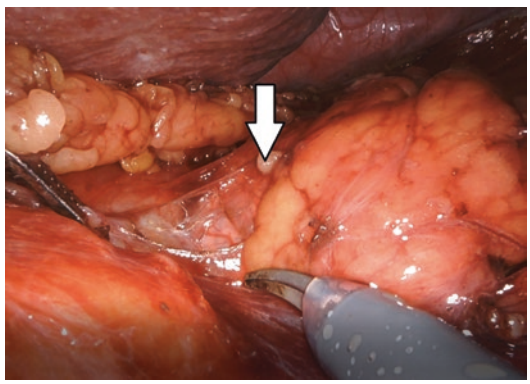

Fig. 4.24 Dissection of the medial aspect of the adrenal mass as indicated by the white arrow to continue the circumferential mobilization of the adrenal from surrounding tissues and organs

tant can utilize a bipolar vessel-sealing device placed through the assistant trocar as shown in Fig. 4.25. When manipulating the adrenal, it is recommended to grasp the tissues surrounding the adrenal tissue to avoid inadvertent fracturing the gland.

5. The remainder of the adrenalectomy proceeds as described in the previous sections, as the excised adrenal gland is placed in an endoscopic specimen bag and the adrenal bed is inspected for hemostasis with pneumoperitoneum, is lowered to 5 mm Hg (Fig. 4.26). Hemostatic materials can be used at this point in any areas where there may be a concern for bleeding. Once the specimen is extracted, the 12 mm trocar site should be closed using the fascial closure device and the remaining port site incisions can be closed at the skin with a subcuticular stitch or staples.

Laparoscopic and Robot-Assisted Partial Adrenalectomy

1. Laparoscopic and robot-assisted partial adrenalectomy (PA) is performed with the same configuration of trocars as used during laparoscopic or robot-assisted total adrenalectomy.
2. Intraoperative ultrasonography can be useful to help identify the adrenal mass, especially when there is a significant amount of perirenal fat. Use of an ultrasound device to localize the adrenal mass is shown in Fig. 4.27.
3. The decision to divide the adrenal vein is based on the proximity of the vein to the adrenal mass. The entire vein can be left intact if the surgeon feels that the adrenal mass can safely be dissected from the normal adrenal tissue without damage to the vein. In some cases, a branch of the adrenal vein that drains the adenoma can be selectively divided, leaving the remainder of the vein intact, as shown in Fig. 4.28.

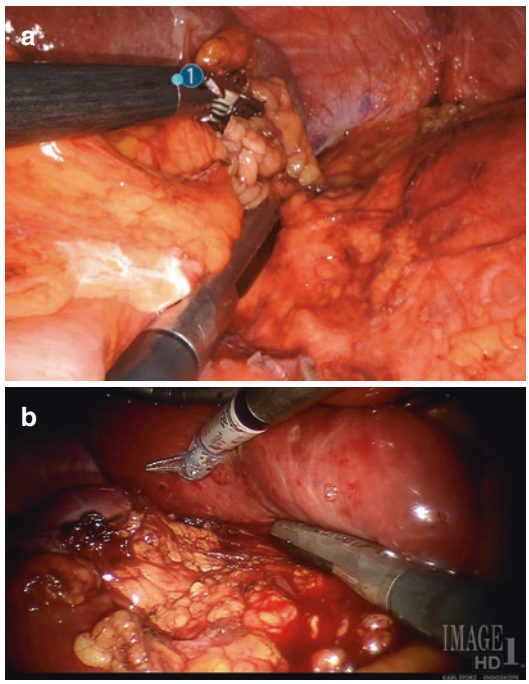

Fig. 4.27 Use of a laparoscopic ultrasound probe to identify the (**a**) left adrenal mass (above) and (**b**) right adrenal mass (*below*)

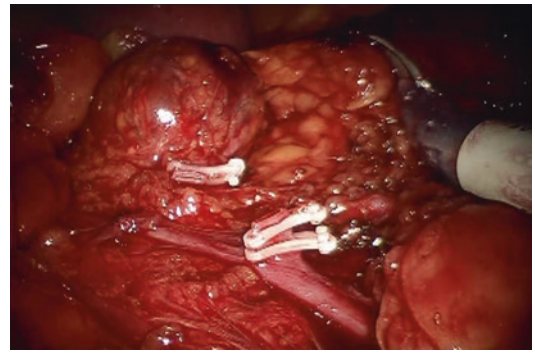

Fig. 4.28 A branch of the left adrenal vein draining the adrenal mass is selectively divided, while the branch draining the normal adrenal tissue is left intact. The adrenal mass is seen adjacent to the single clip

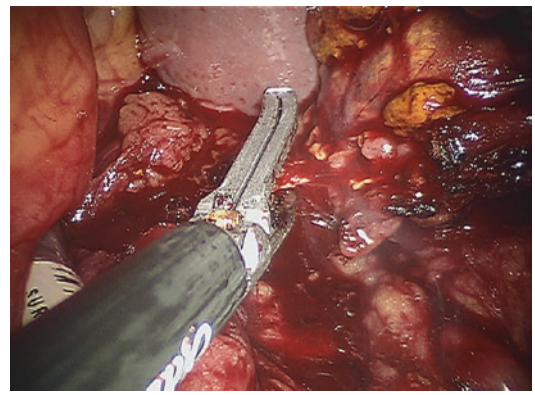

Fig. 4.29 A bipolar vessel-sealing device is used to excise the adenoma from the normal tissue

4. Once the adrenal mass is identified, a bipolar vessel-sealing device can be used to excise the adenoma from the remainder of the adrenal gland (Fig. 4.29). The bipolar vessel-sealing device provides hemostasis when dividing the vascular adrenal tissue. Alternatively, an endovascular stapling device, bipolar forceps, hemostatic polymer clips, or ultrasonic device can be used to divide the adenoma from the uninvolved adrenal tissue.
5. The remaining adrenal tissue is left in situ and is inspected for bleeding with the pneumoperitoneum decreased to 5 mm Hg (Fig. 4.30). As discussed earlier, hemostatic agents such as oxidized cellulose polymer or other hemostatic agents can be used.

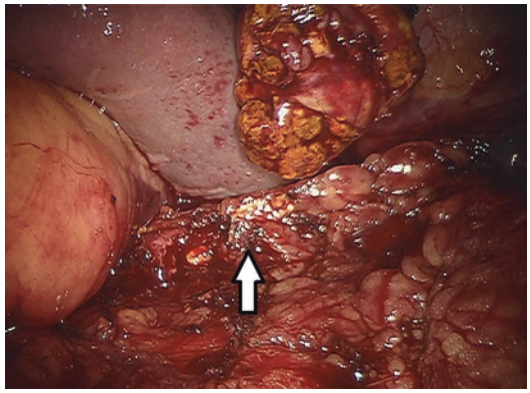

Fig. 4.30 The adrenal mass has been excised and is seen at the top of the image. The remaining adrenal tissue (*arrow*) is left in situ and is inspected for bleeding

6. The specimen is placed in a laparoscopic retrieval bag and removed through one of the 12 mm trocar sites. All trocar sites larger than 10 mm are closed with a fascial closure device, and the trocars are removed under direct vision. The skin is closed with subcuticular sutures or skin staples.

Complications of Laparoscopic Adrenalectomy

The complication rates of laparoscopic adrenalectomy in modern literature range from 0.2% to 11% [5, 14–19]. A comparison of laparoscopic and open adrenalectomy was performed utilizing the National Surgery Quality Improvement Project. The authors found that the morbidity rate was significantly higher in the open group (18.8%) when compared with the laparoscopic group (6.4%) [5]. The incidence of complications varies among series, depending on the definition of a perioperative complication and the Clavien grade of complication reported. A number of factors are reported to affect the rate of complications and are not consistent between studies. Two studies found that obesity correlates with an increased complication rate [14, 19]. Prior ipsilateral open surgery, but not laparoscopic surgery, correlated with an increased rate of conversion to open adrenalectomy in one study [17]. Finally, one group found that the complication rate was significantly lower in patients undergoing laparoscopic adrenalectomy in a higher-volume medical center [14].

Bleeding is the most common complication during and after laparoscopic adrenalectomy, accounting for 40% of complications. The next most common complication is injury to surrounding organs such as the liver, spleen, colon, pancreas, and diaphragm, accounting for less than 5% of all complications. When assessing risk factors for perioperative complications in robotic adrenalectomy, tumor size greater than 5 cm was the only predictive factor for conversion to laparotomy, history of upper gastrointestinal surgery was the only predictive factor for capsular rupture, and conversion to laparotomy and patient age were independent predictive factors for postoperative complications [20]. An appreciation for the adrenal anatomy and proximity to nearby structures can minimize the risk of complications. Excellent exposure to the adrenal gland with mobilization of nearby organs when necessary (spleen, pancreas, liver, duodenum) can improve outcomes and minimize morbidity. Listed in Table 4.2 are the more commonly reported complications of laparoscopic and robot-assisted adrenalectomy and techniques to avoid and manage these complications.

Table 4.2 Complications of laparoscopic and robot-assisted adrenalectomy and techniques to avoid and manage the complications

Complication	Techniques to avoid and manage complication
Bleeding from adrenal vein	Early identification of the adrenal vein Appreciation for aberrant adrenal vein anatomy (branches, multiple veins) When utilizing bipolar vessel-sealing device, leave a small amount of vein tissue attached to the inferior vena cava for vascular control in the event that bleeding is encountered Pressure on the site of bleeding using a radiopaque sponge while exposure to the vein is obtained
Bleeding from renal vein	Awareness of proximity of renal vein to adrenal structures Pressure on the site of bleeding using a radiopaque sponge while exposure to the vein is obtained Careful exposure of renal vein and suture small defects with 5-0 prolene suture
Bleeding from adrenal cortex	Avoid aggressive manipulation of the adrenal gland and traumatic grasping devices If possible, avoid directly grasping adrenal tissue Pressure applied with a radiopaque sponge for several minutes can slow or stop bleeding Hemostatic agents may be necessary to stop bleeding
Injury to inferior vena cava (IVC)	Avoid with complete exposure of the margin of the IVC such that the insertion of adrenal vein into IVC can be visualized Avoid with gentle manipulation of the adrenal vein to avoid an avulsion injury Avoid by expecting anomalous veins (a second renal vein, lumbar veins) and preventing injuries – especially avulsion injuries – to these small vessels Repair small IVC injuries with 5-0 prolene suture If an IVC injury is noted, immediately notify the circulating nurse and anesthesiologist that blood loss and open conversion may be necessary Be prepared at the beginning of the procedure with laparoscopic and open vascular instruments Convert to open surgery early and expeditiously if the injury is beyond the scope of the surgeon's expertise to manage laparoscopically
Diaphragmatic perforation	Avoidance of aggressive dissection lateral to the liver and spleen
Pancreatic injury	Gentle but wide mobilization of the pancreas from the adrenal bed If injury is suspected, intraoperative general surgical consultation If injury is suspected/repaired, closed suction drainage of peritoneal space
Duodenal injury	Avoidance with Kocher maneuver to mobilize the duodenum from the adrenal bed Keep thermal energy instruments away from the duodenum
Splenic injury	Avoid with very gentle retraction on the spleen Cautious use of sharp instruments near the spleen If the spleen is noted to have attachments to omentum or mesentery, divide these attachments before mobilizing the spleen to avoid capsular tear Many splenic injuries can be managed with hemostatic agents – pneumoperitoneum should be decreased to 5 mm Hg after application of these agents to ensure hemostasis General surgical consultation if bleeding persists or a large laceration is noted
Injury to segmental renal arteries/partial renal infarct	Avoid by careful dissection of the inferior margin of the adrenal gland – segmental renal arteries are often found in this area If bleeding is encountered from inadvertent injury to a segmental branch, hemostatic clips or bipolar vessel-sealing device (for vessels less than 7 mm) can be used

Conclusions

Numerous reports and case-controlled studies have validated the benefits of the laparoscopic approach to adrenalectomy over the open approach. The majority of surgeons utilize the transperitoneal technique; however many approaches have been reported in the literature, showing no distinct advantage of any specific technique. Laparoscopic adrenalectomy has consistently shown improved cosmesis, reduced hospital length of stay, decreased analgesic requirements, and a shorter convalescent period. Compared with open adrenalectomy, laparoscopic

adrenalectomy is associated with fewer complications and improved perioperative parameters for patient care, without sacrificing the goals of the operation.

Laparoscopic adrenalectomy has evolved since it was initially described. Refinement in technique and increased experience have resulted in decreased operative times, blood loss, and postoperative pain. As such, laparoscopic adrenalectomy is recognized as the current standard for surgical removal of the adrenal gland. With experience, a detailed understanding of adrenal anatomy, and meticulous laparoscopic dissection, surgeons may further reduce complications associated with laparoscopic and robot-assisted adrenalectomy.

References

1. Gagner M, Lacroix A, Bolté E. Laparoscopic adrenalectomy in Cushing's syndrome and pheochromocytoma. N Engl J Med. 1992;327(14):1033.
2. Prinze R. A comparison of laparoscopic and open adrenalectomies. Arch Surg. 1995;130(5):489–92.
3. Smith C, Weber C, Amerson J. Laparoscopic adrenalectomy: a new gold standard. World J Surg. 1999;23(4):389–96.
4. Gill I. The case for laparoscopic adrenalectomy. J Urol. 2001;166(2):429–36.
5. Elfenbein DM, Scarborough JE, Speicher PJ, Scheri RP. Comparison of laparoscopic versus open adrenalectomy: Results from American College of Surgeons-National Surgery Quality Improvement Project. J Surg Res. 2013;184(1):216–20.
6. Samreen S, Fluck M, Hunsinger M, Wild J, Shabahang M, Blansfield JA. Laparoscopic versus robotic adrenalectomy: a review of the national inpatient sample. J Robot Surg. 2019;13(1):69–75.
7. Faiena I, Tabakin A, Leow J, Patel N, Modi PK, Salmasi AH, et al. Adrenalectomy for benign and malignant disease: utilization and outcomes by surgeon specialty and surgical approach from 2003-2013. Can J Urol. 2017;24(5):8990–7.
8. Economopoulos KP, Mylonas KS, Stamou AA, Theocharidis V, Sergentanis TN, Psaltopoulou T, Richards ML. Laparoscopic versus robotic adrenalectomy: a comprehensive analysis. Int J Surg. 2017;38:95–104.
9. Mishra K, Maurice MJ, Bukavina L, Abouassaly R. Comparative efficacy of laparoscopic versus robotic adrenalectomy for adrenal malignancy. Urology. 2019;123:146–50.
10. Kahramangil B, Berber E. Comparison of posterior retroperitoneal and transabdominal lateral approaches in robotic adrenalectomy: an analysis of 200 cases. Surg Endosc. 2018;32(4):1984–9.
11. Simone G, Anceschi U, Tuderti G, Misuraca L, Celia A, De Concilio B, et al. Robot-assisted partial adrenalectomy for the treatment of Conn's syndrome: surgical technique, and perioperative and functional outcomes. Eur Urol. 2019;75:811–6. https://doi.org/10.1016/j.eururo.2018.07.030.
12. Zeiger MA, Thompson GB, Duh QY, Hamrahian AH, Angelos P, Elaraj D, et al. American Association of Clinical Endocrinologists and American Association of Endocrine Surgeons Medical Guidelines for the Management of Adrenal Incidentalomas: executive summary of recommendations. Endocr Pract. 2009;15(5):450–3.
13. Kahramangil B, Kose E, Berber E. Characterization of fluorescence patterns exhibited by different adrenal tumors: determining the indications for indocyanine green use in adrenalectomy. Surgery. 2018;164(5):972–7.
14. Bergamini C, Martellucci J, Tossi F, Valeri A. Complications in laparoscopic adrenalectomy: the value of experience. Surg Endosc. 2011;25(12):3845–51.
15. Nguyen PH, Keller JE, Novitsky YW, Heniford BT, Kercher KW. Laparoscopic approach to adrenalectomy: review of perioperative outcomes in a single center. Am Surg. 2011;77(5):592–6.
16. Greco F, Hoda MR, Rassweiler J, Fahlenkamp D, Neisius DA, Kutta A, et al. Laparoscopic adrenalectomy in urologic centres: the experience of the German Laparoscopic Working Group. BJU Int. 2011;108(10):1646–51.
17. Mazeh H, Froyshteter AB, Wang TS, Amin AL, Evans DB, et al. Is previous same quadrant surgery a contraindication to laparoscopic adrenalectomy? Surgery. 2012;152(6):1211–7.
18. Hattori S, Miyajima A, Maeda T, Hasegawa M, Takeda T, Kosaka T, et al. Risk factors for perioperative complications of laparoscopic adrenalectomy including single-site surgery. J Endourol. 2012;26(11):1463–7.
19. Dancea HC, Obradovic V, Sartorius J, Woll N, Blansfield JA. Increased complication rate in obese patients undergoing laparoscopic adrenalectomy. JSLS. 2012;16(1):45–9.
20. Greilsamer T, Nomine-Criqui C, Thy M, Ullmann T, Zarnegar R, Bresler L, Brunaud L. Robotic-assisted unilateral adrenalectomy: risk factors for perioperative complications in 303 consecutive patients. Surg Endosc. 2019;33(3):802–10.

5 Robot-Assisted Radical Prostatectomy

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Introduction

Laparoscopic surgery represented a major breakthrough in the urologic field, due to the decreased intraoperative estimated blood loss, shorter hospital stay, and quicker return to function. The main obstacle which prevented the widespread of the laparoscopic approach was the steep learning curve required for a surgeon to achieve proficiency [1].

The advent of robot-assisted laparoscopic surgery represented a great advantage both for experienced laparoscopic surgeons and for laparoscopically naïve ones. Urologists experienced in laparoscopy found in the robot-assisted approach a better quality of vision, with 3D resolution, precise movements, and no limitations on movements. On the other hand, open surgeons were provided with a minimally invasive technique with a simpler and faster learning curve [2].

In the field of oncologic urologic surgery, radical prostatectomy (RP) represents the leading application of the robotic approach [1]. At present, RP represents the standard for long-term cure of localized prostate cancer (PCa), with cancer-specific survival approaching 95% at 15 years after radical surgery [3]. Since the first procedure performed by Binder in May 2000 [4], robot-assisted radical prostatectomy (RARP), carried out using the da Vinci Surgical System™ (Intuitive Surgical, Sunnyvale, CA, USA), has been rapidly accepted as a safe and efficacious treatment option for localized PCa [1]. RARP is currently the leading urologic use of the da Vinci system, with approximately 75% of RPs in North

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S. L. Best, S. Y. Nakada (eds.), *Minimally Invasive Urology*,
https://doi.org/10.1007/978-3-030-23993-0_5

America performed by robot-assisted surgery. Furthermore, 50% of the use of the robotic platforms worldwide is for RARP [5].

RARP can be performed either through a transperitoneal or subperitoneal approach, with more precision and choices for dissection, thanks to the system's 3D vision [2]. Indications for RARP are the same as those for radical retropubic prostatectomy (RRP) and laparoscopic radical prostatectomy (LRP). According to the American Urological Association (AUA) Guidelines 2017, RARP should be offered to younger localized PCa patients (≥65 years old) with life expectancy >10 years [6]. Furthermore, the European Association of Urology (EAU) Guidelines 2017 gave similar recommendations, offering RARP for patients with low- and intermediate-risk localized PCa and a life expectancy >10 years and in high-risk localized PCa patients with >10 years life expectancy as a part of multimodal treatment [7].

Surgical Technique

In 2007, Patel VR et al. described a technique for transperitoneal RARP [8], based on standard laparoscopic [9] and robotic [10] technique described previously. Some differences from these techniques were introduced: the dorsal vein stitch, the suspension stitch, early retrograde dissection of the neurovascular bundle, and continuous anastomosis described by Van Velthoven [11]. This technique, along with the modifications introduced since then, is here described step by step.

Step 1: Incision of the Peritoneum and Entry into the Retropubic Space of Retzius

Instruments

- Right arm: Monopolar scissor (30 W)
- Left arm: Bipolar Maryland (30 W)
- Fourth arm: Prograsp
- Assistant: Microfrance grasper and suction
- Telescope: 0° binocular lens

Peritoneum is incised transversally through the median umbilical ligament (Fig. 5.1); the incision is extended on both sides in an inverted U fashion to the level of the vasa on either side. Countertraction is provided by the assistant and the fourth arm. The peritoneum is dissected to the following boundaries: the pubic bone superiorly, the median umbilical ligaments laterally, and the vas deferens inferolaterally (Fig. 5.2). The pubic tubercle is found and followed laterally to the

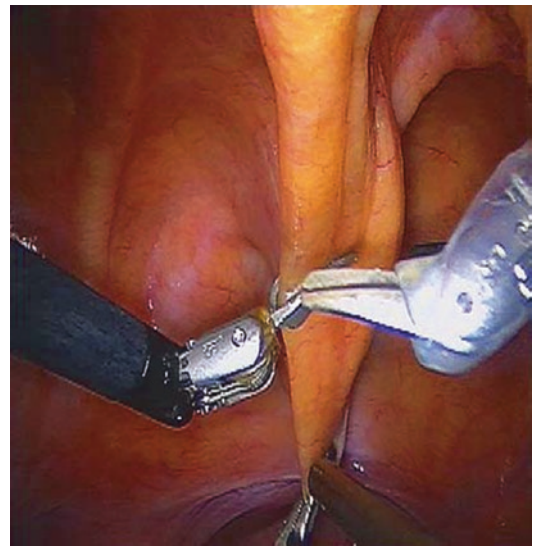

Fig. 5.1 Incising peritoneal fold to enter the retropubic space. (From Patel et al. [8], with permission)

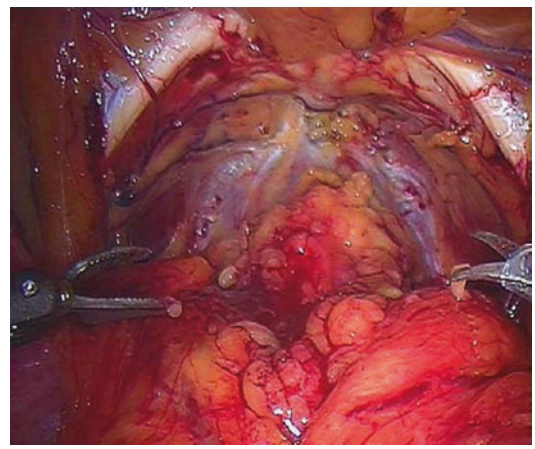

Fig. 5.2 Entry into the retropubic space of Retzius showing the boundary of dissection. (From Patel et al. [8], with permission)

vasa. It is important to dissect the peritoneum all the way up to the base of the vasa to release the bladder and allow tension-free vesicourethral anastomosis.

Step 2: Incision of the Endopelvic Fascia (EPF) and Identification of the Dorsal Venous Complex (DVC)

Instruments

- Right arm: Monopolar scissor (30 W)
- Left arm: Bipolar Maryland (30 W)
- Fourth arm: Prograsp
- Assistant: Microfrance grasper and suction
- Telescope: 0° binocular lens

The important landmarks are the bladder neck, base of the prostate, levator muscles, and apex of the prostate (Fig. 5.3). Once adequate exposure has been obtained, the EPF is opened from the base of the prostate to immediately lateral to the reflection of the puboprostatic ligaments bilaterally using cold scissors. This is the area with the biggest space between the prostate and the levators and the point at which the prostate has most mobility. Proceeding from the base to the apex, the levator fibers are pushed off the prostate until the DVC and urethra are visualized (Fig. 5.4). Extensive dissection of the apex at this time can lead to unnecessary and obtrusive bleeding, so it is important to dissect only that which is necessary to get in a good DVC stitch.

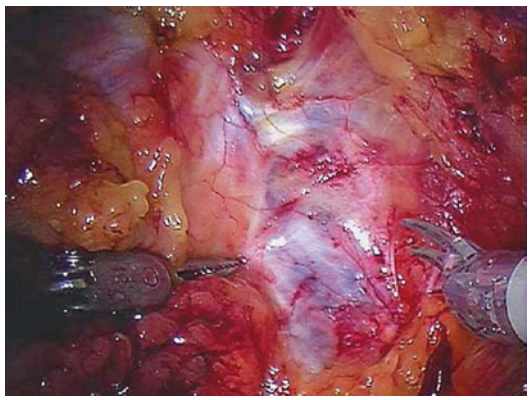

Fig. 5.3 The landmarks for incision of the endopelvic fascia are the bladder neck, base of the prostate, levator muscles, and apex of the prostate. (From Patel et al. [8], with permission)

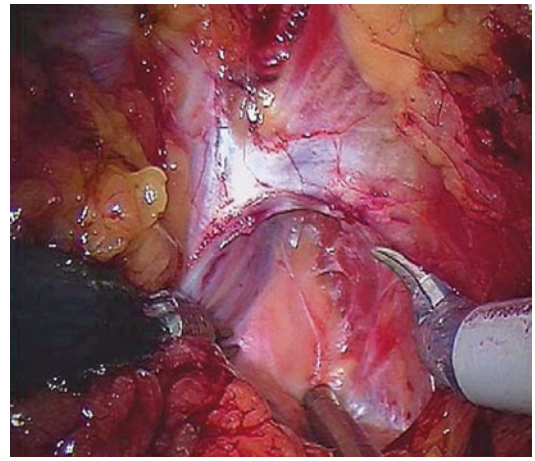

Fig. 5.4 Incision of the endopelvic fascia and identification of the dorsal venous complex. (From Patel et al. [8], with permission)

Step 3: Ligation of the DVC

Instruments

- Right arm: Robotic needle driver
- Left arm: Robotic needle driver
- Assistant: Laparoscopic scissor
- Telescope: 0° binocular lens

Robotic needle drivers are placed via the robotic ports. Patel et al. use a large needle with a non-braided absorbable suture such as Polyglytone™ (e.g., Caprosyn™) on a large CT1 needle. The needle is held about 2/3 back at a slight downward angle and placed in the visible notch between the urethra and DVC (Fig. 5.5). The needle is pushed straight across at 90° and then the wrist is turned to curve around the apex of the prostate. The suture strength needs to be sufficient to allow the needle holders to pull up tight and perform a slip knot, which prevents the suture from loosening as it is tied. A second suture is placed to suspend the urethra to the pubic bone and secondarily ligate the DVC. The DVC is encircled and then stabilized against the pubic bone along with the urethra (Fig. 5.6). The aim of

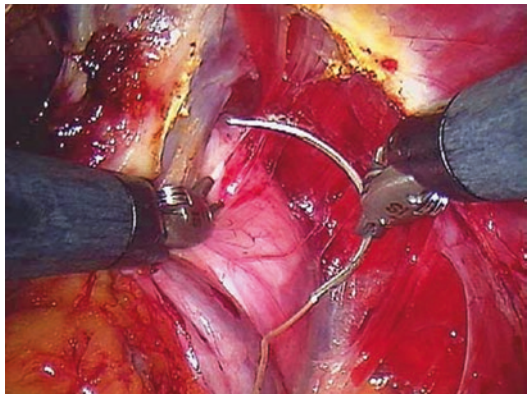

Fig. 5.5 A large CT1 needle is placed in the visible notch between the urethra and DVC. (From Patel et al. [8], with permission)

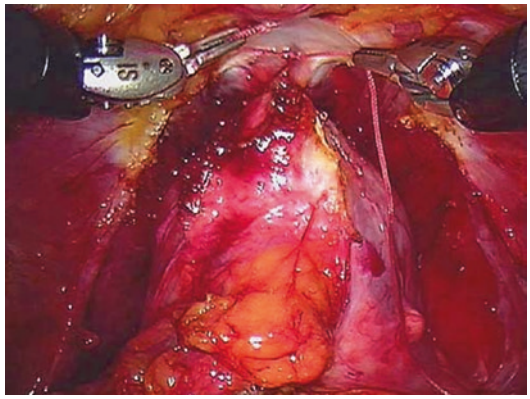

Fig. 5.6 Ligated dorsal venous complex (DVC) and performance of suspension stitch to suspend DVC to pubic bone. (From Patel et al. [8], with permission)

this technique is the stabilization of the urethra avoiding urethral retraction, facilitating the urethral dissection. Patel et al., in a prospective comparative study on 331 patients, found a significant advantage in terms of early recovery of continence at 3 months using a single anterior suspension stitch to the pubic bone (83% vs. 92.9%; $p = 0.013$) [12].

Step 4: Anterior Bladder Neck Dissection

Instruments

- Right arm: Monopolar scissor (30 W)
- Left arm: Bipolar Maryland (30 W)
- Fourth arm: Prograsp

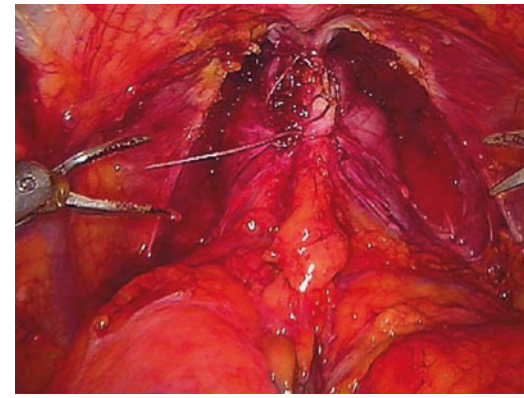

Fig. 5.7 Identification of the bladder neck by cessation of the fat extending from the bladder at the level of the prostatovesical junction. (From Patel et al. [8], with permission)

- Assistant: Microfrance grasper and suction
- Telescope: 30° binocular lens directed downward

The laparoscope is changed to a 30° down-facing lens, which is optimal to see inferiorly. The bladder neck is identified by a cessation of the fat extending from the bladder at the level of the prostatovesical junction (Fig. 5.7). Another technique is to pull on the urethral catheter and visualize the balloon. However, this can be unreliable and misleading after transurethral resection of prostate (TURP) or with a median lobe or large prostate. The robotic arms also provide a moderate amount of visual and sensory feedback to facilitate localization of the boundaries. The bladder is dissected off the prostate in the midline using a sweeping motion of the monopolar scissor while visualizing the bladder fibers. The key is to stay in the midline to avoid lateral venous sinuses till the anterior bladder neck is opened and then dissect on either side of the bladder neck. Once the anterior urethra is divided, the Foley catheter is retracted out of the bladder using the fourth arm, and upward traction is applied to expose the posterior bladder neck (Fig. 5.8).

Step 5: Posterior Bladder Neck

Instruments

- Right arm: Monopolar scissor (30 W)
- Left arm: Bipolar Maryland (30 W)

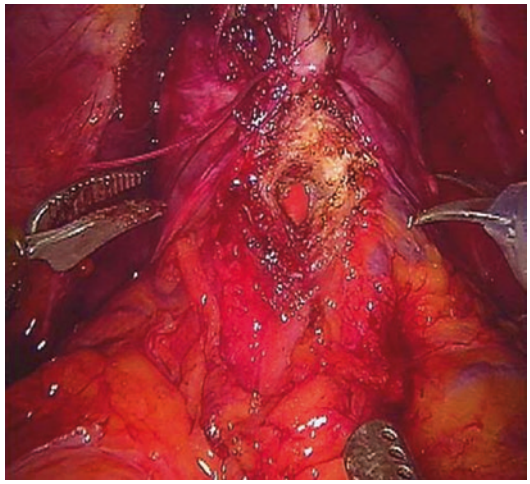

Fig. 5.8 Division of anterior bladder neck. (From Patel et al. [8], with permission)

- Fourth arm: Prograsp
- Assistant: Microfrance grasper and suction
- Telescope: 30° binocular lens directed downward

During the posterior bladder neck dissection, the difficulty is in appreciating the posterior tissue plane between the bladder and prostate and the direction and depth of dissection necessary to locate the seminal vesicles. After incision of the anterior bladder neck, any remaining peripheral bladder attachments should be divided to flatten out the area of the posterior bladder neck and allow precise visualization and dissection of the posterior plane. The full thickness of the posterior bladder neck should be incised at the precise junction between the prostate and the bladder (Fig. 5.9). The lip of the posterior bladder neck is then grasped with the fourth arm and used for gentle traction to visualize the natural plane between the prostate and bladder. The dissection is directed posteriorly and slightly cranially (toward the bladder) to expose the seminal vesicles. It is important to avoid dissecting caudally (toward the prostate) as there is a possibility of entering the prostate and missing the seminal vesicles completely (Fig. 5.10).

Step 6: Seminal Vesicle Dissection

Instruments

- Right arm: Monopolar scissor (30 W)
- Left arm: Bipolar Maryland (30 W)

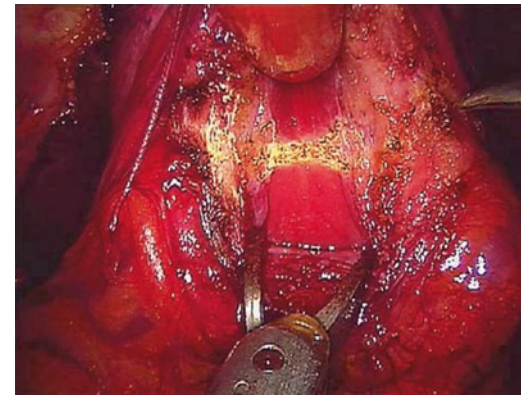

Fig. 5.9 Incising the middle portion of posterior bladder neck. (From Patel et al. [8], with permission)

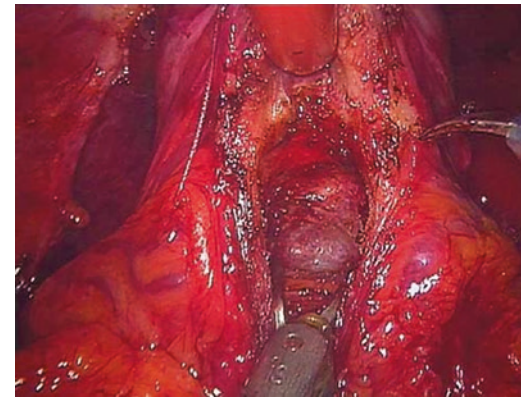

Fig. 5.10 Completed posterior dissection exposing the seminal vesicles. (From Patel et al. [8], with permission)

- Fourth arm: Prograsp
- Assistant: Microfrance grasper and suction
- Telescope: 30° binocular lens directed downward

Once the bladder has been dissected off the prostate, the vasa and seminal vesicles can be identified. The thin fascial layer over the seminal vesicles and vasa should be opened to free the structures for retraction. The fourth arm is used to retract the vasa superiorly. Both vasa are then incised, and the inferior portion of the vas is retracted by the assistant (Fig. 5.11). The vas is then followed posteriorly to expose the tips of the seminal vesicles. Small perforating vessels are cauterized with the bipolar grasper and divided or clipped with a 5 mm clip or Hem-o-lok (Fig. 5.12).

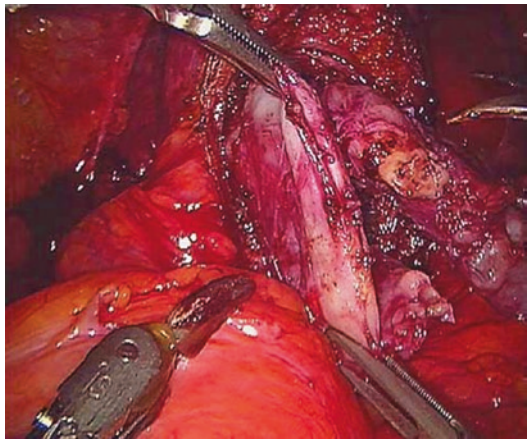

Fig. 5.11 Vas retraced by the fourth arm and the assistant. (From Patel et al. [8], with permission)

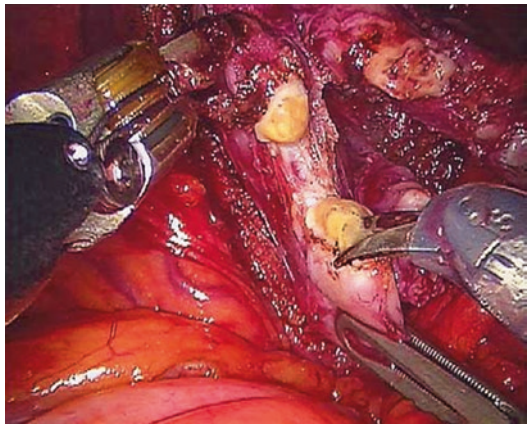

Fig. 5.12 The vas is followed posteriorly to expose the tips of the seminal vesicles. (From Patel et al. [8], with permission)

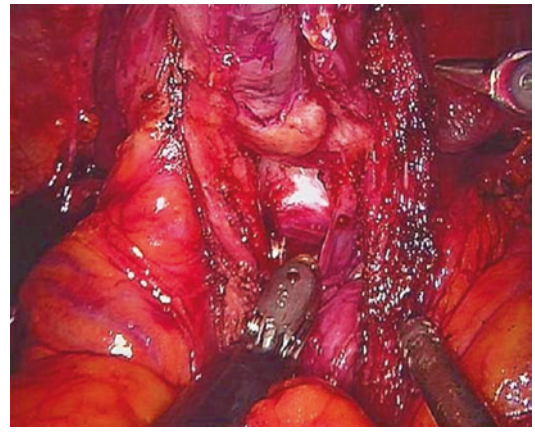

Fig. 5.13 Incision of Denonvilliers' fascia is made at the base of the seminal vesicles to expose the clear pearly white plane between the prostatic capsule and the rectum. (From Patel et al. [8], with permission)

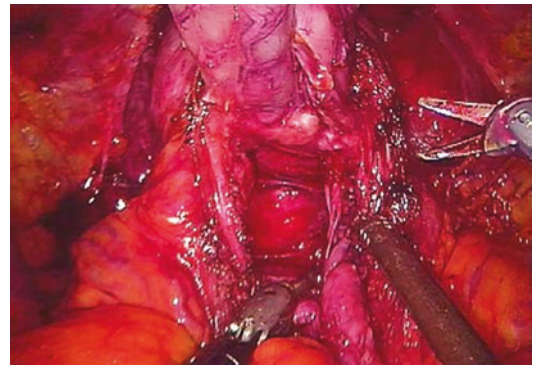

Fig. 5.14 Completed posterior dissection to fully release the prostate. (From Patel et al. [8], with permission)

Step 7: Denonvilliers' Fascia and Posterior Dissection

Instruments

- Right arm: Monopolar scissor (30 W)
- Left arm: Bipolar Maryland (30 W)
- Fourth arm: Prograsp
- Assistant: Microfrance grasper and suction
- Telescope: 30° binocular lens directed downward

The seminal vesicles must be dissected all the way to the base to allow for appropriate elevation of the prostate and identification of the posterior Denonvilliers' fascia (Fig. 5.13). The incision of Denonvilliers' fascia is made at the base of the seminal vesicles. The correct plane can be identified by the presence of a clear pearly white plane between the posterior prostatic capsule and the rectum. When entered correctly, the plane is avascular and spreads easily with the Maryland dissector with minimal bleeding. The posterior space is dissected widely to fully release the prostate and facilitate rotation during the nerve sparing (Fig. 5.14).

Step 8: Nerve Sparing

Instruments

- Right arm: Monopolar scissor (30 W)
- Left arm: Bipolar Maryland (30 W)
- Fourth arm: Prograsp
- Assistant: Microfrance grasper and suction
- Telescope: 30° binocular lens directed downward

The approach to the nerve sparing is retrograde, mirroring the open approach. The periprostatic fascia is incised at the level of the apex and midportion of the prostate (Fig. 5.15). Gentle spreading of the tissue on the lateral aspect of the prostate will allow the prostatic capsule and the neurovascular bundle (NVB) to be identified. No thermal energy is used during dissection of the NVB or ligation of the pedicle. At the apex of the prostate, a plane between the NVB and prostate capsule can be identified and separated (Fig. 5.16). The NVB is then released in a retrograde manner toward the prostatic pedicle. The NVB is stabilized with the Maryland dissector and the prostate is gently stroked away using the scissors. The plane between the NVB sheath and the prostate capsule is relatively avascular, consisting of only small tributary vessels; therefore, no energy or clipping is required close to the path of the NVB. As the dissection proceeds in a retrograde fashion, the NVB can clearly be seen being released off the prostate. The prostate pedicle can then be thinned out with sharp dissection and the path of the NVB clearly delineated at this level. The clear definition of the anatomy allows the placement of two clips on the pedicle away from the NVB and sharp incision to release the prostate completely (Fig. 5.17). It is important to release the NVB to the apex of the prostate in order to prevent injury during the apical dissection.

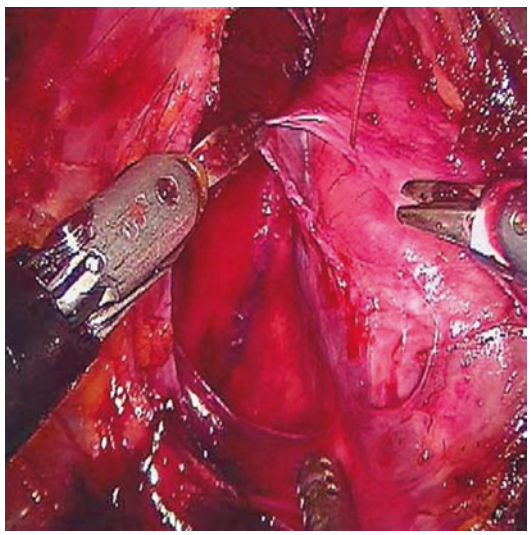

Fig. 5.15 Incision of the periprostatic fascia at the level of the apex and midportion of the prostate. (From Patel et al. [8], with permission)

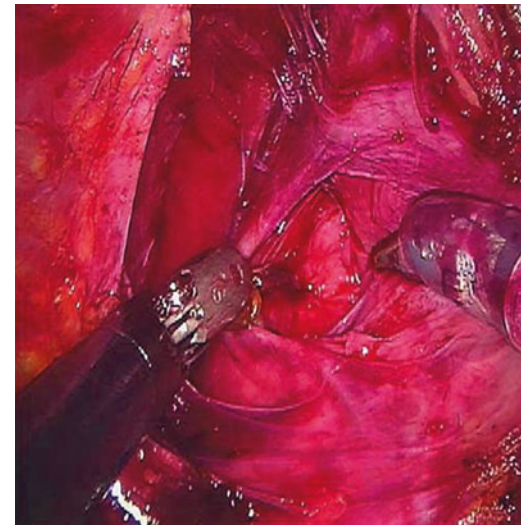

Fig. 5.16 Development of plane between the prostate capsule and the neurovascular bundle. (From Patel et al. [8], with permission)

Step 9: Apical Dissection

Instruments

- Right arm: Monopolar scissor (30 W)
- Left arm: Bipolar Maryland (30 W)
- Fourth arm: Prograsp
- Assistant: Microfrance grasper and suction
- Telescope: 30° binocular lens directed downward

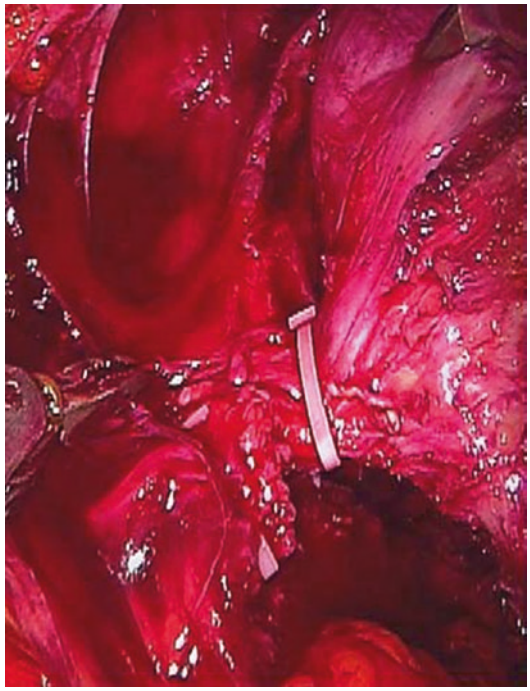

Fig. 5.17 The prostate pedicle ligated away from the neurovascular bundle under direct vision. (From Patel et al. [8], with permission)

The landmarks are the ligated DVC, urethra, apex of the prostate, and NVB. Ligation of the DVC prevents bleeding which may interfere with the apical dissection and division of the urethra under direct vision (Fig. 5.18). Cold scissors are used to divide the DVC and a long urethral stump is developed, as a longer urethral stump facilitates the anastomosis and may improve continence. Complete dissection of the apex and urethra is facilitated by the robotic magnification. The urethra is then incised at the apex of the prostate under direct vision to completely liberate the prostate (Fig. 5.19).

Step 10: Bladder Neck Reconstruction

Instruments

- Right arm: Robotic needle driver
- Left arm: Robotic needle driver
- Fourth arm: Prograsp
- Assistant: Microfrance grasper and suction

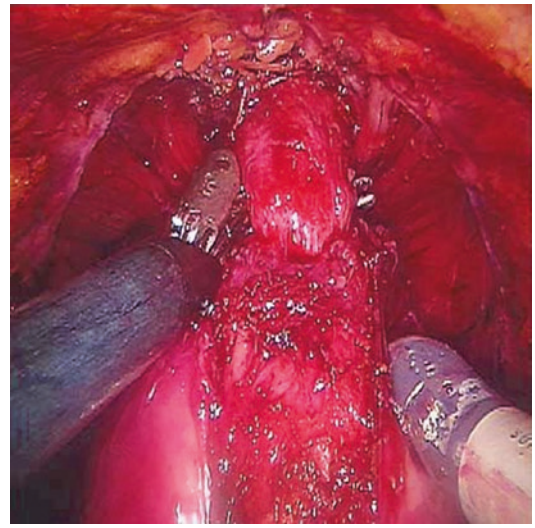

Fig. 5.18 Complete apical dissection to achieve long urethral stump. (From Patel et al. [8], with permission)

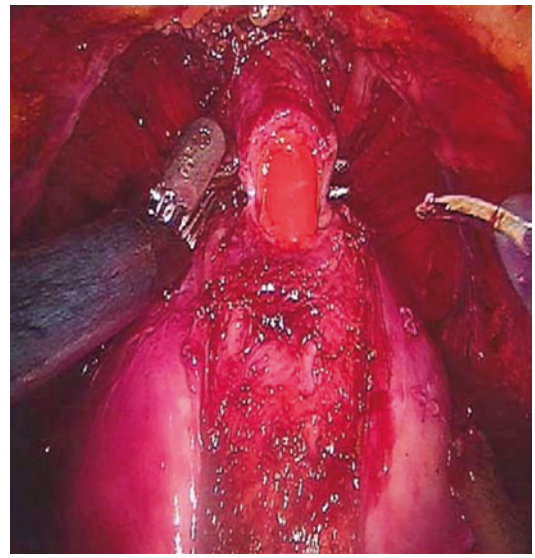

Fig. 5.19 Urethra is incised at the apex of the prostate under direct vision. (From Patel et al. [8], with permission)

Bladder neck preservation is usually attempted during RARP, but, in case of large prostate volume or large median lobe or in patients with previous TURP, a bladder neck reconstruction can be necessary. Before starting the bladder neck reconstruction, it is essential to check the position of the ureteric orifices and their distance from the edge of the bladder

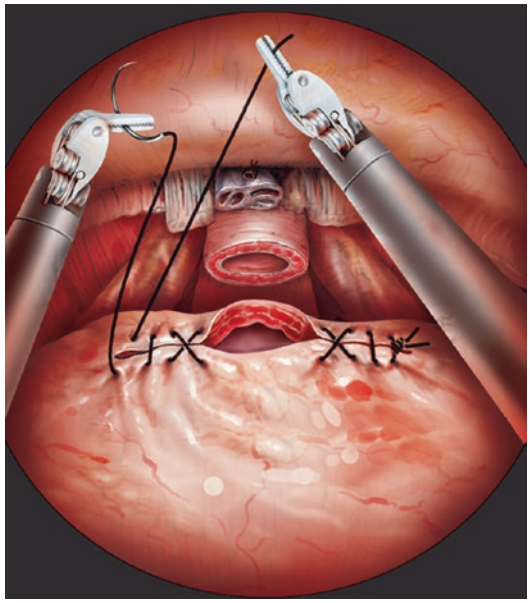

Fig. 5.20 Modified transverse plication for bladder neck reconstruction. (From Lin et al. [13], with permission)

neck. Bilateral plication over the lateral aspect of the bladder is then performed using sutures of 3-0 poliglecaprone, 13 cm long, in a RB-1 needle (Ethicon Inc. Somerville, NJ, USA). The suture begins laterally and runs medially until the bladder neck size matches that of the membranous urethra. The same suture then runs laterally, back to the beginning of the suture, and is tied (Fig. 5.20). Occasionally, additional stitches need to be placed, if indicated, until the bladder neck size matches that of membranous urethra [13].

Step 11: Reconstruction of the Posterior Musculofascial Plate

Instruments

- Right arm: Robotic needle driver
- Left arm: Robotic needle driver
- Fourth arm: Prograsp
- Assistant: Microfrance grasper and suction
- Telescope: 30° binocular lens directed downward

In 2006, Rocco F et al. proposed a technique for restoration of the posterior aspect of the rhabdosphincter (RS) which demonstrated to shorten time to continence in patients undergoing RRP [14]. In 2007, Rocco B et al. described the application of the posterior reconstruction technique to transperitoneal laparoscopic radical prostatectomy (LRP) [15], while, in 2008, Coughlin et al. applied the posterior reconstruction of the rhabdosphincter to RARP with some minor technical modifications [16]. The technique has been further modified in 2011 [17].

The reconstruction is performed using two 3-0 poliglecaprone sutures (on RB-1 needles) tied together, with each individual length being 12 cm. Ten knots are placed when tying the sutures to provide a bolster. The free edge of the remaining Denonvilliers' fascia is identified after the prostatectomy and approximated to the posterior aspect of the RS and the posterior median raphe using one arm of the continuous suture. As a rule, four passes are taken from the right to the left and the suture is tied (Fig. 5.21a, b). The second layer of the reconstruction is then performed with the other arm of the suture approximating the posterior lip of the bladder neck (full thickness) and the vesicoprostatic muscle, as described by Walz et al. [18], to the posterior urethral edge and to the already reconstructed median raphe (Fig. 5.22a, b). This suture is then tied to the end of the first suture arm.

One of the key steps for an appropriate reconstruction is the preservation of the Denonvilliers' fascia when dissecting the posterior plane between the prostate and the rectal wall. If this dissection is performed at the perirectal fat tissue, the Denonvilliers' fascia is not adequately spared, precluding posterior reconstruction.

An updated systematic review and meta-analysis showed that reconstruction of the posterior musculofascial plate improves early return of continence (relative risk 1.77, 95% CI 1.43–2.20; $P < 0.001$) within the first 30 days after RP (Fig. 5.23); furthermore, a trend toward lower leakage rates (relative risk 0.43, 95% CI 0.25–0.75; $P = 0.006$) has been found in patients who received the posterior reconstruction (Fig. 5.24) [19].

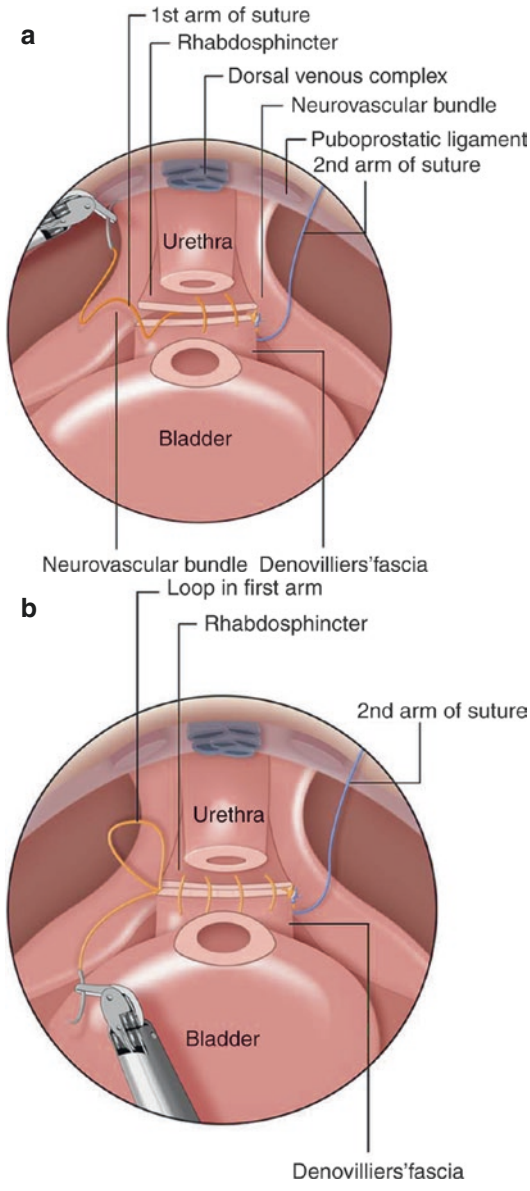

Fig. 5.21 (**a**) First layer of posterior reconstruction. (**b**) The free edge of the remaining Denonvilliers' fascia is approximated to the posterior aspect of the rhabdosphincter reconstruction. (From Coelho et al. [17], with permission)

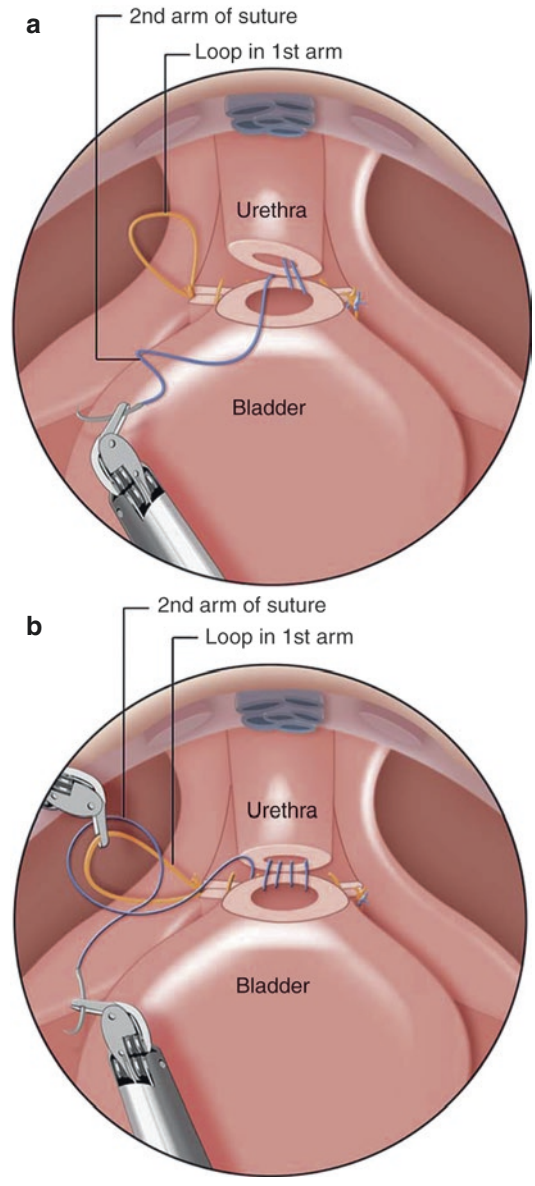

Fig. 5.22 (**a**) Second layer of posterior reconstruction. (**b**) The posterior lip of the bladder neck and vesicoprostatic muscle is sutured to the posterior urethral edge reconstruction. (From Coelho et al. [17], with permission)

Step 12: Urethrovesical Anastomosis

Instruments

- Right arm: Robotic needle driver
- Left arm: Robotic needle driver
- Assistant: Suction and scissor
- Telescope: 30° binocular lens directed downward

The urethra and bladder are re-approximated using a continuous suture as per the technique described by Van Velthoven [11]. Two 20 cm 3-0 Monocryl sutures on RB-1 needles of different colors are tied together with ten knots to provide a bolster. The posterior urethral anastomosis is performed first with one arm of the suture. Three

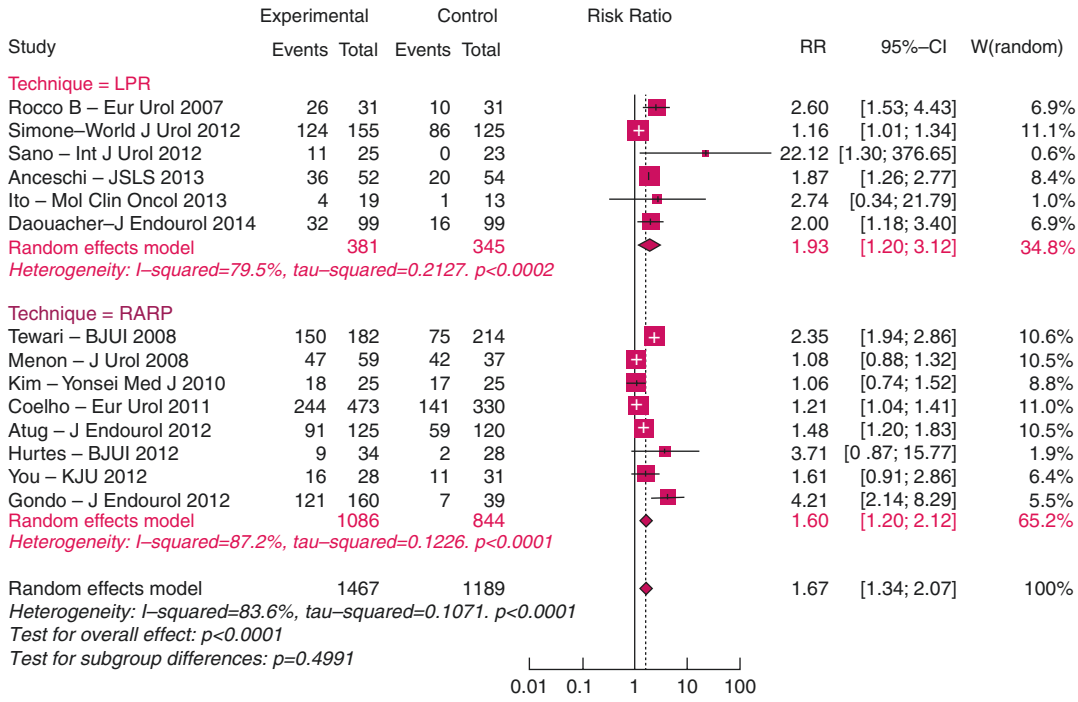

Fig. 5.23 Forest plot of relative risk (RR) for urinary continence at 30 days after catheter removal, stratified by surgical approach: ORP, LRP, and RARP, cumulative analysis. Continence rates were significantly higher in patients undergoing reconstruction of the prostatic musculofascial plate at 30 days after surgery (RR 1.77; 95% CI of RR, 1.43–2.20; $p < 0.001$). (From Grasso et al. [19], with permission)

passes are made through the bladder and two passes through the urethra and the suture is pulled straight up in order to bring the bladder down. The posterior anastomosis is continued in a clockwise direction from the 5 to 9 o'clock position obtaining adequate bites of tissue (Fig. 5.25). This is followed by completion of the anterior anastomosis with the second arm of the suture in a counterclockwise fashion (Fig. 5.26). The key to performing quick watertight anastomosis is to have an adequate urethral length, normal-sized bladder neck, clear operative field, and perineal pressure. A Foley catheter is placed and saline is irrigated to confirm watertight anastomosis. A Jackson–Pratt drain is placed around the anastomosis, and all the trocars are removed under direct vision.

Robot-Assisted Lymph Node Dissection

The lymph node drainage of the prostate appears to occur in the following order: external iliac and obturator (38%), internal iliac (25%), common iliac (16%), para-aortic/para-caval (12%), presacral (8%), and inguinal (1%) [20]. The PLND can be categorized into different categories, including: (1) no PLND; (2) dissection of the obturator nodes (limited PLND); (3) obturator and external iliac lymph node dissection (standard PLND); (4) dissection of the obturator, external and internal iliac lymph nodes (extended PLND); and (5) obturator, external and internal iliac, common iliac, presacral, and other nodes (super extended PLND) [21].

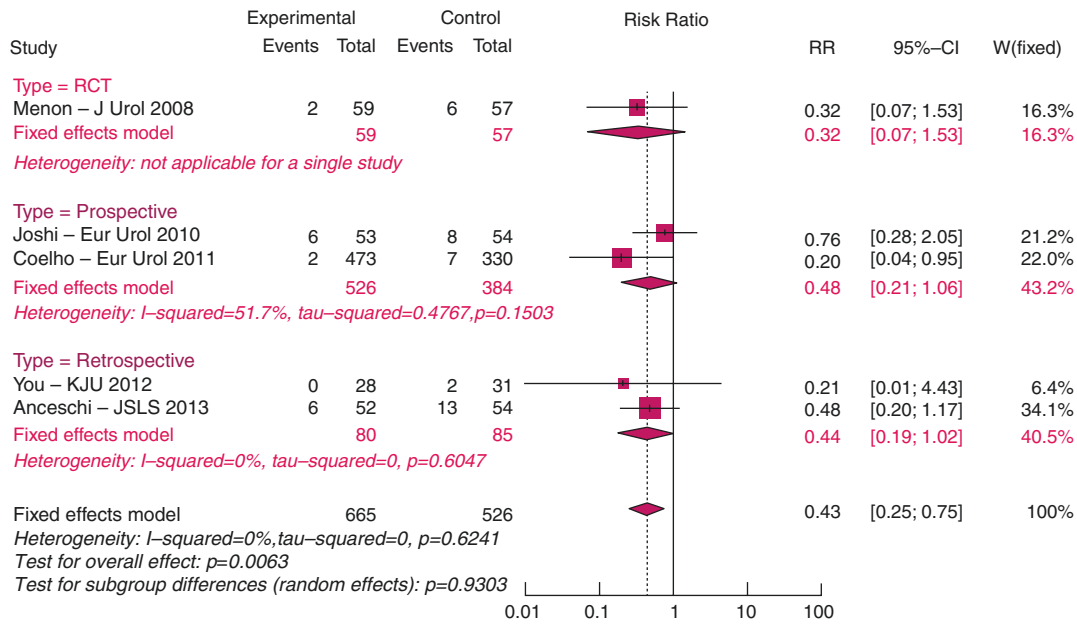

Fig. 5.24 Forest plot of relative risk (RR) for risk of perianastomotic urinary leakage at postoperative cystogram, stratified by type of study: RCT, observational prospective and retrospective, cumulative analysis. A trend toward lower leakage rates is shown in the reconstruction of the prostatic musculofascial plate group (RR 0.43; 95% CI of RR, 0.25–0.75; $p = 0.0065$). (From Grasso et al. [19], with permission)

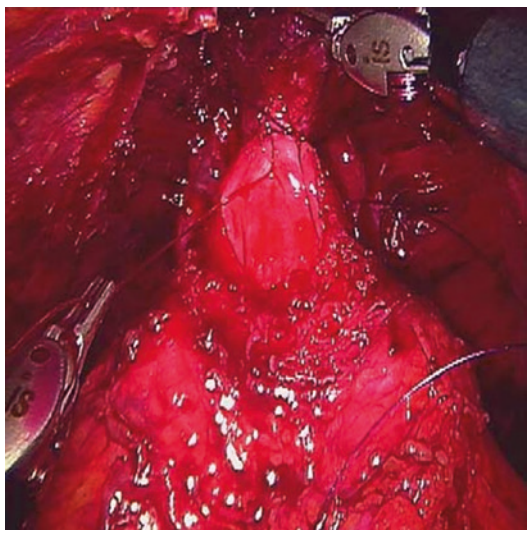

Fig. 5.25 Posterior urethral anastomosis starting at 5 o'clock position. (From Patel et al. [8], with permission)

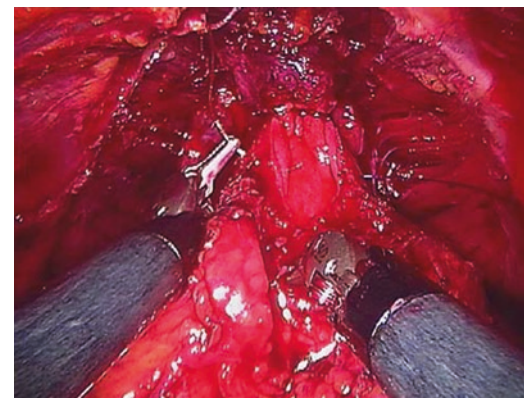

Fig. 5.26 Completion of posterior anastomosis in a clockwise direction. (From Patel et al. [8], with permission)

Indications for lymph dissection during RARP are the same as those during RRP; however, at present there is no good quality evidence to support a specific extent PLND over the other or even to demonstrate that any form of PLND significantly improves oncological outcomes as compared to no PLND [21]. According to the AUA guidelines, PLND should be offered to patients with unfavorable intermediate-risk or high-risk

disease [6]. Moreover, ˃5% likelihood of having nodal metastasis in intermediate-risk or high-risk patients using the available nomograms is an indication for extended PLND, according to the EAU Guidelines [7].

An appropriate PLND includes removal of all node-bearing tissue from an area bounded by the external iliac artery anteriorly, the pelvic sidewall laterally, the bladder wall medially, the floor of the pelvis posteriorly, Cooper ligament distally, and the common iliac artery/ureter crossing proximally. When these anatomic boundaries are respected, PLND usually retrieves ≥10 lymph nodes [22].

Several authors reported the feasibility of an extended PLND in course of RARP, including external iliac, internal iliac, and obturator lymph nodes [23, 24]. A systematic review and meta-analysis demonstrated that robotic extended PLND obtained a lymph node yield ranging from 12 to 19 and positive node rates ranging from 11% to 24%, according to the different patient characteristics; however, this template was associated with higher complication rates [25].

Furthermore, Chung et al. [26] compared transperitoneal and extraperitoneal limited dissection, showing a similar lymph node yield with a slightly higher risk of postoperative lymphoceles for the extraperitoneal approach.

Tips, Tricks, and Challenging Cases

Dissection of the Bladder Neck

Dissection of the bladder neck represents one of the most challenging steps of RARP, particularly in the presence of difficult anatomic conditions, which can be natural, such as the presence of a median lobe, or due to previous surgery, as in case of TURP.

The line of dissection of the anterior bladder neck can be identified by pulling the catheter, operating a traction with the fourth arm, or by means of a symmetric pressure of the right and left arm (Fig. 5.27). The use of a low monopolar energy helps in maintaining the features of the tissue and so in distinguishing the muscular tissue of the detrusor from the glandular tissue of the prostate.

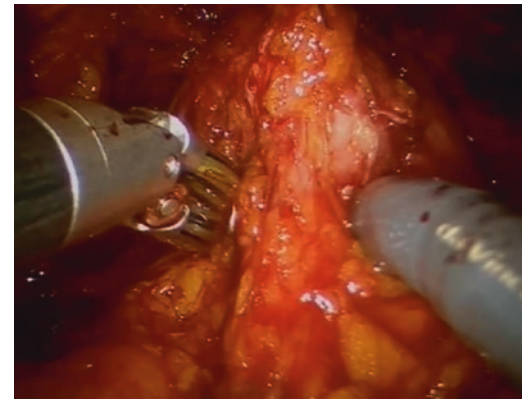

Fig. 5.27 The line of dissection of the anterior bladder neck can be identified by means of a symmetric pressure of the right and left arm

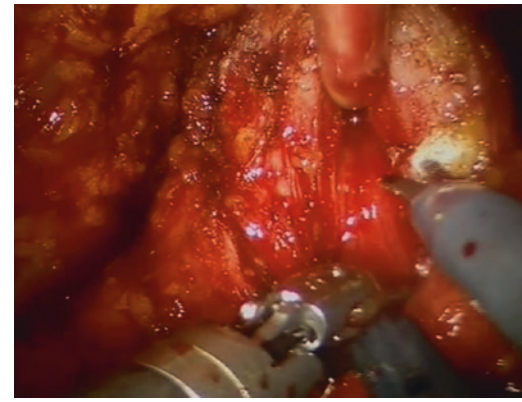

Fig. 5.28 The dissection of the posterior bladder neck begins on the lateral aspects of the detrusor

The approach to the posterior bladder neck is based on two opposite tractions: that on the catheter superiorly and that on the bladder neck cranially. The incision begins on the lateral aspects of the detrusor (Fig. 5.28). After releasing the lateral muscular fibers, and so transferring the traction on the midline, the bladder neck is dissected. A constant traction is made by means of the left arm; the scissors, with separate blades, develop the surgical plane, until the seminal vesicles are visible (Fig. 5.29).

In the presence of a median lobe, traction on the catheter can help identify an eventual asymmetry of the lobes. The dissection of the anterior

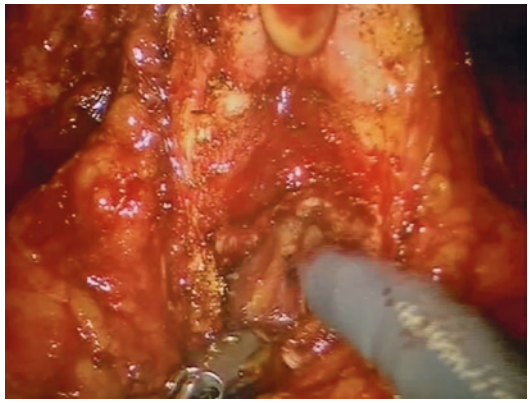

Fig. 5.29 The dissection of the posterior bladder neck ends when the seminal vesicles are visible

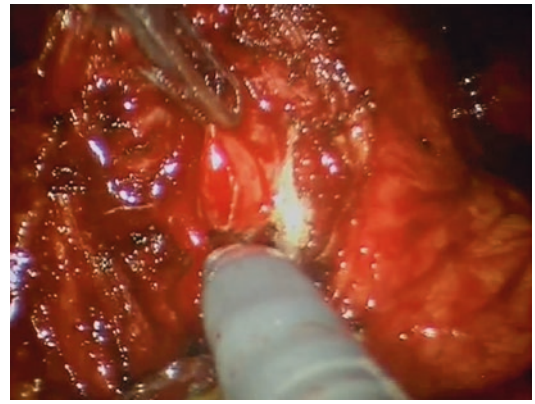

Fig. 5.30 Traction on the median lobe improves exposition

bladder neck begins again on the midline, until the catheter is identified and suspended. The lateral aspects of the detrusor are separated, while a traction is exerted with the left arm. When the median lobe becomes evident, the point of traction is changed to improve exposition (Fig. 5.30). Special attention should be given to the thickness of the posterior aspect of the bladder neck. In 2012, Coelho et al. reviewed postoperative outcomes of 1693 patients who underwent RARP performed by a single surgeon. Three hundred and twenty-three (19%) presented a median lobe (ML). The authors did not find significant differences between patients with or without ML in terms of estimated blood loss, length of hospital stay, pathologic stage, complication rates, anastomotic leakage rates, overall PSM rates, and PSM rate at the bladder neck. The median overall operative time was slightly greater in patients with ML (80 vs. 75 min, $P < 0.001$); however, there was no difference in the operative time when stratifying this result by prostate weight. Continence rates were also similar between patients with and without ML at 1 week (27.8% vs. 27%, $P = 0.870$), 4 weeks (42.3% vs. 48%, $P = 0.136$), 12 weeks (82.5% vs. 86.8%, $P = 0.107$), and 24 weeks (91.5% vs. 94.1%, $P = 0.183$) after catheter removal [27].

The bladder neck defect after TURP can create many difficulties in the dissection (Fig. 5.31). The catheter is pulled cranially and superiorly,

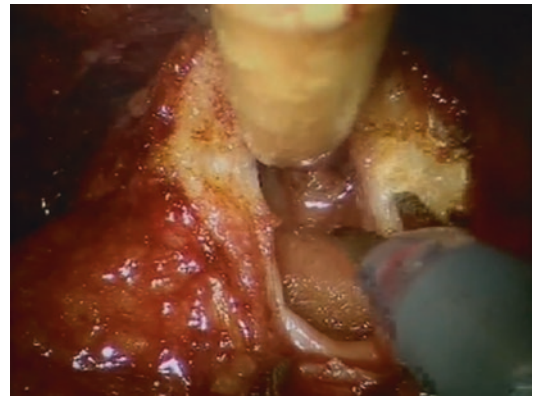

Fig. 5.31 Bladder neck defect after transurethral resection of the prostate

exposing the large defect of the bladder neck. Here it is even more important to separate the lateral aspect before dissection on the midline. The presence of scar tissue can make it more difficult to distinguish the muscular from the glandular tissue. Tugcu et al. compared 25 patients with previous history of prostatic surgery for benign prostatic hyperplasia (TURP in 20 patients and open prostatectomy in 5 patients) and 36 patients who were naïve to prostatic surgery, demonstrating significant increase in the operative time, estimated blood loss, and complication rates (40% vs. 19%) in patients with past history of prostatic surgery. However, there were no significant differences between the groups as regards the functional outcomes [28].

RARP in Obese Patients

RARP in obese patients can sometimes be a technically challenging procedure as a result of the deeper and narrower pelvis and the excess periprostatic and abdominal fat that obscure vision and reduce the robotic working space. In such patients, some precautions are required in order to overcome obesity's associated difficulties: increasing the Trendelenburg position of the table from 25° to 30° (use bean bags and gel pads to avoid sliding of the patient). Moreover, the trocar position should be modified according to the patients' habitus; thus in obese patients it should be placed more laterally and proximally to allow deeper access in the pelvis. Furthermore, changing the telescope form 30° to 0° may improve vision during the apical dissection and vesicourethral anastomosis if the pubic bone interferes in the working field, obscuring vision [29].

RARP in Patients with Small BMI and Narrow Pelvis

On the other hand, surgeons may encounter two main problems in patients with small BMI and narrow pelvis undergoing RARP: external clashing of robotic arms and narrow working space internally. These can be avoided by adjusting the distance to a minimum of 8 cm externally or using a three-arm robot with additional port for the assistants [29].

The Role of the Prostatic Vasculature as a Landmark for Nerve Sparing During Robot-Assisted Radical Prostatectomy

In 2011, Patel VR et al. performed a retrospective video analysis of 133 consecutive patients who underwent RARP with nerve sparing performed using a retrograde, antegrade, or combined approach [30].

After opening sharply the levator fascia over the prostate, they observed the presence of a distinctive prostatic artery (PA) that could be found between the midprostate and base. The artery entered the prostate on the anterolateral aspect, and it was easily recognized by its large size and tortuosity (Fig. 5.32a). Delicately developing a plane of dissection between the PA and the prostate resulted in a natural detachment of the NVB from the prostate. For a complete NS, the correct plane of dissection was recognized by the presence of pearly areolar tissue and was gently developed posteriorly following the prostatic contour until the previously created posterior plane was reached. After detaching the prostate,

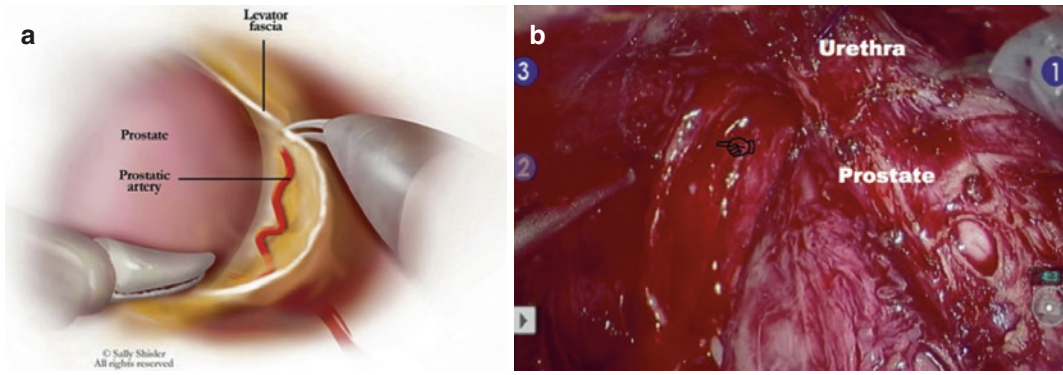

Fig. 5.32 (**a**) The prostatic artery (PA) can be recognized after opening the levator fascia on the base of the prostate. It has a large diameter and a tortuous configuration, which makes it easy to be recognized intraoperatively. It continues alongside the prostate occupying the medial aspect of the neurovascular bundle (NVB). (**b**) Complete left nerve sparing; the prostate has been detached from the NVB. Note how the pointed PA follows the course of the NVB and enters the perineum behind the urethra. (From Patel et al. [30], with permission)

it was evident that the PA was located at the most medial aspect of the NVB and followed its course down into the perineum (Fig. 5.32b).

In absence of a distinctive PA, the presence of multiple capsular arteries (CAs) was another common finding. These arteries are found on the lateral aspect of the prostate forming a mesh throughout the thickness of the NVB. The most superficial of these CAs can be recognized after opening the levator fascia over the prostate. It is located over the medial border of the NVB fat, close to the point where the fat ends over the prostate (Fig. 5.33a). In this case, the plane of dissection can be reached by delicately sweeping the plane between the CA and the prostate with the robotic scissors. This plane is less pronounced and harder to find than in the presence of a distinctive PA. A key to its identification is to follow the direction of the prostatic contour. As the dissection gets deeper between the CA and the prostate, multiple CAs can be found at different depths at the medial border of the NVB (Fig. 5.33b). The right plane of dissection is maintained by following the pearly areolar tissue between these arteries and the prostate. At the end of the dissection, the plane created will meet the previously developed posterior plane.

The authors measured the area of residual nerve tissue on the posterolateral aspect at the level of the midprostate as a way to assess the amount of nerve preservation. The area of residual nerve tissue was significantly less when the NS was performed medial to the landmark artery (LA) (median interquartile range [IQR] of 0 [0–3] mm2 vs. 14 [9–25] mm2; $p < 0.001$). The overall positive surgical margin (PSM) rate for the 133 patients was 9.02% (12 of 133), with 8.3% (9 of 108) in pT2 and 12% (3 of 25) in pT3. Side-specific PSM rate in those patients with an NS performed medial to the LA was 3.2%.

In 27% of the operated sides, the authors were not able find any LAs after opening the levator fascia over the prostate. Because the CAs are embedded in fatty tissue, an increased amount of fat in the NVB can prevent the identification of these small vessels. Although the amount of fat contained in the NVB is variable and depends on individual body habitus, a constant finding was the configuration of this fat on the prostate. The NVB fat forms an apron embedding the prostate on the posterior and lateral aspects, and a delimitation of the NVB fat lying over the prostate can usually be identified (Fig. 5.34a). The authors found that the plane of dissection between the

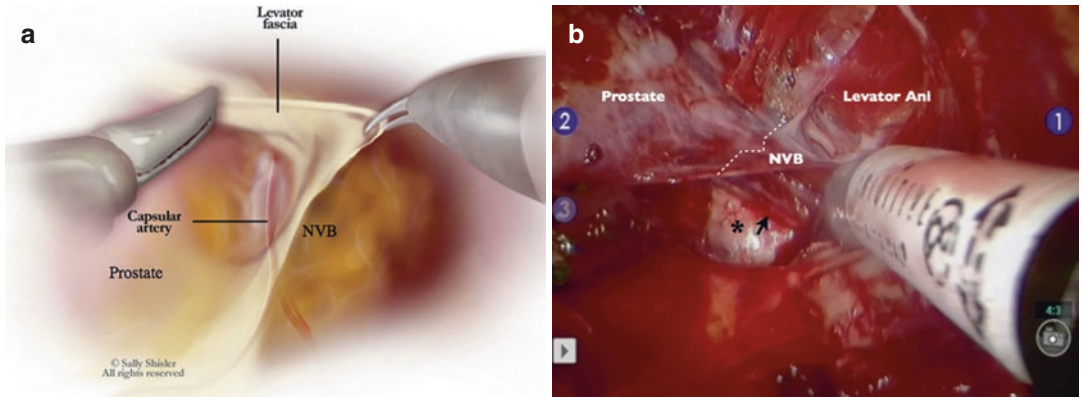

Fig. 5.33 (**a**) Capsular arteries (CAs) can be recognized after opening the levator fascia. They are found more distally than the prostatic artery (PA), at the level of the midprostate. CAs are thin, harder to identify, and do not have a tortuous configuration like the PA. They usually end in small twigs at the apex and do not perforate into the perineum. (**b**) A plane of dissection has been developed between the landmark CA and the prostate. Notice that as the dissection gets deeper, additional CAs are found along the medial aspect of the neurovascular bundle (neurovascular bundle [NVB]; *arrow*). The right plane of dissection for a complete nerve sparing is to stay on the medial aspect of the CAs, through the pearly areolar tissue between the prostate and the NVB (*asterisk*). (From Patel et al. [30], with permission)

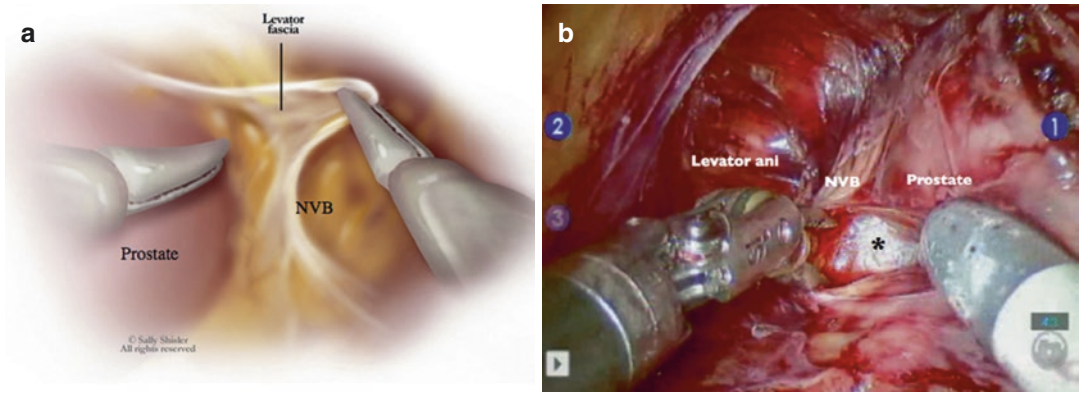

Fig. 5.34 (**a**) The point where the neurovascular bundle (NVB) fat ends on the lateral aspect of the prostate is usually evident and can be used as landmark for nerve sparing when no elements of the prostatic artery can be identified. (**b**) Development of a plane between the NVB fat and the prostate leads to a natural detachment of the prostate from the NVB at the areolar plane existing between them (*asterisk*). (From Patel et al. [30], with permission)

NVB and the prostate could be found by gently sweeping the fat at the point where it ends over the lateral border of the prostate. The plane is extended along the prostatic contour until the areolar plane is reached and dissection reaches the previously created posterior plane (Fig. 5.34b).

The description of these arteries allowed grading the amount of nerve sparing into five grades based on the amount of tissue left by the surgeon on each side [31]. Some evidence supported the hypothesis that NVB is not an all or none phenomenon and that the graded NVB sparing (partial NVB sparing) may significantly affect the postoperative erectile function [32].

In this setting, Patel et al. [33] developed the PRECE (predicting extracapsular extension), which is a side-specific statistical tool based on the combination of five clinic-pathological variables (age, PSA, clinical stage, percentage of positive cores on biopsy, and Gleason sum). This tool is capable of predicting the presence and the amount of tumor out of each prostatic lobe and provides a decision rule allowing the graded dissection outside the prostatic capsule.

Salvage RARP

Radiation therapy is one of the treatment options for prostate cancer. According to the EAU Guidelines, dose-escalated intensity-modulated radiation therapy (IMRT) is the gold standard, as it is characterized by less toxicity compared to the three-dimensional conformal radiotherapy (3D-CRT) [7].

According to the American Society for Therapeutic Radiology and Oncology (ASTRO) criteria, recurrence after RT for localized PCa can be defined by a PSA value of 2 ng/ml above the nadir after RT [34]. In this setting, more than 50% of patients will experience biochemical recurrence (BCR) within 10 years after RT for clinically localized prostate cancer [35].

Salvage RP (sRP) is characterized by good cancer control results ranging from 47% to 83% and 28% to 53% for biochemical relapse-free survival at 5 and 10 years, respectively [35]. However, sRP is technically demanding, and experienced surgeons are needed to optimize outcomes: in fact, RT-induced cystitis, fibrosis, and tissue plane obliteration can lead to significant complications such as rectal injuries, anastomotic stricture, impotence, and urinary incontinence. The da Vinci Surgical System helps the surgeon in performing salvage surgery by its 3D vision and 10× magnification, which help careful dissection [36].

According to Chen et al. [37], ideal candidates for salvage surgery should be young and healthy and have a life expectancy of >10 years. They also suggested studying these patients with cystoscopy, which can identify subtrigonal tumor

extension, and urodynamic study. In fact, men with a poorly compliant bladder or subclinical detrusor hyperreflexia are poor candidates for sRP alone: in these patients, augmentation cystoplasty should be considered.

Distant metastases are less frequent in patients who initially present with a low-risk disease (PSA <10 ng/ml, PSA velocity <2.0 ng/ml per year, biopsy Gleason score of ≤6, T1c or T2a tumor stage) [38], a time to PSA failure >3 years [39], a PSA doubling time >8–12 months [40], and a PSA level at the time of salvage therapy <10 ng/ml [41]. Thus, patients with these features are expected to achieve a better outcome from sRP.

In salvage RARP, Chauhan et al. [42] suggested assessing the integrity of the rectal wall before performing the anastomosis in a similar three-step fashion. Firstly, the rectal wall was inspected under the 10× magnification and 3D vision of the da Vinci Surgical System. Secondly, the pelvic cavity was filled with normal saline while insufflating the rectal tube (the absence of bubbles signified no major injuries). Finally, a flexible sigmoidoscope was inserted into the rectum and the robotic camera light was turned off: any transilluminance suggested a thinning of the rectal wall [42].

Ogaya-Pinies et al. [36] discussed the oncological and functional outcomes of salvage RARP in 96 patients after RT or ablative techniques, demonstrating a median operative time, median estimated blood loss, median catheterization time, and median length of hospital stay were 125 minutes, 100 ml, 12 days, and 1 day, respectively. Nerve-sparing approach either partial or complete was possible in 85 patients (88.6%). PSMs were reported in 16 patients (16.7%). The authors reported 22 minor complications (Clavien grades I–II), including: urinary tract infection (4 patients), epididymitis (1 patient), postoperative bleeding (2 patients), acute urinary retention (2 patients), and urinary leak treated by prolonged catheterization (12 patients). Furthermore, there were four major complications (Clavien grades III–IV), including: urinary leakage that required re-catheterization (2 patients), one patient who suffered myocardial infarction, and one patient who developed lymphocele. At 12-month follow-up, 55 patients (57.3%) were completely continent, 25 patients (26%) used 1–2 pads/day, and 16 patients (16.7%) used ≥3pads/day, while only 17 (17.7%) out of 31 preoperatively potent patients remained potent postoperatively. At a limited follow-up of 14 months, 81 patients (84.38%) were BCR-free 12 months after sRARP.

In 2016 a review article included 10 case series with 197 men who had undergone sRARP following different modalities of radiotherapy; the authors demonstrated a mean operative time, EBL, catheter time, and hospitalization of 178.8 minutes, 153 ml, 11.7 days, and 2.3 days, respectively. Furthermore, continence was reported in 60.4% at a mean follow-up period of 18.6 months, and potency was demonstrated in 26%. Overall, 31 major complications (Clavien > II) were reported among all series. The authors concluded that sRARP is becoming increasingly acceptable; however, the patient should be counseled about the potential functional outcomes and complications [43]. Furthermore, there is some evidence to support that NVB sparing during sRARP is feasible and safe in selected patients, providing better recovery of potency; however, it should be performed by highly experienced surgeons [44].

Clinical Practice

Comparison Between RRP, LRP, and RARP

In 2010, Coelho et al. compared available evidences for RRP, LRP, and RARP provided by high-volume centers, identifying published series of 250 patients or more [45]. This review was conducted to compare perioperative, functional, and oncological outcomes of the three approaches in the absence of randomized trials.

The weighted means for operative time were 165 min (range 131–204 min) for RRP, 162.6 min (130–236 min) for the RARP series, and 205 min (100–266 min) for the LRP series. The mean estimated blood loss (EBL) for RRP, LRP, and RARP was 951, 291.5, and 164.2 ml, respectively. The

mean intraoperative and postoperative RRP transfusion rates for RRP, LRP, and RARP were 20.1%, 3.5%, and 1.4%, respectively. In terms of hospital stay, RP series account for a weighted mean of 3.48 days; the mean hospital stay for LRP and RARP was 4.87 and 1.43 days, respectively.

The weighted mean postoperative complication rates for RRP, LRP, and RARP were 10.3% (range of means 4.8–26.9%), 10.98% (range of means 8.9–27.7%), and 10.3% (range of means 4.3–15.7%), respectively. The mean open conversion rate for RARP was 0.34% (range of means 0–1.6%) and for LRP was 1.76% (range of means 0–2.4%). The pathologic stage in the RARP series was of 78.2% pT2 tumors and 20.5% pT3 tumors. LRPs were performed on 64% pT2 and 32.6% pT3 tumors and RRPs on 64.3% pT2 and 31.5% pT3 tumors. RARP revealed a mean overall PSM rate of 13.6%, whereas LRP and RRP yielded a PSM of 21.3% and 24%, respectively. The mean PSM rate for pT2 and pT3 tumors in the RARP series was 9.6% and 37.1%, respectively; in the open series, it was 16.8% and 42%, respectively; and in the LRP series, it was 12.4% and 39.2%, respectively.

In this study, the definition of continence adopted to collect the data from the studies was the use of no absorbent pads or the use of one pad only for security. The weighted mean continence rates at 12 months of follow-up for RRP, LRP, and RARP were 79, 84.8, and 92%, respectively.

The weighted mean potency rates for patients who underwent RRP with unilateral or bilateral nerve sparing, at 12 months of follow-up, were 43.1% and 60.6%, respectively. The LRP weighted mean potency rates for patients who received unilateral and bilateral nerve-sparing procedures, at 12 months of follow-up, were 31.1% and 54%, respectively; finally, RARP patients who received unilateral and bilateral nerve-sparing procedures had potency rates, at 12 months of follow-up, of 59.9% and 93.5%, respectively.

In conclusion, the authors found that LRP and RARP were associated with decreased operative blood loss and decreased risk of transfusion when compared with RRP. Lower weighted mean PSM rates and higher continence and potency rates were observed after RARP compared with RRP and LRP.

In 2018 another systematic review and meta-analysis of 33 studies comparing the perioperative, oncological, and functional outcomes between RARP, LRP, and RRP demonstrated that RARP was associated with significantly lower EBL and transfusion rates compared to LRP and RRP; however, operative time and PSM were significantly lower in RARP compared to LRP but not to RRP. As regards the functional outcomes, RARP was associated with significantly higher continence and potency rates than LRP and RRP [46].

Tang et al. performed a meta-analysis of 78 studies comparing RARP and RRP, showing that RARP had a significantly longer operative time but less EBL, transfusion rates, PSM, and shorter hospitalization. Furthermore, overall complication rate was lower with RARP than with RRP. No significant difference between the two approaches was reported as regards the continence rates at 3 and 12 months, while potency recovery rate was significantly higher with RARP at 3 and 12 months. Moreover, BCR-free survival was higher and readmission rate was lower in RARP patients [47].

Best Practice Recommendations for RARP: The Pasadena Consensus Panel

In 2012, a consensus conference of 17 world leaders in prostate cancer and radical prostatectomy was organized in Pasadena, California, and at the City of Hope Cancer Center, Duarte, California, under the auspices of the European Association of Urology Robotic Urology Section to systematically review the currently available data on RARP, to critically assess current surgical techniques, and to generate best practice recommendations to guide clinicians and related medical personnel [22].

The Pasadena Consensus Panel (PCP) [22] confirmed the indications for RARP, identical to those accepted for RRP and for LRP. Furthermore,

the PCP identified some patients subgroups who should be treated by an "experienced" surgeon, such as obese patients (body mass index [BMI] >30), patients with prostate volume >70 cm3, patients with previous TURP or other surgery for BPH, patients with large median lobe, high-risk patients requiring extended pelvic lymph node dissection, and patients with previous pelvic surgery. Only very experienced surgeons should perform salvage RARP after radiation therapy, cryotherapy, or high-intensity focused ultrasound (HIFU) [36].

Considering deeper insights into the distribution and course of the cavernous nerves, which in recent years have allowed clinicians to increase their knowledge about prostate anatomy and specifically about the network of nerves surrounding the prostate, seminal vesicles, and urethral sphincter [18], the PCP reviewed indications for nerve-sparing surgery.

A maximum preservation of cavernous nerves (CNs) (full nerve sparing) can be obtained by following the plane between the prostatic capsule and the multilayer tissue of the prostatic fascia. This kind of nerve sparing is recommended for sexually active and functional men without comorbidities and limited-risk disease. Partial nerve sparing, obtained following the planes within the multilayer tissue of the prostatic fascia, is recommended for preoperative potent men without comorbidities and intermediate- or high-risk localized disease, while patients with erectile dysfunction and/or comorbidities, or not interested in sexual activity, should undergo minimal nerve sparing; that is, the preservation of CNs running at the posterolateral surface of the prostate. When the disease is clearly extraprostatic, patients should undergo a non-nerve-sparing surgery [22].

Regarding PLND, the PCP agreed that a bilateral extended PLND is indicated for intermediate- and high-risk patients. A PLND should be considered optional in low-risk patients (D'Amico criteria [48] or N+ risk <3% according to available nomograms).

Concerning the patient preparation, the PCP gave the following indications: ≥4–6 weeks should pass from biopsy to surgery; it is standard procedure to advise patients to stop taking all anticoagulants a week before surgery, although some emerging evidence suggests that allowing continued low-dose nonsteroidal anti-inflammatory drugs or aspirin is not associated with the occurrence of bleeding events and could be beneficial in preventing serious adverse cardiac thrombotic events; early mobilization and mechanical venous thromboembolism (VTE) prophylaxis are advised in patients without risk factors, while patients with increased risk of VTE should be treated with low molecular weight heparin (LMWH) until the patient is no longer at increased risk of VTE (generally 5–7 days) or prolonged for a longer period (28 days after surgery), especially for very-high-risk patients (e.g., previous VTE); antibiotic prophylaxis (a single perioperative course) using second- or third-generation cephalosporin is recommended.

The PCP discussed the application of RARP to patients with high-risk PCa. The available studies suggest that RARP is a feasible option for men with high-risk PCa and can achieve equivalent oncologic and functional outcomes compared with RRP. Several studies have challenged the use of RARP in high-risk patients, suggesting that complication and positive margin rates are too high; however, the PCP agreed that the findings could reflect early experience with robotic technology and surgeons who are still on their learning curve.

Outcomes of RARP

Perioperative Outcomes and Complications

Perioperative complications are a major surgical outcome for radical RARP. In 2012, Novara et al. published a systematic review and meta-analysis whose aim was to evaluate complication rates following RARP, risk factors for complications after RARP, and surgical techniques to improve complication rates after RARP. A cumulative analysis of all studies comparing RARP with RRP or LRP in terms of perioperative complications was also performed [25].

Between the factors which could affect perioperative outcomes of RARP, higher BMI resulted to be related to longer operative time; higher prostate volume was associated with longer operative time, higher blood loss, longer catheterization time, and slightly longer in-hospital stay; prior BPH surgery was associated with longer operative time; and the presence of median lobe was associated with longer operative time and higher blood loss.

Perioperative outcomes were not affected by the adoption of the transperitoneal approach compared with the extraperitoneal approach, by preservation of the bladder neck, or by the adoption of interfascial dissection of the neurovascular bundle.

The mean complication rate of RARP is 9% (range, 3–26%). Main complications are summarized in Table 5.1. Prostate volume and number of cases performed are independent predictors of the occurrence of complications of any grade, whereas the number of cases performed is an independent predictor of high-grade complications. Preoperative PSA and presence of cardiac comorbidity are independent predictors of medical complications of any grade, whereas age, biopsy GS, presence of hyperlipidemia, and gastroesophageal reflux disease are associated with surgical complications of any grade [49].

Comparison of RARP with RRP and LRP approach showed that blood loss and transfusion rate are lower in RARP than in RRP, whereas only transfusion rate is lower in RARP than in LRP. All the other parameters are similar, regardless of the surgical approach [25].

In 2016, Pucheril et al. [50] performed a systematic review addressing the peri- and postoperative complication of RARP and providing clinically based evidence on how to avoid and manage RARP complications. This review included 37 studies and demonstrated an overall median complication rate of 12.6% (range 3.1–42%), most of which were minor complications (Clavien-Dindo grades 1 and 2). Main complications reported in this review are summarized in Table 5.2 [50]. In conclusion, the authors concluded that RARP is a safe procedure with low overall complication rates.

Table 5.1 Mean complication rates after RARP

Complication	Rate (%)
Blood transfusion	2.0
Lymphocele/lymphorrhea	3.1
Urine leak	1.8
Reoperation	1.6

Oncologic Outcomes

Long-term data regarding BCR of PCa after RARP are sparse and inconsistent. This can be explained by the stage migration of prostate cancer in the era of PSA screening, which rendered the BCR rates in the clinical practice unclear [51]. Diaz et al. [52] studied the 10-year oncological outcomes after RARP in 483 clinically localized PCa patients, showing 73.1% (95% CI 68.3–77.8), 97.5% (95% CI 96.0–99.1), and 98.8% (95% CI 97.7–99.9) for the BCR-free survival, the metastasis-free survival (MFS), and the cancer-specific survival (CSS), respectively. The main predictive variables for the BCR-free survival were the Gleason score and preoperative PSA or the equivalent D'Amico groups. Of the patients with BCR, 68.5% received salvage therapy.

Sukumar et al. [51] reported RARP long-term oncological outcomes in one of the largest cohorts published (4803 patients). In this cohort, pathological Gleason score ≥3 + 4 and patients with ≥pT3a were found in 67.5% and 34.4%, respectively. BCR was stated in 9.8% of patients, of which 6.6% developed distant metastasis. The 8-year BCR-free survival, MFS, and CSS were 81%, 98.5%, and 99.1%, respectively; however, in patients with nodal metastasis the 5-year BCR-free survival, MFS, and CSS were 26.3%, 77.7%, and 96.1%, respectively.

Recently, Wang et al. [53] published a meta-analysis of the 5-year and 10-year oncological outcomes after RARP, comparing it to RRP. The meta-analysis included 20 studies with 19,954 patients who underwent RARP and 938 patients who underwent open radical prostatectomy. The pooled 5-year BCR-free survival and CSS after RARP were 80% (95% CI 0.77–0.82) and 97%

Table 5.2 Main complication rates after RARP according to Pucheril et al. [50]

	Rate range (%)	Avoidance and management
Intraoperative complications		
Robotic malfunction	0.2–0.4	Routine maintenance of robotic systems
Access-related complications	0.03–0.2	Thorough review of patients' history and examination
Neurapraxia	0.1–3.4	Proper positioning of the patient
Corneal abrasions	0.1–0.6	Using transparent occlusive eye dressing instead of taping the eyes
Ureteral injury	0.06–0.9	Management depends on location and severity
Rectal injuries	0.1–2.2	Wait 4–6 weeks after biopsy to perform RARP to allow the inflammation to subside
Postoperative complications		
Small bowel obstruction	0.1–4.2	Management depends on severity
Pelvic hematoma	0.9–2.4	Meticulous dissection and hemostasis
Lymphocele	0.1–30.9	Use bipolar energy and careful use of clips while performing the lymph node dissection
Deep venous thrombosis and pulmonary embolism	0.2–2.5	Pneumatic compression devices and early ambulation
Urine anastomotic leak	0.5–5	Proper training and adherence to anastomotic principles
Port-site hernia	0–7	Transverse incision and interrupted closure of midline fascia in patients with larger prostates
Bladder neck contracture	0.3–3.2	Avoid Hem-o-Lok clip use around the urethrovesical anastomosis and suprapubic catheter drainage may be considered
Urinary retention	0.3–8	NA
Urinary tract infection	0.2–5.1	NA
Transfusion	1–17	NA
Wound complications	0.1–2.5	NA
Ileus	0.1–3.6	NA
Metal stenosis	0.1–1.6	NA
Urethral stricture	0.3–0.4	NA
Reoperation	0.3–3.2	NA
Myocardial infarction	0.1–0.4	NA
Mortality	0–0.4	NA

RARP robot-assisted radical prostatectomy

(95% CI 0.96–0.98), respectively; however, it is worth mentioning that there was high heterogeneity between the studies in calculating the BCR-free survival but not the CSS. Furthermore, the pooled 10-year BCR-free survival after RARP from five studies with 11,408 patients was 79%; however, high heterogeneity between studies was reported. As regards the comparison with open radical prostatectomy, the pooled 5-year BCR-free survival was significantly higher in patients undergoing RARP; however, the pooled 10-year BCR-free survival and the pooled 5-year CSS showed no significant difference between both approaches.

More data are available on other outcomes that can be considered surrogates for oncologic control (e.g., positive surgical margin [PSM] rates). PSMs defined as tumor at the inked margin of the prostatectomy specimen are a risk factor for disease progression after surgery [54]. The impact of PSMs on cancer-related outcome has been studied extensively; yet, the association between PSMs and cancer-specific mortality is still a matter of debate. Recently, Zhang et al. [54] demonstrated in a meta-analysis of 32 cohort studies including 141,222 subjects that PSMs were significantly associated with greater risk of cancer-specific mortality (hazard ratio = 1.23, p value <0.001) and overall mortality (hazard ratio = 1.09, p value = 0.009).

A systematic review by Novara et al. [25] evaluated oncologic outcomes after RARP in

terms of lymph node yield, PSMs, use of adjuvant therapy, and BCR-free survival. This systematic review revealed that extended lymph node dissection yielding a reasonably high number of lymph nodes is feasible during RARP.

The mean PSM rate reported was 9% in pT2 diseases, 37% in pT3, and 50% in pT4. The authors found that the most relevant predictors of PSMs are tumor features (e.g., PSA, pT stage, Gleason score, and prostate volume), surgeon-related characteristics (e.g., caseload, type of RARP training, and prior surgical experience), or procedure-related issues (e.g., type of nerve-sparing approach, technique for dorsal venous complex control). Much evidence suggests that PSMs in pT2 disease are, for the most part, iatrogenic and hence potentially avoidable [55]. Furthermore, based on a recent systematic review, RARP is associated with lower risk of PSMs compared to RRP (risk difference, -0.04; *p* value = 0.02) [56].

Very few data are available on the use of adjuvant therapies; this could mean that a limited number of patients received such treatments following RARP; on the other hand, the use of adjuvant therapies might depend on patient selection and indications that are affected by local practice [25].

All the cumulative analyses performed by Novara et al. [25], comparing RARP with RRP and LRP, demonstrated similar PSM rates and BCR-free survival estimates, regardless of the surgical approach.

Continence Outcomes

Urinary incontinence is among the most stressing drawbacks of RP regardless of the surgical approach [57]. The International Continence Society defined incontinence as "the complaint of any involuntary leakage of urine" [58]. Stress incontinence is the most frequently observed type of incontinence after radical prostatectomy, even if a considerable number of patients present a mixed urge and stress syndrome.

Sphincter dysfunction is mainly a result of injury to the sphincter mechanism during prostatic surgery; considering this mechanism, incontinence is usually associated with abdominal pressure increase. In the most severe cases, it can be gravitational [59].

In 2012, Ficarra et al. [57] performed a systematic review evaluating prevalence and risk factors for urinary incontinence after RARP and comparing RARP versus RRP or LRP in terms of the urinary continence recovery rate.

In this study, 12 months' urinary incontinence rates (using no pad as the continence definition) ranged from 4% to 31%, with a mean value of 16%. Methodological aspects (like continence definitions, tools used for data collection, different follow-up intervals) can influence the prevalence of urinary incontinence after RARP.

The authors found that the most relevant preoperative predictors of urinary incontinence after RARP were patient age, BMI, comorbidity index, lower urinary tract symptoms, and prostate volume. Puboprostatic-sparing techniques, bladder neck preservation, selective dorsal venous complex division, nerve-sparing technique, and posterior musculofascial and anterior reconstruction were identified as surgical aspects potentially able to reduce the risk of urinary continence after RARP. However, only a few comparative studies analyzed the impact of some of these surgical aspects on urinary continence recovery. In their cumulative analyses, Ficarra et al. demonstrated a statistically significant advantage in favor of RARP in comparison with RRP and LRP in terms of 12 months' urinary continence recovery (Fig. 5.35).

Haglind et al. [60] compared the continence outcomes after RARP (1847 patients) and RRP (778 patients) in a prospective, nonrandomized trial. The primary endpoint was to evaluate the presence of incontinence (defined as the change of pad at least once per 24 hours). The authors reported incontinence rates of 21.3% and 20.2% in RARP and RRP, respectively. They found no significant difference between the two approaches after adjustment for possible confounders.

Recently, Grabbert et al. [61] reported a post-prostatectomy continence rate of 53% (using the definition of no pads per day) and 77% (one safety pad per day) at 12-month follow-up regardless of the surgical approach (RARP or RRP).

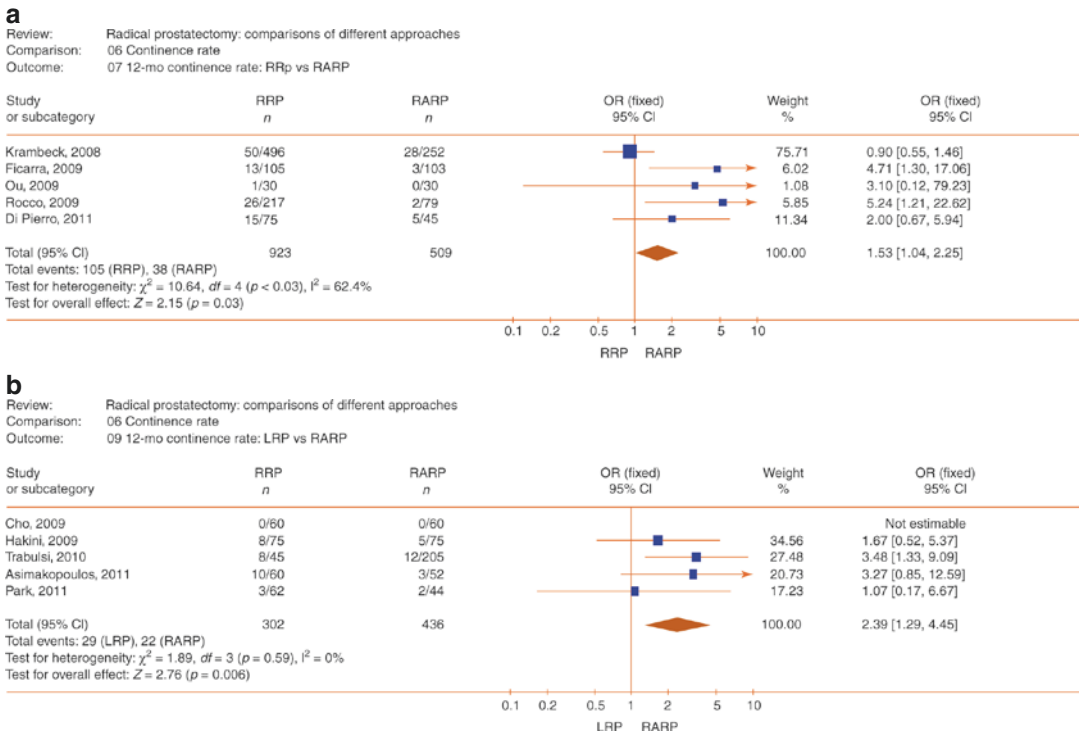

Fig. 5.35 (**a**) Cumulative analysis of studies comparing robot-assisted radical prostatectomy versus retropubic radical prostatectomy in terms of 12 months' urinary continence recovery. (**b**) Cumulative analysis of the studies comparing robot-assisted radical prostatectomy versus laparoscopic radical prostatectomy in terms of 12 months' urinary continence recovery. CI confidence interval, LRP laparoscopic radical prostatectomy, OR odds ratio, RARP robot-assisted radical prostatectomy. (From Ficarra et al. [57], with permission)

Moreover, they reported no statistically significant impact of the surgical approach (RARP and RRP) on the continence rates at 3 months, 12 months, 24 months, and 36 months (p-value = 0.052, 0.389, 0.183, 0.879, respectively). On the other hand, a recent Cochrane review stated that RARP might provide little to no difference in the urinary quality of life as compared to RRP [62].

Potency Outcomes

The neurovascular bundles (NVBs) were first described in 1982 by Walsh and Donker. These authors demonstrated that erectile dysfunction following RP occurred secondary to injury to the cavernosal nerves (CNs), a group of parasympathetic nerves originating from the pelvic plexus and running together with arteries and veins (capsular vessels of the prostate) on a prominent NVB on the posterolateral aspect of the prostate and eventually ending in the corpus cavernosum of the penis [63].

Further studies about the distribution of nerves within the NVB demonstrated that these nerves are organized into three functional compartments, in which the CNs are located on the anteromedial aspect of the NVB closest to the prostate. Other nerves within the NVB located laterally and inferiorly to the CN innervate the levator muscle and rectum, respectively [31, 64].

A recent systematic review of the literature by Ficarra et al. [65] reported that nerve-sparing RARP was associated with an incidence of 12- and 24-month erectile dysfunction ranging from 10% to 46% and from 6% to 37%, respectively. These widely different rates of erectile dysfunction are attributable especially to the different definitions of erectile dysfunction.

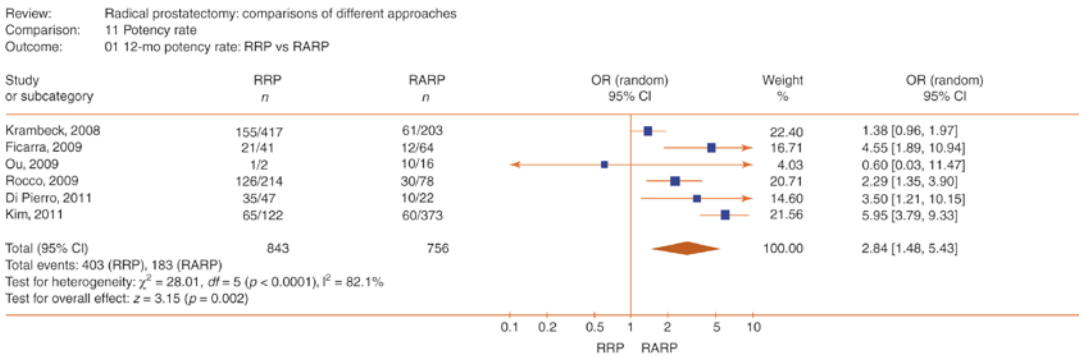

Fig. 5.36 Cumulative analyses of 12 months' potency rates following robot-assisted radical prostatectomy or retropubic radical prostatectomy. CI confidence interval, OR odds ratio, RARP robot-assisted radical prostatectomy, RRP retropubic radical prostatectomy. (From Ficarra et al. [65], with permission)

This systematic review showed that for patients who underwent RARP, relevant predictors of outcome are age at surgery, baseline erectile function, presence of comorbidities, extension of the nerve-sparing procedure, and use of athermal or thermal dissection.

Concerning the comparison between RARP and RRP, this study demonstrated, for the first time, a significant advantage in favor of RARP in comparison with RRP in terms of 12 months' potency rates (Fig. 5.36).

Recently, a Cochrane review showed that RARP might probably provide little to no difference in the sexual quality of life as compared to RRP [62].

The Concepts of "Trifecta" and "Pentafecta"

Widespread prostate-specific antigen (PSA) screening and the consequent diagnosis of prostate cancer in younger and healthier men with organ-confined disease have underlined the importance of urinary and sexual function recovery after surgery [3]. The term "trifecta" was adopted to describe combined oncological, continence, and potency outcomes in 2004, at the Challenges in Laparoscopy Conference, in Rome, and at the Evolving Strategies in Prostate Cancer Meeting in New York in September 2005 [66].

In 2011, Patel VR et al. reported a new concept for reporting outcomes of RARP: the "pentafecta" [67]. In addition to the traditional trifecta outcomes, two perioperative variables were included in the pentafecta: no postoperative complications and negative surgical margins. The idea of this new method for reporting outcomes of RARP came from the consideration that perioperative complications can affect the satisfaction with the procedure even in patients who would later achieve the trifecta.

Novelties in RARP

Enhanced Recovery After Surgery (ERAS)

ERAS is a multidisciplinary approach to the patient's care involving healthcare personnel from different specialties (surgeons, anesthesiologists, nurses, dieticians, etc.) throughout the patient's pathway in the hospital, including clinics, preoperative units, the operation room, recovery unit, and the ward. It was first developed in 2001 for gastrointestinal surgeries. The main aim of ERAS is to reduce the perioperative and postoperative complications and duration of hospital stay and to boost easier recovery and earlier return to normal activity while maintaining the quality of surgery [68].

The EAU Robotic Urology Section (ERUS) meeting of 2018, held in Marseille, France, discussed the implementation of the ERAS protocol in urologic surgeries, and the working group on

ERAS released a protocol for its application in the hospital. The protocol is based on three main concepts: minimally invasive surgery, standardized clinical pathway, and patient integration in every step of the process of care. The protocol is available at http://erus18.uroweb.org/wp-content/uploads/ERAS-Protocol-070718.pdf.

Nazzani et al. [69] showed that the duration of hospital stay following nine major surgeries (including prostatectomy) has significantly decreased over time since the introduction of ERAS protocol with subsequent decrease in total hospital charges. Furthermore, Sugi et al. [70] performed the only study using ERAS during RARP, comparing 123 patients who underwent RARP with conventional care and 75 patients who underwent RARP with ERAS protocol, reporting significantly shorter time to first defecation in the ERAS group ($p = 0.006$); however, the duration of hospital stay was not significantly different between the groups.

"Real Time" Pathological Examination of Specimens

Cancer-free surgical margins are among the critical points determining the quality of surgery, as PSMs are associated with increased risk of disease recurrence and cost of management. Furthermore, there is a great variability among surgeons and institutions in the rates of PSMs despite recent improvements in surgical techniques and diagnoses [54]. Intraoperative detection of PSMs during RARP is of great interest, especially in patients undergoing NVB-sparing approach, to provide the delicate balance between functional outcomes and oncological radicality [71].

Several options have been proposed for the intraoperative detection of PSMs, among which NeuroSAFE is the most established and studied technique. NeuroSAFE stands for neurovascular structure-adjacent frozen-section examination and it has proved to be a valid tool for detection of PSM during nerve-sparing RARP. It was applied on 1040 patients, resulting in a significant improvement in the rate of NVB technique from 81% to 97%with simultaneous reduction in the rate of PSMs from 24% to 16% [72].

Another new technology that was introduced during the EAU Section of Uro-Technology (ESUT) meeting 2018, held in Modena, Italy, is RARP with the intraoperative integrated 3D model of the results of the PRECE nomogram with real-time Cellvizio scan and ex vivo fluorescence and reflectance confocal microscopy (FCM) [73, 74]. This technology has not yet been introduced into clinical practice, as further studies are required to confirm its added value to the current clinical practice; however, it seems to be a promising alternative to the current available tools. Cellvizio is a confocal laser endomicroscopy that allows in vivo "real-time" examination of tissues, while the FCM is an ex vivo optical microscopy that is capable of analyzing fresh specimens with a histopathological-like resolution and 91% diagnostic accuracy for prostatic tissue examination when compared to histopathology [75].

Dehydrated Human Amnion/Chorion Membrane (dHACM)

The introduction of robotic surgery in the field of PCa resulted in improved and precise dissection of the NVB with subsequent improvement in the quality of NVB sparing; however, a delay in the recovery of potency persists. This may be explained by the stretch injury of the NVB and other traumas (dissection, traction, and thermal injury) during RARP, resulting in neuropraxia. In these setting the use of growth factors and anti-inflammatory substances such as dHACM may improve the recovery of potency by slowing down or preventing the inflammatory reaction of the tissues [76]. In 2017 Ogaya-Pinies et al. compared 235 patients who underwent RARP with bilateral placement of dHACM with 705 patients who underwent RARP without placement of dHACM, reporting a significantly lower time to potency recovery in the dHACM group vs. the control group (2.37 months vs. 3.94 months, $p<0.0001$). Furthermore, the analysis showed significantly lower time to potency in patients with partial nerve sparing and dHACM versus patients with partial nerve sparing and no dHACM (3.05 months vs. 3.92 months, $p = 0.021$) [76].

References

1. Babbar P, Hemal AK. Robot-assisted urologic surgery in 2010 - Advancements and future outlook. Urol Ann. 2011;3(1):1–7.
2. Piechaud P. State of the art: urologic surgery. J Visc Surg. 2011;148(5. Suppl):e27–9.
3. Patel VR, Coelho RF, Chauhan S, Orvieto MA, Palmer KJ, Rocco B, et al. Continence, potency and oncological outcomes after robotic-assisted radical prostatectomy: early trifecta results of a high-volume surgeon. BJU Int. 2010;106(5):696–702.
4. Binder J, Kramer W. Robotically-assisted laparoscopic radical prostatectomy. BJU Int. 2001;87(4):408–10.
5. Wagner C, Srougi V, Sanchez-Salas R. Getting ready for the first robotic prostatectomy, from basics to real practice. Curr Opin Urol. 2017;27(4):323–9.
6. Sanda MG, Cadeddu JA, Kirkby E, Chen RC, Crispino T, Fontanarosa J, et al. Clinically localized prostate cancer: AUA/ASTRO/SUO guideline. Part II: recommended approaches and details of specific care options. J Urol. 2018;199(4):990–7.
7. Mottet N, Bellmunt J, Bolla M, Briers E, Cumberbatch MG, De Santis M, et al. EAU-ESTRO-SIOG guidelines on prostate cancer. Part 1: screening, diagnosis, and local treatment with curative intent. Eur Urol. 2017;71(4):618–29.
8. Patel VR, Shah KK, Thaly RK, Lavery H. Robotic-assisted laparoscopic radical prostatectomy: the Ohio State University technique. J Robot Surg. 2007;1(1):51–9.
9. Guillonneau B, Vallancien G. Laparoscopic radical prostatectomy: the Montsouris technique. J Urol. 2000;163(6):1643–9.
10. Pasticier G, Rietbergen JB, Guillonneau B, Fromont G, Menon M, Vallancien G. Robotically assisted laparoscopic radical prostatectomy: feasibility study in men. Eur Urol. 2001;40(1):70–4.
11. Van Velthoven RF, Ahlering TE, Peltier A, Skarecky DW, Clayman RV. Technique for laparoscopic running urethrovesical anastomosis: the single knot method. Urology. 2003;61(4):699–702.
12. Patel VR, Coelho RF, Palmer KJ, Rocco B. Periurethral suspension stitch during robot-assisted laparoscopic radical prostatectomy: description of the technique and continence outcomes. Eur Urol. 2009;56(3):472–8.
13. Lin VC, Coughlin G, Savamedi S, Palmer KJ, Coelho RF, Patel VR. Modified transverse plication for bladder neck reconstruction during robotic-assisted laparoscopic prostatectomy. BJU Int. 2009;104(6):878–81.
14. Rocco F, Carmignani L, Acquati P, Gadda F, Dell'Orto P, Rocco B, et al. Restoration of posterior aspect of rhabdosphincter shortens continence time after radical retropubic prostatectomy. J Urol. 2006;175(6):2201–6.
15. Rocco B, Gregori A, Stener S, Santoro L, Bozzola A, Galli S, et al. Posterior reconstruction of the rhabdosphincter allows a rapid recovery of continence after transperitoneal videolaparoscopic radical prostatectomy. Eur Urol. 2007;51(4):996–1003.
16. Coughlin G, Dangle PP, Patil NN, Palmer KJ, Woolard J, Jensen C, et al. Surgery illustrated--focus on details. Modified posterior reconstruction of the rhabdosphincter: application to robotic-assisted laparoscopic prostatectomy. BJU Int. 2008;102(10):1482–5.
17. Coelho RF, Chauhan S, Orvieto MA, Sivaraman A, Palmer KJ, Coughlin G, et al. Influence of modified posterior reconstruction of the rhabdosphincter on early recovery of continence and anastomotic leakage rates after robot-assisted radical prostatectomy. Eur Urol. 2011;59(1):72–80.
18. Walz J, Burnett AL, Costello AJ, Eastham JA, Graefen M, Guillonneau B, et al. A critical analysis of the current knowledge of surgical anatomy related to optimization of cancer control and preservation of continence and erection in candidates for radical prostatectomy. Eur Urol. 2010;57(2):179–92.
19. Grasso AA, Mistretta FA, Sandri M, Cozzi G, De Lorenzis E, Rosso M, et al. Posterior musculofascial reconstruction after radical prostatectomy: an updated systematic review and a meta-analysis. BJU Int. 2016;118(1):20–34.
20. Mattei A, Fuechsel FG, Bhatta Dhar N, Warncke SH, Thalmann GN, Krause T, et al. The template of the primary lymphatic landing sites of the prostate should be revisited: results of a multimodality mapping study. Eur Urol. 2008;53(1):118–25.
21. Fossati N, Willemse PM, Van den Broeck T, van den Bergh RCN, Yuan CY, Briers E, et al. The benefits and harms of different extents of lymph node dissection during radical prostatectomy for prostate cancer: a systematic review. Eur Urol. 2017;72(1):84–109.
22. Montorsi F, Wilson TG, Rosen RC, Ahlering TE, Artibani W, Carroll PR, et al. Best practices in robot-assisted radical prostatectomy: recommendations of the Pasadena Consensus Panel. Eur Urol. 2012;62(3):368–81.
23. Gandaglia G, De Lorenzis E, Novara G, Fossati N, De Groote R, Dovey Z, et al. Robot-assisted radical prostatectomy and extended pelvic lymph node dissection in patients with locally-advanced prostate cancer. Eur Urol. 2017;71(2):249–56.
24. Menon M, Shrivastava A, Bhandari M, Satyanarayana R, Siva S, Agarwal PK. Vattikuti Institute prostatectomy: technical modifications in 2009. Eur Urol. 2009;56(1):89–96.
25. Novara G, Ficarra V, Mocellin S, Ahlering TE, Carroll PR, Graefen M, et al. Systematic review and meta-analysis of studies reporting oncologic outcome after robot-assisted radical prostatectomy. Eur Urol. 2012;62(3):382–404.
26. Chung JS, Kim WT, Ham WS, Yu HS, Chae Y, Chung SH, et al. Comparison of oncological results, functional outcomes, and complications for transperitoneal versus extraperitoneal robot-assisted radical prostatectomy: a single surgeon's experience. J Endourol. 2011;25(5):787–92.

27. Coelho RF, Chauhan S, Guglielmetti GB, Orvieto MA, Sivaraman A, Palmer KJ, et al. Does the presence of median lobe affect outcomes of robot-assisted laparoscopic radical prostatectomy? J Endourol. 2012;26(3):264–70.
28. Tugcu V, Atar A, Sahin S, Kargi T, Gokhan Seker K, IlkerComez Y, et al. Robot-assisted radical prostatectomy after previous prostate surgery. JSLS. 2015;19(4):e2015.00080.
29. Samavedi S, Abdul-Muhsin H, Pigilam S, Sivaraman A, Patel VR. Handling difficult anastomosis. Tips and tricks in obese patients and narrow pelvis. Indian J Urol. 2014;30(4):418–22.
30. Patel VR, Schatloff O, Chauhan S, Sivaraman A, Valero R, Coelho RF, et al. The role of the prostatic vasculature as a landmark for nerve sparing during robot-assisted radical prostatectomy. Eur Urol. 2012;61(3):571–6.
31. Schatloff O, Chauhan S, Sivaraman A, Kameh D, Palmer KJ, Patel VR. Anatomic grading of nerve sparing during robot-assisted radical prostatectomy. Eur Urol. 2012;61(4):796–802.
32. Moskovic DJ, Alphs H, Nelson CJ, Rabbani F, Eastham J, Touijer K, et al. Subjective characterization of nerve sparing predicts recovery of erectile function after radical prostatectomy: defining the utility of a nerve sparing grading system. J Sex Med. 2011;8(1):255–60.
33. Patel V, Sandri M, Grasso AAC, De Lorenzis E, Palmisano F, Albo G, et al. A Novel Tool for predicting extracapsular extension during graded partial nerve sparing in radical prostatectomy. BJU Int. 2018;121(3):373–82.
34. Roach M 3rd, Hanks G, Thames H Jr, Schellhammer P, Shipley WU, Sokol GH, et al. Defining biochemical failure following radiotherapy with or without hormonal therapy in men with clinically localized prostate cancer: recommendations of the RTOG-ASTRO Phoenix Consensus Conference. Int J Radiat Oncol Biol Phys. 2006;65(4):965–74.
35. Hennequin C, Hannoun-Levi JM, Rozet F. Management of local relapse after prostate cancer radiotherapy: surgery or radiotherapy? Cancer Radiother. 2017;21(6–7):433–6.
36. Ogaya-Pinies G, Linares-Espinos E, Hernandez-Cardona E, Jenson C, Cathelineau X, Sanchez-Salas R, et al. Salvage robotic-assisted radical prostatectomy: oncologic and functional outcomes from two high-volume institutions. World J Urol. 2018. https://doi.org/10.1007/s00345-018-2406-4. [Epub ahead of print].
37. Chen BT, Wood DP Jr. Salvage prostatectomy in patients who have failed radiation therapy or cryotherapy as primary treatment for prostate cancer. Urology. 2003;62 Suppl 1:69–78.
38. Nguyen PL, D'Amico AV, Lee AK, Suh WW. Patient selection, cancer control, and complications after salvage local therapy for postradiation prostate-specific antigen failure: a systematic review of the literature. Cancer. 2007;110(7):1417–28.
39. Freedland SJ, Humphreys EB, Mangold LA, Eisenberger M, Dorey FJ, Walsh PC, et al. Risk of prostate cancer-specific mortality following biochemical recurrence after radical prostatectomy. JAMA. 2005;294(4):433–9.
40. Zelefsky MJ, Ben-Porat L, Scher HI, Chan HM, Fearn PA, Fuks ZY, et al. Outcome predictors for the increasing PSA state after definitive external-beam radiotherapy for prostate cancer. J Clin Oncol. 2005;23(4):826–31.
41. Rogers E, Ohori M, Kassabian VS, Wheeler TM, Scardino PT. Salvage radical prostatectomy: outcome measured by serum prostate specific antigen levels. J Urol. 1995;153(1):104–10.
42. Chauhan S, Patel MB, Coelho R, Liss M, Rocco B, Sivaraman AK, et al. Preliminary analysis of the feasibility and safety of salvage robot-assisted radical prostatectomy after radiation failure: multi-institutional perioperative and short-term functional outcomes. J Endourol. 2011;25(6):1013–9.
43. Zargar H, Lamb AD, Rocco B, Porpiglia F, Liatsikos E, Davis J, et al. Salvage robotic prostatectomy for radio recurrent prostate cancer: technical challenges and outcome analysis. Minerva Urol Nefrol. 2017;69(1):26–37.
44. Bonet X, Ogaya-Pinies G, Woodlief T, Hernandez-Cardona E, Ganapathi H, Rogers T, et al. Nerve-sparing in salvage robot-assisted prostatectomy: surgical technique, oncological and functional outcomes at a single high-volume institution. BJU Int. 2018;122(5):837–44.
45. Coelho RF, Rocco B, Patel MB, Orvieto MA, Chauhan S, Ficarra V, et al. Retropubic, laparoscopic, and robot-assisted radical prostatectomy: a critical review of outcomes reported by high-volume centers. J Endourol. 2010;24(12):2003–15.
46. Du Y, Long Q, Guan B, Mu L, Tian J, Jiang Y, et al. Robot-Assisted Radical Prostatectomy is more beneficial for prostate cancer patients: a system review and meta-analysis. Med Sci Monit. 2018;24:272–87.
47. Tang K, Jiang K, Chen H, Chen Z, Xu H, Ye Z. Robotic vs. Retropubic radical prostatectomy in prostate cancer: a systematic review and an meta-analysis update. Oncotarget. 2017;8(19):32237–57.
48. D'Amico AV, Whittington R, Malkowicz SB, Schultz D, Blank K, Broderick GA, et al. Biochemical outcome after radical prostatectomy, external beam radiation therapy, or interstitial radiation therapy for clinically localized prostate cancer. JAMA. 1998;280(11):969–74.
49. Agarwal M, Agrawal MS, Mittal R, Sachan V. A randomized study of aspiration and sclerotherapy versus laparoscopic deroofing in management of symptomatic simple renal cysts. J Endourol. 2012;26(5):561–5.
50. Pucheril D, Campbell L, Bauer RM, Montorsi F, Sammon JD, Schlomm T. A Clinician's guide to avoiding and managing common complications during and after robot-assisted laparoscopic radical prostatectomy. Eur Urol Focus. 2016;2(1):30–48.
51. Sukumar S, Rogers CG, Trinh QD, Sammon J, Sood A, Stricker H, et al. Oncological outcomes after robot-assisted radical prostatectomy: long-term follow-up in 4803 patients. BJU Int. 2014;114(6):824–31.

52. Diaz M, Peabody JO, Kapoor V, Sammon J, Rogers CG, Stricker H, et al. Oncologic outcomes at 10 years following robotic radical prostatectomy. Eur Urol. 2015;67(6):1168–76.
53. Wang L, Wang B, Ai Q, Zhang Y, Lv X, Li H, et al. Long-term cancer control outcomes of robot-assisted radical prostatectomy for prostate cancer treatment: a meta-analysis. Int Urol Nephrol. 2017;49(6):995–1005.
54. Zhang L, Wu B, Zha Z, Zhao H, Yuan J, Jiang Y, et al. Surgical margin status and its impact on prostate cancer prognosis after radical prostatectomy: a meta-analysis. World J Urol. 2018;36:1803.
55. Philippou Y, Harriss E, Davies L, Jubber I, Leslie T, Bell RW, et al. Prostatic capsular incision during radical prostatectomy has important oncological implications. A systematic review and meta-analysis. BJU Int. 2018. https://doi.org/10.1111/bju.14522. [Epub ahead of print].
56. Srougi V, Bessa J Jr, Baghdadi M, Nunes-Silva I, da Costa JB, Garcia-Barreras S, et al. Surgical method influences specimen margins and biochemical recurrence during radical prostatectomy for high-risk prostate cancer: a systematic review and meta-analysis. World J Urol. 2017;35(10):1481–8.
57. Ficarra V, Novara G, Rosen RC, Artibani W, Carroll PR, Costello A, et al. Systematic review and meta-analysis of studies reporting urinary continence recovery after robot-assisted radical prostatectomy. Eur Urol. 2012;62(3):405–17.
58. Gajewski JB, Schurch B, Hamid R, Averbeck M, Sakakibara R, Agro EF, et al. An International Continence Society (ICS) report on the terminology for adult neurogenic lower urinary tract dysfunction (ANLUTD). Neurourol Urodyn. 2018;37(3):1152–61.
59. Kielb SJ, Clemens JQ. Comprehensive urodynamics evaluation of 146 men with incontinence after radical prostatectomy. Urology. 2005;66(2):392–6.
60. Haglind E, Carlsson S, Stranne J, Wallerstedt A, Wilderang U, Thorsteinsdottir T, et al. Urinary incontinence and erectile dysfunction after robotic versus open radical prostatectomy: a prospective, controlled, nonrandomised trial. Eur Urol. 2015;68(2):216–25.
61. Grabbert M, Buchner A, Butler-Ransohoff C, Kretschmer A, Stief CG, Bauer RM. Long-term functional outcome analysis in a large cohort of patients after radical prostatectomy. Neurourol Urodyn. 2018;37(7):2263–70.
62. Ilic D, Evans SM, Allan CA, Jung JH, Murphy D, Frydenberg M. Laparoscopic and robot-assisted vs open radical prostatectomy for the treatment of localized prostate cancer: a Cochrane systematic review. BJU Int. 2018;121(6):845–53.
63. Walsh PC, Donker PJ. Impotence following radical prostatectomy: insight into etiology and prevention. J Urol. 1982;128(3):492–7.
64. Costello AJ, Brooks M, Cole OJ. Anatomical studies of the neurovascular bundle and cavernosal nerves. BJU Int. 2004;94(7):1071–6.
65. Ficarra V, Novara G, Ahlering TE, Costello A, Eastham JA, Graefen M, et al. Systematic review and meta-analysis of studies reporting potency rates after robot-assisted radical prostatectomy. Eur Urol. 2012;62(3):418–30.
66. Pierorazio PM, Spencer BA, McCann TR, McKiernan JM, Benson MC. Preoperative risk stratification predicts likelihood of concurrent PSA-free survival, continence, and potency (the trifecta analysis) after radical retropubic prostatectomy. Urology. 2007;70(4):717–22.
67. Patel VR, Sivaraman A, Coelho RF, Chauhan S, Palmer KJ, Orvieto MA, et al. Pentafecta: a new concept for reporting outcomes of robot-assisted laparoscopic radical prostatectomy. Eur Urol. 2011;59(5):702–7.
68. Ljungqvist O, Scott M, Fearon KC. Enhanced recovery after surgery: a review. JAMA Surg. 2017;152(3):292–8.
69. Nazzani S, Preisser F, Mazzone E, Tian Z, Mistretta FA, Shariat SF, et al. In-hospital length of stay after major surgical oncological procedures. Eur J Surg Oncol. 2018;44(7):969–74.
70. Sugi M, Matsuda T, Yoshida T, Taniguchi H, Mishima T, Yanishi M, et al. Introduction of an enhanced recovery after surgery protocol for robot-assisted laparoscopic radical prostatectomy. Urol Int. 2017;99(2):194–200.
71. Preston MA, Breau RH, Lantz AG, Morash C, Gerridzen RG, Doucette S, et al. The association between nerve sparing and a positive surgical margin during radical prostatectomy. Urol Oncol. 2015;33(1):18.e1–6.
72. Beyer B, Schlomm T, Tennstedt P, Boehm K, Adam M, Schiffmann J, et al. A feasible and time-efficient adaptation of NeuroSAFE for da Vinci robot-assisted radical prostatectomy. Eur Urol. 2014;66(1):138–44.
73. Bianchi G, Breda A, Puliatti S. Live surgery: Robot Assisted Radical Prostatectomy (RARP) on the PrECE nomogram with real time Cellvizio scan and ex vivo confocal control EAU Section of Uro-Technology (ESUT) in conjunction with the Italian Endourological Association (IEA); 24–26 May 2018; Modena, Italy. 2018.
74. Puliatti S, Sighinolfi MC, Rocco B, Patel V, Francesco P, Micali S, Eissa A, Torricelli P, Bianchi G. First live case of augmented reality robot-assisted radical prostatectomy from 3D magnetic resonance imaging reconstruction integrated with PRECE model (Predicting Extracapsular extension of prostate cancer). Urology Video J. 2019;1:100002.
75. Puliatti S, Bertoni L, Pirola GM, Azzoni P, Bevilacqua L, Eissa A, Elsherbiny A, Sighinolfi MC, Chester J, Kaleci S, Rocco B, Micali S, Bagni I, Bonetti LR, Maiorana A, Malvehy J, Longo C, Montironi R, Bianchi G. Giovanni Pellacani, x vivo fluorescence confocal microscopy: the first application for real-time pathological examination of prostatic tissue. BJU Int. 2019; https://doi.org/10.1111/bju.14754.
76. Ogaya-Pinies G, Palayapalam-Ganapathi H, Rogers T, Hernandez-Cardona E, Rocco B, Coelho RF, et al. Can dehydrated human amnion/chorion membrane accelerate the return to potency after a nerve-sparing robotic-assisted radical prostatectomy? Propensity score-matched analysis. J Robot Surg. 2018;12(2):235–43.

Robot-Assisted Partial Nephrectomy

6

Nathan A. Brooks and Chad R. Tracy

Introduction

The increased use of cross-sectional imaging over the last 30 years has led to a corresponding increase in the detection of renal masses as well as a stage migration toward tumors less than 7 cm (clinical T1a and b tumors) [1, 2]. Accordingly, the focus of treatment has also shifted from open radical nephrectomy to nephron-sparing partial nephrectomy, and now to minimally invasive partial nephrectomy. Currently, major groups including the American Urologic Association (AUA), the European Association of Urologists (EAU), and the US-based National Cancer Center Network (NCCN) guidelines recommend partial nephrectomy, when possible, for localized renal masses (Table 6.1). In the United States, minimally invasive nephrectomy has largely shifted from laparoscopic to robotic surgery [3].

Multiple studies have sought to evaluate the role of partial versus radical nephrectomy in the treatment of small renal masses (T1a). EORTC 30904 randomized patients to one of the two approaches and found oncologic equivalence between the two modalities without demonstrable overall survival benefits between cohorts [4]. Conversely, the preponderance of observational studies on cT1 tumors have consistently demonstrated equivalent oncologic outcomes of partial nephrectomy compared to radical nephrectomy, with a survival and morbidity advantage favoring partial nephrectomy [5–8]. Kim et al. reported a 19% absolute risk reduction in all-cause mortality, 29% absolute risk reduction in cancer specific mortality, and a 61% absolute risk reduction for development of severe (stage IV–V) chronic kidney disease (CKD) [9]. Comparatively, analysis of the eGFR changes in the EORTC trial demonstrated that PN decreases the incidence of stage III CKD compared to RN but not stage IV or V CKD [10]. Due to the fact that a lower GFR has been linked to long-term cardiovascular complications [11, 12], current practice dictates that, when feasible, partial nephrectomy should be the preferred treatment for clinical T1 tumors and select patients with cT2 tumors, such as those with preexisting CKD, risk factors for medical CKD, a solitary kidney, or familial renal tumor syndromes [13].

Although the use of robotic partial nephrectomy has increased dramatically over the last decade [14], no randomized trials have compared open versus traditional laparoscopic or robotic partial nephrectomy (RPN). However, a meta-analysis of 3,418 patients across 8 studies demonstrated no difference between the three approaches regarding conversion rate to radical nephrectomy, blood transfusion rate, ischemia time, change in estimated glomerular filtration

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S. L. Best, S. Y. Nakada (eds.), *Minimally Invasive Urology*,
https://doi.org/10.1007/978-3-030-23993-0_6

Table 6.1 Summary of the AUA, NCCN, and EAU guidelines for partial nephrectomy

Guideline issuing organization	Tumor size	Solitary kidney	Bilateral tumors	Chronic kidney disease	Proteinuria	Surgical priority
AUA (2017)	<4 cm	Prioritize	Prioritize	Prioritize	Prioritize	Negative margins Avoid prolonged warm ischemia time (<30 min)
NCCN (2017)	<4 cm – preferred 4–7 cm –consider	Appropriate	Appropriate	Appropriate	NC	NC
EAU (2014)	<4 cm – preferred 4–7 cm – favored if feasible	NC	NC	NC	NC	Surgical approach should be selected so as not to compromise oncologic or functional outcomes

AUA American Urologic Association, *NCCN* National Cancer Center Network, *EUA* European Association of Urologists, *NC* no comment

rate (eGFR), or surgical margin status [15]. RPN, however, is associated with a lower rate of conversion to open surgery or radical surgery with shorter ischemia time duration when compared to the laparoscopic approach [16]. When performing RPN, several authors have suggested that the learning curve to limit ischemia time is between about 15 to 30 cases based on surgeon experience as well as tumor complexity [17–19].

Multiple varied factors should be contemplated during planning of robotic partial nephrectomy, including the ideal surgical approach (transperitoneal vs. retroperitoneal), potential for prolonged warm ischemia time based on tumor complexity [20], and intraoperative tumor excision techniques (enucleation vs. wedge resection or partial nephrectomy). In experienced hands and appropriately selected patients, the outcomes of RPN via either a transperitoneal or retroperitoneal approach provide similar outcomes [21] and the decision on the approach should be based on surgeon familiarity and tumor location (anterior vs. posterior). Warm ischemia should be limited to as brief as possible and preferably should be less than 25 min. In patients who may require longer ischemia times, consideration should be given to using intraoperative ice, early unclamping [22], and/or partial clamping [23]. Off-clamp (no ischemia) partial nephrectomy can be considered by experienced surgeons in patients with small, peripheral tumors in whom ischemia time is important as it preserves renal function in the perioperative period but does not appear to benefit long-term renal function [23–26]. Tumor enucleation may be considered for patients with multiple masses or who need maximal parenchymal preservation but is associated with a higher positive margin rate (albeit without differences in local tumor recurrence) [27, 28].

Equipment list (transperitoneal and retroperitoneal approach)

1. 30°-angled robotic lens
2. Veress needle (or Hassan port)
3. Trocars
   (a) (Transperitoneal):
      (i) Da Vinci Xi™: 3-, 8-mm robotic trocars and one 8-mm bladeless optical robotic trocar. A bariatric 8-mm trocar may be used for the fourth arm to open additional space between instruments
      (ii) Da Vinci Si™: 3-, 8-mm robotic trocars, one 12-mm trocar with visual obturator. A bariatric 8-mm trocar may be used for the fourth arm to open additional space between instruments

- 3-0 VLOC CV-23 cut to 6 inches with a Lapra-Ty placed before the loop (x2)
- 0 Polysorb V-20 needle cut to 5 inches (3 undyed, 3 dyed)
  - A knot is tied at the end of the suture leaving a 1 cm tail
  - A Lapra-Ty is placed to the left of knot (towards the needle side)
  - A 10 mm Weck clip is placed to the left of the Lapra-Ty placing the suture in the middle of the clip
  - The final, approximately 4 inch suture is pictured below
- When closing the renorrhaphy, alternate between dyed and undyed sutures

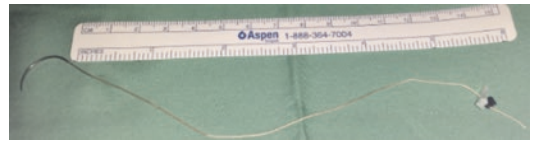

Fig. 6.1 Suture preparation for renorrhaphy

   (b) Retroperitoneal
      (i) Da Vinci Xi™: 3-, 8-mm robotic trocars and 1 Da Vinci robotic Hasson trocar
      (ii) Da Vinci Si™: 3-, 8-mm robotic trocars, one 12-mm Hasson trocar
4. Assistant trocars
   (a) Right sided: one, 5-mm trocar for liver retraction
   (b) Both sides: one 12-mm trocar (Airseal™, Conmed, Utica, NY)
5. Laparoscopic instruments
   (a) Short- and long-tip laparoscopic suction
   (b) Laparoscopic scissors
   (c) Laparoscopic bulldog vascular clamps
   (d) Needle driver (to bring suture in and out)
   (e) Laparoscopic ultrasound probe
   (f) Polymer locking ligation system (Weck®Hem-o-lok®, Teleflex™, Morrisville, NC)
   (g) Absorbable suture clip applier (Lapra-Ty™, Ethicon® US LLC, Cincinnati, OH)
   (h) Hemostatic agents (Floseal™, Baxter Healthcare, Deerfield, IL, or Surgiflo®, Ethicon® US LLC, Cincinnati, OH) with laparoscopic applier (optional)
   (i) Laparoscopic specimen bag
   (j) 15Fr Round drain (optional)
6. Robotic instruments
   (a) Monopolar scissors
   (b) Fenestrated bipolar forceps
   (c) Prograsp forceps
   (d) Needle drivers × 2
7. Suture
   (a) 6″ 2-0 barbed suture × 2 with Lapra-Ty applied proximal to the distal loop to oversew the deep resection bed.
   (b) 5″ 0 polyglactin suture on V-20 needle × 4–6 with a Hem-o-lok clip and Lapra-Ty placed 2 cm from the end for the renorrhaphy. Placing a knot distal to the Lapra-Ty prevents slipping of the clips when being introduced through the trocar (Fig. 6.1). Dyed and undyed sutures can be prepared and alternated during the renorrhaphy.
   (c) 4-0 or 5-0 polypropylene suture for vascular emergency.
   (d) Skin and fascial closure suture.
8. Adjunctive agents:
   (a) Indocyanine green (optional): 2.5 mg starting dose given immediately after hilar clamping [29]
   (b) Mannitol (optional) no longer used in our practice due to lack of evidence in its favor [30]
9. Kidney-shaped retroperitoneal dilating balloon (Spacemaker Structural Balloon dilator, Medtronic, Minneapolis, MN)
10. Emergency instrumentation (in room, not open)
   (a) Open nephrectomy instrumentation
   (b) Emergency wrench for robot platform
   (c) Laparoscopic stapler with vascular staple loads

Robot-Assisted Partial Nephrectomy, Transperitoneal Approach

Introduction

The transperitoneal approach for partial nephrectomy is well suited as an approach for most renal tumors. For surgeons new to the robotic approach,

the anatomy and approach are similar to the laparoscopic and open transperitoneal approaches. Important structures to be cognizant of while performing dissection include the liver, large bowel, duodenum, and the inferior vena cava on the right and the spleen, large bowel, pancreas, aorta, and superior mesenteric artery on the left. The transperitoneal approach is less suited for posterior tumors, which require complete mobilization of the kidney within Gerota's fascia.

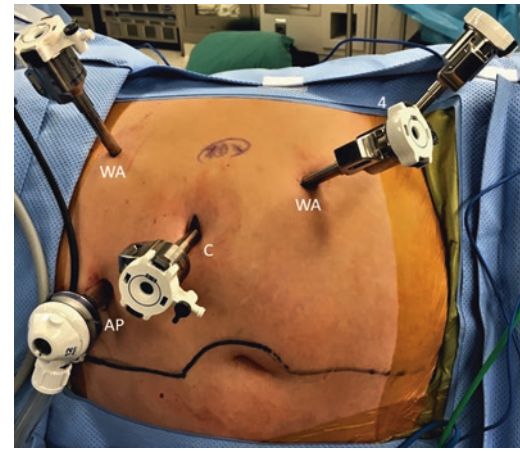

Fig. 6.2 Transperitoneal partial nephrectomy port placement. The initial port (camera port, "C") is placed under direct observation using the 8-mm robotic Visiport™ (Xi) or the 12-mm visible port (Si) (VeraOne™, Medtronic, Minneapolis, MN). The two main working arms (WA) triangulate to the tumor and the fourth arm (4) is positioned just superior and medial to the iliac crest for upward retraction on the kidney. Use of the long bariatric robotic trocar for the fourth arm helps reduce clashing of the robotic arms. For right-sided cases, a 5-mm port is placed immediately inferior to the xyphoid process for insertion of a locking grasper for liver retraction. A 12-mm assistant port (AP) is placed 6–8 cm superiomedially to the camera port in line with the inferior robotic arm, fourth arm, and camera port. The midline is marked prior to the surgery in obese patients

Step by Step

1. Ensure proper sutures and equipment have been prepared for the case per above specifications and that supplies for open conversion and a vascular stapler are within close proximity.
2. Positioning. The patient is placed in a modified flank position at 45–60° using Laminectomy bolsters. The patient's iliac crest is positioned over the break in the table and the table is flexed, if needed, to open the hips and create space for the robotic arms. The patient is securely fastened to the bed and the upper arm is placed either on an arm support or pillows. All pressure points are padded adequately to prevent positioning injuries.
3. Pneumoperitoneum is established using either the Veress or open (Hasson) technique.
4. Port placement (Fig. 6.2). The initial optical port is placed under direct observation using the 8-mm robotic Visiport™ (Xi) or the 12-mm visible port (Si) (VeraOne™, Medtronic, Minneapolis, MN). The remainder of the robotic trocars are placed under vision with the two main working arms triangulating to the tumor and the fourth arm positioned just superior and medial to the iliac crest for upward retraction on the kidney. Use of the long bariatric robotic trocar for the fourth arm helps reduce clashing of the robotic arms. For right-sided cases, a 5-mm port is placed immediately inferior to the xyphoid process for insertion of a locking grasper that can be used for liver retraction. A 12-mm assistant port is placed 6–8 cm superiomedially to the camera port in line with the inferior robotic arm, fourth arm, and camera port.
5. Robot docking. The robot is brought in at a 15° angle toward the patient's head with the arms positioned to provide maximal working space and limit instrument clashing. Instrumentation for the 4-arm approach includes a 30° down lens, monopolar scissors for the right hand, fenestrated bipolar forceps for the left arm, and a Prograsp forceps for the fourth arm.
6. Bowel reflection. The peritoneum is incised lateral to colon to reflect the colon medially. The proper plane of dissection is readily apparent by identifying the color difference between the pale fat of the retroperitoneum and the brighter yellow fat of the mesentery.

On the left, dissection continues beyond the splenic flexure until the spleen lies medially without additional traction. Care must be taken to avoid injury to the vessels of the splenic hilum as well as the tail of the pancreas. On the right, care is taken to kocherize the duodenum medially. The peritoneum overlying the superior pole of the kidney is incised along the inferior aspect of the liver to allow for upward retraction during hilar dissection. A locking grasper is inserted through the sub-xyphoid port, passed beneath the liver, and affixed to the lateral body wall musculature to retract the liver superiorly. With either side, the medial dissection is complete once the adrenal is identified superiorly and the gonadal vein inferiorly.

7. Ureteral identification and hilar dissection. A 3–4 cm incision is made in Gerota's fascia medial to the lower pole along the lateral side of the gonadal vein in order to identify the ureter (Fig. 6.3). The ureter and surrounding perinephric fat is lifted superiorly and the attachments to the posterior wall are bluntly dissected along the psoas muscle. The fourth arm is inserted into this opening to balance the kidney laterally and place the hilum on stretch.
8. Renal hilar dissection. Dissection continues medial to the ureter from inferior to superior by releasing the anterior fascia along the entirety of the medial surface of the kidney and separating the retroperitoneal fat into packets for ligation. The fourth arm tension should be continually adjusted to assure the hilum remains on stretch. Once the renal vein is identified, a window is created posteriorly to expose the renal artery. Preoperative cross-sectional imaging should be scrutinized closely for identification of accessory arteries and veins that may require additional dissection.
9. Lesion identification. The perinephric fat is carefully dissected from the renal capsule in the region of the tumor in order to expose several centimeters of normal renal capsule circumferentially around the tumor. For lateral and posterior tumors, the dissection should continue until the kidney can be rotated for adequate exposure. Fat may be removed and sent to pathology or left attached to the tumor surface to be used for retraction.
10. Lesion demarcation. An intraoperative ultrasound is used to verify the mass and systematically demarcate the boarders of dissection, assuring an adequate surgical margin. The fat over tumor can be left on a handle for dissection or removed at this point and sent for histologic analysis. Use of TilePro® allows for simultaneous visualization of the tumor and ultrasound (Fig. 6.4).
11. Preparation for dissection. It is imperative to assure all instrumentation is ready and available prior to clamping of the renal artery. Utilization of a routine checklist helps reduce the possibility of missing supplies/instrumentation. It is our practice to check that all ports are placed deep enough to expose the robotic remote center (thick black line on port) and prevent dislodgement during instrument exchange. Bulldog clamps (depending on the number vessels) are

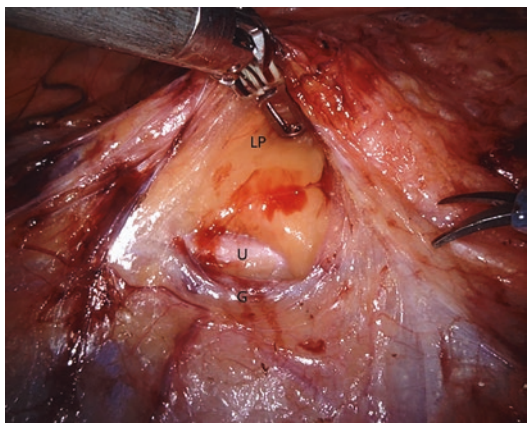

Fig. 6.3 After the colon is reflected, an incision is made in Gerota's just off the lower pole (LP). Blunt dissection proceeds toward the psoas until the ureter (U) and gonadal vein are identified (G). The ureter is lifted anteriorly and the gonadal is displaced posteriorly until the psoas muscle is encountered. This allows for elevation of the kidney and renal hilum and for dissection to proceed cephalad to the renal hilum

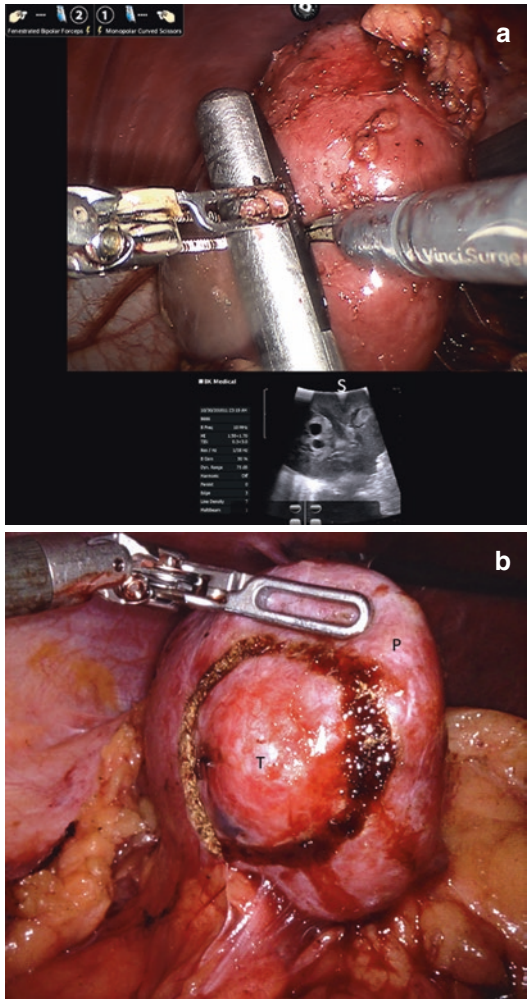

Fig. 6.4 (**a**) The ultrasound probe is placed over the mass and the borders of the mass are systematically demarcated using electrocautery. The scissors are seen at the top of the image and act as a hyperechoic marker (S). (**b**) Using the ultrasound probe, the margins of the tumor (T) have been demarcated from normal parenchyma (P) by monopolar cautery

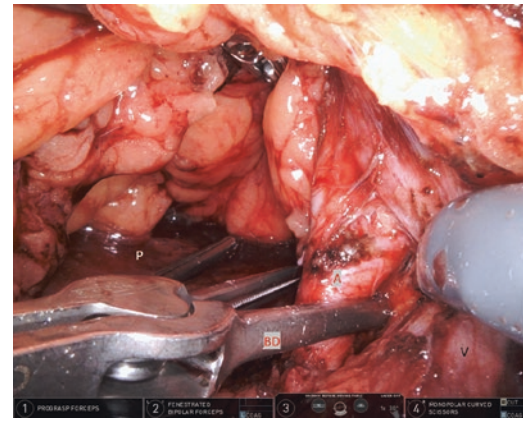

Fig. 6.5 The renal hilum is controlled. The patient's head is in the right of the picture and the psoas muscle (P) is seen laterally. The fourth robotic arm is used to lift the kidney into the air providing traction under the lower pole to the expose the hilum. A vascular clamp (BD) is then placed on the artery (A). We generally place two vascular clamps on the renal artery. We do not generally clamp the renal vein (V), however it could be clamped at this stage after arterial control

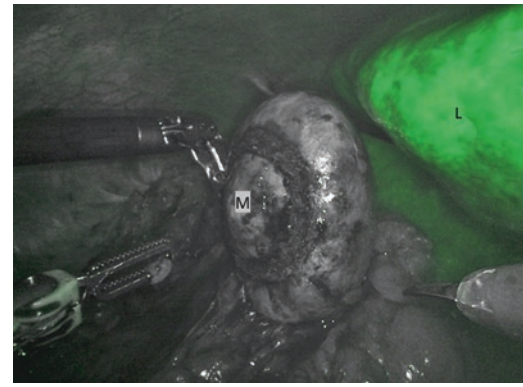

Fig. 6.6 Administration of 2.5 mg of Indocyamine green with the firefly system after renal artery clamping confirms excellent vascular control to the kidney and mass (M).There is vascular flow the liver (L)

placed medial to the kidney in preparation for clamping.

12. Lesion excision. The hilum is placed on stretch and a bulldog clamp is placed on the renal artery(s) (Fig. 6.5). We do not routinely clamp the renal vein [31]. If desired, indocyanine green can be administered to ensure complete vascular control using the fluorescence light on the daVinci Robotic system (Firefly, Fig. 6.6). Using the monopolar scissors, the capsule and immediate underlying parenchyma are incised using electrocautery, followed by a combination of blunt and cold excision to dissect around the contour of the mass, leaving an adequate parenchymal margin. Intermittent cautery can be used to control any small vessels encountered during the

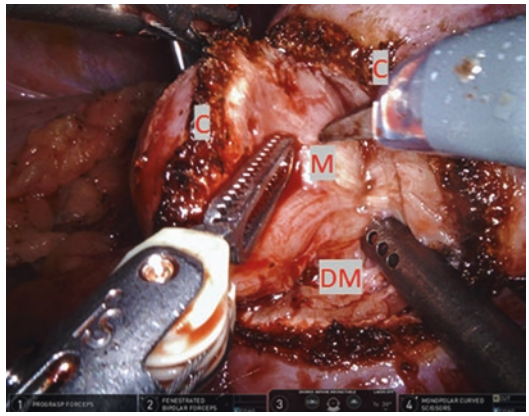

Fig. 6.7 Wedge resection of tumor. The capsule and immediate underlying parenchyma are incised using electrocautery and monopolar scissors (C). Using blunt and cold excision, dissection continues along the contour of the mass leaving an adequate parenchymal margin (M). Intermittent cautery can be used to control small vessels encountered during the dissection. If there are concerns for adequacy of the resection margin (not pictured), the deep resection margin (DM) can be excised separately. We do not routinely send a deep margin

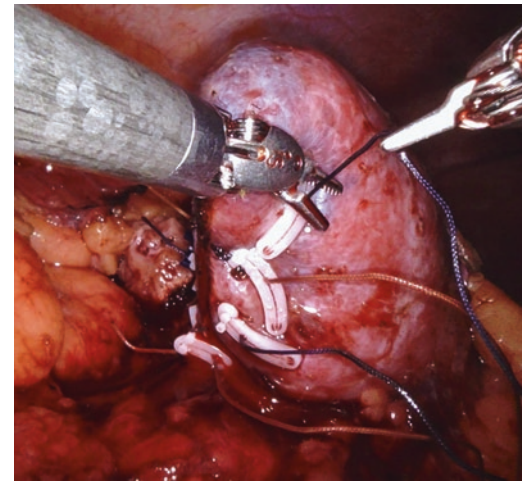

Fig. 6.8 Sliding clip renorrhaphy technique. The suture is placed through the side farthest from the assistant. There should be about 1 cm of space from the suture entry and exit point from the renal and approximately 1 cm of space between each suture. Following suture placement, a Hem-o-lock clip is applied, and the sutures are alternatively tightened in order to prevent excessive tension on any individual suture

dissection. The bed is inspected. If there appears a tumor at the deep resection margin, this can be excised separately, though we do not routinely send a deep margin (Fig. 6.7).

13. Closure of the excision bed. A 6-inch, 3-0 barbed suture with a Lapra-Ty at the end is used to over sew the base of the defect, with openings in the collecting system closed separately from vasculature when present. The process can be repeated with additional sutures as needed to assure the entire base has been over sewn. If planning an early clamping technique, the hilar clamps can be removed at this point and additional arteries can be over sewn.
14. Renorrhaphy. The renal defect is closed using the sliding-clip renorrhaphy technique [32] (Fig. 6.8). We start the suture at the side farthest from the assistant to allow for easier access for final clip placement. The suture is passed 1 cm from the renal defect in an interrupted fashion leaving approximately 1 cm of space between each suture. After all sutures are placed, a Hem-o-lock clip is applied, and the sutures are alternatively tightened to prevent excessive tension on any one individual suture.
15. The vascular clamps are removed keeping the renorrhaphy in view if possible. If bleeding is encountered, the sutures may be further tightened. When necessary, additional renorrhaphy sutures or hemostatic agents can be utilized to stop bleeding. Once all sutures are placed and tightened, Lapra-ty clips are used to secure the sliding clip (Fig. 6.9).
16. Completion of case. If there is a large defect in the renal collecting system or there is concern for postoperative leak, a drain can be introduced through the fourth arm port and placed inside of Gerota's fascia. The fascia is then re-approximated with a vicryl or barbed suture. The specimen is placed into a laparoscopic bag and brought through an assistant port depending on location and the size of the specimen. The incisions are then closed, irrigated, and injected with local anesthetic.

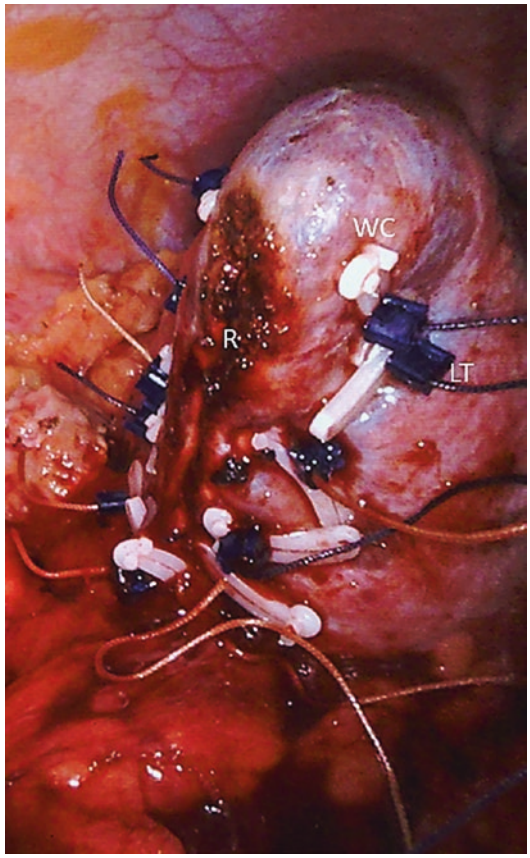

Fig. 6.9 After completion of the partial nephrectomy, the renorrhaphy (R) is well approximated using the sliding Weck Clip (WC) and Lapra-Ty (LT)

Robot-Assisted Partial Nephrectomy, Retroperitoneal Approach

Introduction

The retroperitoneal approach is preferred for posterior tumors and for patients with extensive prior abdominal surgery. While the retroperitoneal approach is initially less familiar than the transperitoneal approach, with practice it can decrease operative times for posterior tumors [19]. Oncologic and perioperative outcomes for both approaches are equivalent.

Step by Step

1. Ensure proper sutures and equipment have been prepared for the case per above specifications and that supplies for open conversion and a vascular stapler are within close proximity.
2. Positioning. The patient is placed over the break in full flank at 90° with the bed maximally flexed. The patient is secured to the bed using 3″ tape and all pressure points are padded adequately. The upper arm is placed either on an arm support that is low to the body on pillows.
3. Initial trocar placement. A 1.5-cm incision is made one fingerbreadth above the superior iliac crest, just lateral to the triangle of Petit (composed of the iliac crest inferiorly, latissimus dorsi posteriorly, and external oblique anteriorly). Blunt dissection is carried out down to the fascia, which can be bluntly opened with a tonsil clamp. A 0 polyglactin suture is placed on either side of the opening to anchor the Hasson cannula. Using the tip of the pointer finger the dissection is carried out bluntly through the fascia and into the retroperitoneal space by sweeping the finger along the anterior surface of the psoas muscle.
4. Creating a space. Initial blunt digital dissection should focus on separating the peritoneum from the anterior abdominal wall. Once adequate space has been created, the kidney-shaped balloon dissector is placed into the retroperitoneal space with the port facing the anterior abdomen toward the assistant. The 30° laparoscope is inserted into the trocar for direct visualization during balloon expansion. The balloon should be inflated with 40–60 compressions until adequate space has been created and the balloon has completely unfolded. Landmarks are: superiorly, the transversus abdominis muscle and the anterior layer of the peritoneum, and inferiorly, the psoas tendon and ureter. Depending on the quantity of retroperitoneal fat, the lower pole of the kidney within the Gerota's fascia may also be identified. The balloon is left inflated

for an additional minute to help with compression of any small venous vessels. The balloon is then deflated and replaced with a 12-mm Hasson port and affixed to the fascia with the previously placed sutures. The retroperitoneum is insufflated to 15 mmHg.

5. Additional port placement (Fig. 6.10). The first robotic arm port is placed under direct vision 6–8 cm posterior to the initial camera port just above the indentation of the erector spinae muscles in the space under the 12th rib. Using this port, a laparoscopic Kittner or grasper can be used to further dissect the peritoneum from the anterior abdominal wall to create space for the remaining robotic arms. Care should be taken to avoid inadvertent entry into the peritoneum. The second robotic arm is placed 6–8 cm medial to the camera port and the fourth arm is placed 6–8 cm medial to the second arm. An assistant port is placed in the anterior axillary line 6–8 cm inferior to the third arm and cephalad to the anterior superior iliac spine. For the assistant port, we prefer use of an Airseal trocar (Conmed, Utica, NY), which provides continuous smoke evacuation and stable pneumoperitoneum even with continuous suction.
6. Robot Docking. On the Si robot, the robotic cart is brought over the patient's head, parallel to the spine, and angled back toward the kidney. Preparation for this positioning should be described to anesthesia prior to the case so that anesthesia machines can be positioned to allow adequate space for the patient cart. As the Xi robot can be rotated on the main boom, it is significantly easier to dock. The patient cart can be brought in from the side of the patient and then rotated to angle toward the head of the bed. Instrumentation for the 4-arm approach includes a 0° lens, monopolar scissors for the right hand, fenestrated bipolar forceps for the left arm, and a Prograsp forceps for the fourth arm.
7. Expansion of the retroperitoneal space. The retroperitoneal fat is lifted from the posterior abdominal musculature and psoas muscle using blunt dissection. In most cases, identification of

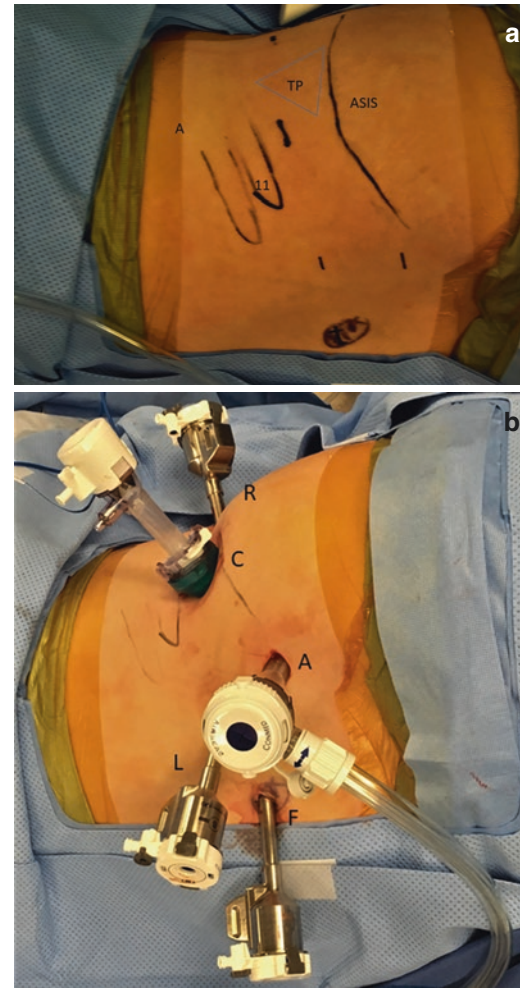

Fig. 6.10 (**a**) Landmarks for a left retroperitoneal partial nephrectomy include the axillary line (A), the iliac crest (Curvilinear Line), the anterior superior iliac spine (ASIS), and the 11th rib (11). The triangle of Petit (TP) (composed of the iliac crest inferiorly, latissimus dorsi posteriorly and external oblique anteriorly) is the landmark used for camera port placement. (**b**) Port configuration for left-sided retroperitoneal partial nephrectomy. The ports are placed in a line. The camera port (C) is placed first one fingerbreadth above the superior iliac crest, just medial to the triangle of Petit (composed of the iliac crest inferiorly, latissimus dorsi posteriorly, and external oblique anteriorly). The space is expanded first bluntly and then with the kidney-shaped balloon. The right-hand trocar (R) is placed just above the indentation of the erector spinae muscles in the space under the 12th rib. The left arm trocar (L) is placed 6–8 cm medial to and in line with the camera port and the fourth arm trocar (F) is placed 6–8 cm medial and in line with the left arm trocar. An assistant port (A) is placed in the anterior axillary line 6–8 cm inferior to the left arm trocar and cephalad to the anterior superior iliac spine

Gerota's fascia will be facilitated by excision of the retroperitoneal para-nephric fat. This fat should be excised and either removed out the assistant port or placed to the side for later retrieval with the specimen.

8. Dissection of the renal hilum. Gerota's fascia is lifted anteriorly and then entered in a plane horizontal to the psoas muscle. The muscle is followed superiorly while continuing to retract the fat anteriorly until arterial pulsations are noted, confirming the location of the hilum. Often the hilum will be identified by following the psoas fibers up to the junction of the psoas and quadratus lumborum near their insertion into the diaphragm. The artery(s) are carefully separated from their surrounding fat and lymphatics. For right-sided tumors, the retroperitoneal approach can help facilitate clamping of an early branching renal artery behind the vena cava.
9. Tumor demarcation, excision, and defect closure are identical to the steps described above for the transperitoneal approach.

Peri- and Postoperative Considerations

Patient selection and counseling on expectation and complications prior to RPN is essential. Several reviews and meta-analyses have examined the outcomes of RPN (Table 6.2) [33].

Table 6.2 Postoperative complications following partial nephrectomy

Clavien-Dindo grade	Complication	Management	Comment
1	Ileus	Supportive care	
	Hemorrhage/hematoma	Trend hemoglobin or hematocrit	
	Renal failure	Hydration if pre-renal, minimize nephrotoxic medications, manage electrolyte disturbance	Rarely will patients require dialysis
	Wound infection	Wound packing and/or antibiotics	
2	Severe blood loss	Blood transfusion	
	Urinary tract infection	Antibiotics	
	Thromboembolism	Anticoagulation or IVC filter	Slightly increases risk of bleeding
3	Pseudoaneurysm/ large-volume hemorrhage	Immediate: surgical exploration or open surgery if unable to control robotically Delayed: angioembolization	
	Urine leak	Escalating degrees of drainage with ureteral stenting, possible percutaneous drain placement, percutaneous nephrostomy tube placement, and urethral catheter placement	Can be managed with a combination of these techniques performed in a stepwise manner
	Diaphragmatic violation with symptomatic pneumothorax and rarely hydropneumothorax	Aspiration vs. thoracostomy tube	If recognized intraoperatively, we recommend repair of the injury
4	Cerebral vascular event	Medical consultation and appropriate management with or without intensive care admission	Cardiac stenting will require therapeutic antiplatelet therapy and the patient should be monitored for signs of bleeding
	Cardiac arrhythmia or acute coronary syndrome		
	Several respiratory distress		
	Rhabdomyolysis		
5	Death		Postoperative death is rare but important to discuss with patients when providing preoperative counselling

The overall complication rate after RPN is reported to be 12% with most complications being grades 1–3 [33]
IVC Inferior vena cava

Robotic partial nephrectomy offers superiority to open partial nephrectomy in regard to EBL, complication rate, hospital stay, eGFR decline, hospital readmission rate, and cancer recurrence while offering superior ischemia time, conversion rate, surgical margin rate, complication rate, and mortality rate when compared to laparoscopic partial nephrectomy [34]. Alternatives to RPN include PN via any other approach, radical nephrectomy, percutaneous ablative therapy for select patients [35], and active surveillance [36].

Patient counseling and selection includes a discussion of the procedure risks (Table 6.3) [16, 37–39]. The most clinically significant operative complications from robotic partial nephrectomy are hemorrhage requiring angioembolization and urinary leak, occurring in <1% of patients in contemporary series from high-volume centers respectively, although likelihood of either complication will often depend on tumor complexity [40, 41]. The rate of bleeding requiring a blood transfusion from the aforementioned studies ranges from 2.2% to 7.2%. In other studies, the rate of significant bleeding is a high as 11.3% for on-clamp robotic partial nephrectomies and as high as 29.2% for selective or off-clamp partial nephrectomy [26]. The rate of thromboembolic events (VTE) after minimally invasive renal cancer surgery is <2% and generally occurs within 30 days of surgery [42]. Eighty-one milligrams of aspirin is safe to continue through the perioperative period and pharmacologic thromboembolic prophylaxis (such as subcutaneous heparin) is also safe to use, though might not decrease the VTE rate [43, 44]. Systemic, therapeutically dosed anticoagulation and antiplatelet agent administration have been shown to in increase overall complications and hemorrhagic complications in patients undergoing RPN [45] and therefore the risk of VTE and need for therapeutic anticoagulation must be weighed against the risk of bleeding from VTE prophylaxis.

Immediate postoperative bleeding often suggests a lack of venous or arterial control during the closure of the renorrhaphy and can be managed with blood transfusions, selective percutaneous embolization, or emergent reoperation. Delayed hemorrhage after partial nephrectomy most often occurs from a ruptured arterial pseudoaneurysm. Delayed hemorrhage has been described anywhere from 5 to 30 days (average 10 days) after surgery [46]. Patient presentation can vary from isolated gross hematuria to gross hematuria with cardiovascular collapse. This life-threatening complication should be managed with emergent selective angioembolization. In a stable patient, confirmation of vascular bleeding can be confirmed using CT angiography, but this step should be omitted in patients with significant bleeds or unstable patients who benefit from immediate angioembolization.

Perinephric urine leaks after RPN occur secondary to incomplete closure of the collecting system or breakdown of the closure. Risk factors for a urine leak include increasing tumor size and nearness to the collecting system. Most leaks will resolve with prolonged perinephric drainage. For patients that do not respond to percutaneous drainage, placement of a ureteral stent and Foley catheter may be advised to allow complete decompression of the urinary system. Alternatively, if space allows, a percutaneous nephrostomy tube can be placed in the collecting system to assure adequate drainage and allow for healing of the defect [47, 48].

The rate of positive surgical margins after RPN is low ranging from 2.3% to <8% [30]. Risk factors for a positive surgical margin include larger tumors, higher patient comorbidity, and patient age [49, 50]. While some studies have shown no long-term sequelae of positive margins, others have suggested that the presence of a positive surgical margin is associated with a risk of any site disease relapse and decreased overall survival [51]. Taken collectively, positive surgical margins may increase the rate of local recurrence; however, this risk is low and immediate completion nephrectomy is seldom warranted. In the event of a positive surgical margin, imaging follow-up with special attention paid to the resection bed is prudent [52, 53].

Robotic partial nephrectomy is a safe, reproducible procedure with a comparatively low learning curve compared to laparoscopic nephrectomy, with oncologic outcomes that are equivalent to other approaches. Ultimately the decision to proceed with robotic partial nephrec-

Table 6.3 Review of data from systematic review and meta-analysis of robotic partial nephrectomy

Study	Total patients (*n*)	Mean warm ischemia time (min)	Change in eGFR (ml/min)	Operative time (min)	Mean length of stay (d)	Rate of positive margin (%)	Conversion rate to open (%)	Conversion rate to radical (%)	Estimated blood loss (ml)
Choi et al. [16]	1152	18–35.5	9.3–14	140–376	2–7	0–11	0–5	0–1	93–490
Aboumarzouk et al. [37]	717	14.1–35.3	NR	152–233	0–6.2	0–5.5	0–4	NR	122–368
Laydber et al. [38]	701	21	5.4%	196	3.6	1.7	1.7	NR	182 (7.4% transfusion rate)
Pavan et al.[a] [39]	291[b]	22.5–31	4.2	170–281	2.5–5.3	3.5			118–428

NR Not reported

[a]Report for renal masses over 4 cm only, in this study, there was slight increase in postoperative complication rate for tumors >4 cm compared to those <4 cm

[b]Denotes maximum number for all analysis. Some analysis differed in sample size

tomy should be based on patient and tumor characteristics as well as surgeon familiarity of the approach.

References

1. Kane CJ, Mallin K, Ritchey J, Cooperberg MR, Carroll PR. Renal cell cancer stage migration. Cancer. 2008;113(1):78–83.
2. Hock LM, Lynch J, Balaji KC. Increasing incidence of all stages of kidney cancer in the last 2 decades in the United States: an analysis of surveillence, epidemiology, and end results program data. J Urol. 2002;167(1):57–60.
3. Ghani KR, Sukumar S, Sammon JD, Rogers CG, Trinh Q-D, Menon M. Practice patterns and outcomes of open and minimally invasive partial nephrectomy since the introduction of robotic partial nephrectomy: results from the nationwide inpatient sample. J Urol. 2014;191(4):907–13.
4. Van Poppel H, Da Pozzo L, Albrecht W, Matveev V, Bono A, Borkowski A, et al. A prospective, randomised EORTC intergroup phase 3 study comparing the oncologic outcome of elective nephron-sparing surgery and radical nephrectomy for low-stage renal cell carcinoma. Eur Urol. 2011;59(4):543–52.
5. Miller DC, Schonlau M, Litwin MS, Lai J, Saigal CS. Renal and cardiovascular morbidity after partial or radical nephrectomy. Cancer. 2008;112(3):511–20.
6. Huang WC, Elkin EB, Levey AS, Jang TL, Russo P. Partial nephrectomy versus radical nephrectomy in patients with small renal tumors--is there a difference in mortality and cardiovascular outcomes? J Urol. 2009;181(1):55–61; discussion 61–2.
7. Thompson RH, Boorjian SA, Lohse CM, Leibovich BC, Kwon ED, Cheville JC, et al. Radical nephrectomy for pT1a renal masses may be associated with decreased overall survival compared with partial nephrectomy. J Urol. 2008;179(2):468–73.
8. Patard J-J, Shvarts O, Lam JS, Pantuck AJ, Kim HL, Ficarra V, et al. Safety and efficacy of partial nephrectomy for all T1 tumors based on an international multicenter experience. J Urol. 2004;171(6, Part 1):2181–5.
9. Kim SP, Thompson RH, Boorjian SA, Weight CJ, Han LC, Murad MH, et al. Comparative effectiveness for survival and renal function of partial and radical nephrectomy for localized renal tumors: a systematic review and meta-analysis. J Urol. 2012;188(1):51–7.
10. Scosyrev E, Messing EM, Sylvester R, Campbell S, Van Poppel H. Renal function after nephron-sparing surgery versus radical nephrectomy: results from EORTC randomized trial 30904. Eur Urol. 2014;65(2):372–7.
11. Lane BR, Demirjian S, Derweesh IH, Takagi T, Zhang Z, Velet L, et al. Survival and functional stability in chronic kidney disease due to surgical removal of nephrons: importance of the new baseline glomerular filtration rate. Eur Urol. 2015;68(6):996–1003.
12. Capitanio U, Terrone C, Antonelli A, Minervini A, Volpe A, Furlan M, et al. Nephron-sparing techniques independently decrease the risk of cardiovascular events relative to radical nephrectomy in patients with a T1a–T1b renal mass and normal preoperative renal function. Eur Urol. 2015;67(4):683–9.
13. Mir MC, Derweesh I, Porpiglia F, Zargar H, Mottrie A, Autorino R. Partial nephrectomy versus radical nephrectomy for clinical T1b and T2 renal tumors: a systematic review and meta-analysis of comparative studies. Eur Urol. 2017;71(4):606–17.
14. Patel HD, Mullins JK, Pierorazio PM, Jayram G, Cohen JE, Matlaga BR, et al. Trends in renal surgery: robotic technology is associated with increased use of partial nephrectomy. J Urol. 2013;189(4):1229–35.
15. Wu Z, Li M, Liu B, Cai C, Ye H, Lv C, et al. Robotic versus open partial nephrectomy: a systematic review and meta-analysis. PLoS One. 2014;9(4):e94878.
16. Choi JE, You JH, Kim DK, Rha KH, Lee SH. Comparison of perioperative outcomes between robotic and laparoscopic partial nephrectomy: a systematic review and meta-analysis. Eur Urol. 2015;67(5):891–901.
17. Mottrie A, De Naeyer G, Schatteman P, Carpentier P, Sangalli M, Ficarra V. Impact of the learning curve on perioperative outcomes in patients who underwent robotic partial nephrectomy for parenchymal renal tumours. Eur Urol. 2010;58(1):127–33.
18. Haseebuddin M, Benway BM, Cabello JM, Bhayani SB. Robot-assisted partial nephrectomy: evaluation of learning curve for an experienced renal surgeon. J Endourol. 2009;24(1):57–61.
19. Moriarty MA, Nepple KG, Tracy CR, Strigenz ME, Lee DK, Brown JA. Impact of robotic fellowship experience on perioperative outcomes of robotic-assisted laparoscopic partial nephrectomy. Curr Urol. 2015;9(1):19–23.
20. Rosevear HM, Gellhaus PT, Lightfoot AJ, Kresowik TP, Joudi FN, Tracy CR. Utility of the RENAL nephrometry scoring system in the real world: predicting surgeon operative preference and complication risk. BJU Int. 2012;109(5):700–5.
21. Hughes-Hallett A, Patki P, Patel N, Barber NJ, Sullivan M, Thilagarajah R. Robot-assisted partial nephrectomy: a comparison of the transperitoneal and retroperitoneal approaches. J Endourol. 2013;27(7):869–74.
22. Peyronnet B, Baumert H, Mathieu R, Masson-Lecomte A, Grassano Y, Roumiguié M, et al. Early unclamping technique during robot-assisted laparoscopic partial nephrectomy can minimise warm ischaemia without increasing morbidity. BJU Int. 2014;114(5):741–7.
23. Volpe A, Blute ML, Ficarra V, Gill IS, Kutikov A, Porpiglia F, et al. Renal ischemia and function after partial nephrectomy: a collaborative review of the literature. Eur Urol. 2015;68(1):61–74.

24. Simone G, Gill IS, Mottrie A, Kutikov A, Patard J-J, Alcaraz A, et al. Indications, techniques, outcomes, and limitations for minimally ischemic and off-clamp partial nephrectomy: a systematic review of the literature. Eur Urol. 2015;68(4):632–40.
25. Porpiglia F, Bertolo RG, Amparore D, Checcucci E, Mele F, Morra I, et al. Cold-ischemia technique during robot-assisted partial nephrectomy: perioperative results, functional and oncological outcomes with one-year follow-up (ERUS poster abstract). Eur Urol Suppl. 2016;15(7):235.
26. Cacciamani GE, Medina LG, Gill TS, Mendelsohn A, Husain F, Bhardwaj L, et al. Impact of renal hilar control on outcomes of robotic partial nephrectomy: systematic review and cumulative meta-analysis. Eur Urol Focus. 2018; https://doi.org/10.1016/j.euf.2018.01.012. [Epub ahead of print].
27. Wang L, Hughes I, Snarskis C, Alvarez H, Feng J, Gupta GN, Picken MM. Tumor enucleation specimens of small renal tumors more frequently have a positive surgical margin than partial nephrectomy specimens, but this is not associated with local tumor recurrence. Virchows Arch. 2017;470(1):55–61.
28. Minervini A, Ficarra V, Rocco F, Antonelli A, Bertini R, Carmignani G, et al. Simple enucleation is equivalent to traditional partial nephrectomy for renal cell carcinoma: results of a nonrandomized, retrospective, comparative study. J Urol. 2011;185(5):1604–10.
29. Ferroni MC, Sentell K, Abaza R. Current role and indications for the use of indocyanine green in robot-assisted urologic surgery. Eur Urol Focus. 2018;4(5):648–51.
30. Power NE, Maschino AC, Savage C, Silberstein JL, Thorner D, Tarin T, et al. Intraoperative mannitol use does not improve long-term renal function outcomes after minimally invasive partial nephrectomy. Urology. 2012;79(4):821–6.
31. Tracy CR, Terrell JD, Francis RP, Wehner EF, Smith J, Litorja M, et al. Characterization of renal ischemia using DLP hyperspectral imaging: a pilot study comparing artery-only occlusion versus artery and vein occlusion. J Endourol. 2010;24(3):321–5.
32. 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.
33. Sand M, Hyams E, Stifelman M. Complications of robotic partial nephrectomy. In: Ghavamian R, editor. Complications of laparoscopic and robotic urologic surgery. New York: Springer New York; 2010. p. 159–69.
34. Cacciamani GE, Medina LG, Gill T, Abreu A, Sotelo R, Artibani W, et al. Impact of surgical factors on robotic partial nephrectomy outcomes: comprehensive systematic review and meta-analysis. J Urol. 2018;200(2):258–74.
35. Thompson RH, Atwell T, Schmit G, Lohse CM, Kurup AN, Weisbrod A, et al. Comparison of partial nephrectomy and percutaneous ablation for cT1 renal masses. Eur Urol. 2015;67(2):252–9.
36. Pierorazio PM, Johnson MH, Ball MW, Gorin MA, Trock BJ, Chang P, et al. Five-year analysis of a multi-institutional prospective clinical trial of delayed intervention and surveillance for small renal masses: the DISSRM Registry. Eur Urol. 2015;68(3):408–15.
37. Aboumarzouk OM, Stein RJ, Eyraud R, Haber G-P, Chlosta PL, Somani BK, et al. Robotic versus laparoscopic partial nephrectomy: a systematic review and meta-analysis. Eur Urol. 2012;62(6):1023–33.
38. Laydner H, Kaouk JH. Robotic partial nephrectomy: the new horizon. Arab J Urol. 2012;10(1):2–9.
39. Pavan N, Derweesh IH, Mir CM, Novara G, Hampton LJ, Ferro M, et al. Outcomes of laparoscopic and robotic partial nephrectomy for large (>4 cm) kidney tumors: systematic review and meta-analysis. Ann Surg Oncol. 2017;24(8):2420–8.
40. Maurice MJ, Ramirez D, Kara Ö, Malkoç E, Nelson RJ, Fareed K, et al. Optimum outcome achievement in partial nephrectomy for T1 renal masses: a contemporary analysis of open and robot-assisted cases. BJU Int. 2017;120(4):537–43.
41. Kaouk JH, Khalifeh A, Hillyer S, Haber G-P, Stein RJ, Autorino R. Robot-assisted laparoscopic partial nephrectomy: step-by-step contemporary technique and surgical outcomes at a single high-volume institution. Eur Urol. 2012;62(3):553–61.
42. Jordan BJ, Matulewicz RS, Trihn B, Kundu S. Venous thromboembolism after nephrectomy: incidence, timing and associated risk factors from a national multi-institutional database. World J Urol. 2017;35(11):1713–9.
43. Kara O, Zargar H, Akca O, Andrade HS, Caputo P, Maurice MJ, et al. Risks and benefits of pharmacological prophylaxis for venous thromboembolism prevention in patients undergoing robotic partial nephrectomy. J Urol. 2016;195(5):1348–53.
44. Packiam VT, Nottingham CU, Cohen AJ, Pearce SM, Shalhav AL, Eggener SE. The impact of perioperative aspirin on bleeding complications following robotic partial nephrectomy. J Endourol. 2016;30(9):997–1003.
45. Pradere B, Peyronnet B, Seisen T, Khene Z, Ruggiero M, Vaessen C, et al. Impact of anticoagulant and antiplatelet drugs on perioperative outcomes of robotic-assisted partial nephrectomy. Urology. 2017;99:118–22.
46. Shapiro EY, Ari Hakimi A, Hyams ES, Cynamon J, Stifelman M, Ghavamian R. Renal artery pseudoaneurysm following laparoscopic partial nephrectomy. Urology. 2009;74(4):819–23.
47. Meeks JJ, Zhao LC, Navai N, Perry KT, Nadler RB, Smith ND. Risk factors and management of urine leaks after partial nephrectomy. J Urol. 2008;180(6):2375–8.
48. Yamamoto T, Kinoshita H, Ikeda J, Sugi M, Matsuda T. Refractory urinary fistula with infundibular stenosis after partial nephrectomy. Int J Urol. 2015;22(2):219–21.
49. Maurice MJ, Zhu H, Kim SP, Abouassaly R. Reexamining the association between positive

surgical margins and survival after partial nephrectomy in a large american cohort. J Endourol. 2016;30(6):698–703.
50. Shum CF, Bahler CD, Sundaram CP. Impact of positive surgical margins on overall survival after partial nephrectomy—a matched comparison based on the National Cancer Database. Urol Oncol. 2018;36(3):90.e15–21.
51. Shah PH, Moreira DM, Okhunov Z, Patel VR, Chopra S, Razmaria AA, et al. Positive surgical margins increase risk of recurrence after partial nephrectomy for high risk renal tumors. J Urol. 2016;196(2):327–34.
52. Yossepowitch O, Thompson RH, Leibovich BC, Eggener SE, Pettus JA, Kwon ED, et al. Positive surgical margins at partial nephrectomy: predictors and oncological outcomes. J Urol. 2008;179(6):2158–63.
53. Permpongkosol S, Colombo JR, Gill IS, Kavoussi LR. Positive surgical parenchymal margin after laparoscopic partial nephrectomy for renal cell carcinoma: oncological outcomes. J Urol. 2006;176(6):2401–4.

Robotic-Assisted Radical Cystectomy

7

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Introduction

The role of robot-assisted radical cystectomy (RARC) in the treatment of bladder cancer is expanding. Advocates suggest that this minimally invasive operation offers reduced blood loss, less pain, and the promise of shorter hospitalizations with fewer complications and equivalent oncologic outcomes. Most of these putative advantages have yet to be demonstrated and are balanced against the increased up-front cost of the robotic platform and longer operative times. Nevertheless, the evidence available to date suggests a robust future for this relatively new technology.

Modern radical cystectomy with lymph node dissection, as described by Marshall and Whitmore in 1949, has been associated with high complication rates. In that pioneering report of six patients, two expired of surgical complication before leaving the hospital and at least another two had significant morbidity [1]. Since that time, the application of improved operative and in-hospital strategies and care pathways has resulted in decreased mortality and morbidity, but modern series of open radical cystectomy (ORC) continue to be plagued by significant complication rates. When the standardized Clavien-Dindo [2] complication reporting scale is strictly applied, open cystectomy complication rates at centers of excellence reach into the 60–70% range [3]. Other high-volume centers have reported lower rates, albeit in the absence of a standardized reporting system [4].

History of Minimally Invasive Cystectomy

Since the first reported pure laparoscopic cystectomy in 1995 [5, 6] and then the robotic approach in 2002 [7], an increasing number of series have been published. Early retrospective series suggested a possible benefit to robotic approach, and very few data reporting RARC outcomes to be inferior to open cystectomy in clinical or oncologic efficacy. Usage of the robotic platform for cystectomy increased, and large non-randomized database assessments continued to show non-inferiority of this approach [8]. More recently, a number of randomized controlled trials (RCTs) have been completed, confirming those early suggestions of oncologic equivalence, but not showing a clear benefit to performing the extirpative portion of the operation with robotic assistance [9].

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S. L. Best, S. Y. Nakada (eds.), *Minimally Invasive Urology*,
https://doi.org/10.1007/978-3-030-23993-0_7

Seminal Randomized Controlled Trials to Date

Memorial Sloan Kettering Cancer Center prospectively randomized 118 patients between 2010 and 2013 to RARC with extracorporeal diversion or ORC. Assessing the primary endpoint of Clavien-Dindo grade 2–5 complication rates, no difference was found between ORC and RARC in their hands. This similarity was extended to include length of stay, margin status, nodal yield, and cost where no significant difference was found for any parameter.

The larger, multicenter "RAZOR" trial analyzed 302 randomized patients from 2011 to 2014 that were operated on by experienced surgeons at multiple institutions and all of whom again underwent extracorporeal diversion in both arms [10]. These patients showed no differences in the primary outcome of cancer-specific survival and overall survival at 2 years. Additionally, there was no difference in positive margins, nodal yield, recurrences, or quality-of-life measures. As with virtually all other comparative studies, RARC took longer to complete (over 7 h compared to 6) and conferred lower blood loss (300 cc vs. 700 cc) and a lower transfusion rate (24% vs. 45%) [10]. A slightly shorter length of stay was observed in the robotic cystectomy arm (6 days vs. 7 days) of this trial.

These trials and others [11, 12] support noninferiority of RARC compared to ORC. With expert surgeons on both sides, no difference is seen in complication rates, but the consistent finding of lower blood loss, lower transfusion rate, and perhaps shorter stay, with equivalent oncologic and QOL outcomes, continues to support further study and usage of the robotic platform in radical cystectomy. Data distinguishing potential benefits of the robotic platform itself from anticipated top-tier outcomes in the hands of experts regardless of approach remain to be gathered. No RCT to date has included intracorporeal urinary diversion, and given that the majority of complications in cystectomy associate with bowel manipulation, significant benefits may yet be recognized with intracorporeal urinary diversion and maturation of the technology. It bears noting that the benefit of lower blood loss appears to occur as a direct result of the robotic surgical approach: not only is this effect essentially universal to laparoscopic surgery of all types, but it accrues immediately and without the learning curve that is necessary for other markers of quality cystectomy such as surgical time, margin status, and lymph node yield [13].

Unanswered Questions

Experienced robotic surgeons can perform intracorporeal ileal conduit as rapidly and safely as open [14], and single-center comparisons suggest that RARC with intracorporeal neobladder may be superior, at least in some ways, to ORC with neobladder [14, 15]. RCTs such as the upcoming iROC [16] are desperately needed to better answer the question of benefit from performing the bowel diversion intracorporeally. Assessments of cost benefit are difficult to extrapolate beyond any single institution, but in light of the cost of treatment of surgical complications, there exists potential to be cost-effective despite higher upfront costs if RARC, with or without intracorporeal diversion, results in decreased complications. It bears mentioning that one analysis suggested that the cost of a single complication of cystectomy adds $27,936 to the bill [17], while the incremental cost of the robotic system was found to be $1640 in a contemporaneous report [18].

Guidelines have been established that can be used to assess quality of cystectomy and associated lymph node dissection, regardless of approach. Herr et al. and the Bladder Cancer Collaborative Group evaluated the collective experience of 16 experienced surgeons from 4 major institutions and proposed standards for radical cystectomy and pelvic lymph node dissection [4]. For experienced surgeons, defined as performing at least ten radical cystectomy surgeries per year, surgical quality benchmarks were negative surgical margins in >90% of cases and extirpation of a mean of 10–14 nodes, recognizing that such standards will not be met in some of the most difficult cases.

Whether the operation is performed through a minimally invasive approach (robotic or laparoscopic) or open surgical approach, the principles of radical cystectomy remain the same. Surgeons are accountable for surgical margins, extent of node dissection and both serve as quality metrics, which have been proven to correlate with bladder cancer survival outcomes.

It is worth noting that most series of RARC well exceed these guidelines for margin status and nodal collection (positive margins under 10% and greater than 10 lymph nodes collected). Undoubtedly, case and patient mix will impact any surgeon or institution's outcomes.

Surgical Indications and the Learning Curve

Urothelial carcinoma that is invasive or superficial disease resistant to intravesical treatment are the primary indications for radical cystectomy. The possibility of decreased surgical morbidity, blood loss, or at minimum improved patient perception may allow for higher utilization of "early" cystectomy in cases of high-grade superficially invasive disease, an indication that is commonly underutilized.

Learning Curve

Similar to all surgical procedures, robotic cystectomy has a learning curve. One assessment suggested that complication rates decrease after 20 cases while blood loss, margin status, and lymph node yield were constant across higher versus lower tertiles of case volume in the hands of surgeons already experienced in ORC [19]. Roswell Park Cancer Center [20] and the International Robotic Cystectomy Consortium database [13] both show a clear decrease in surgical time that is associated with a surgeon's completing 20 cases; interestingly this was achieved at Roswell Park Cancer Center despite increasing time being devoted to the LND and resulting higher nodal yields. Some of the earliest cases in both those reports lasted over 10 h in total operative time, but improvements may appear rapidly and one excellent study showed that after 21 patients average operative time reached 390 min, and decreased by 27 min for each subsequent 10 patients [13]. After 30 cases, a mean lymph node count of 20 can be surpassed and will continue to climb; interestingly, blood loss remains almost entirely constant across all experience levels, suggesting a specific benefit of this technology that functions independently of surgeon.

A significant element in the operative speed may be surgical team improvement as familiarity with the steps of the case increases. A stepwise approach to learning RARC is appropriate, beginning with an initial focus on safe and expedient extirpation of the bladder and lymph nodes with attention to achieving surgical positive margin rates under 5–7% (15% in T3+) and lymph node yields of 20. These parameters, as well as 90-day complication rates and QOL metrics, should be reviewed as the program reaches 20–30 patients in volume, and at intervals thereafter, to assure quality. In a surgeon's early experience, especially those with less experience with RALP, case selection ought to be confined to lower body mass index (BMI) patients and those without significant indicators of frailty or pulmonary compromise.

Patient Selection The selection of robotic versus open approach is clearly best assessed in the context of each individual surgeon and team experience. Comparative outcomes are still hard to assess at this relatively early point in the track record of robotic cystectomy, but it is worth noting that in virtually all published series robotic cystectomy takes longer to perform than open but is associated with notably lower blood loss.

Obesity Laparoscopic surgery is generally suitable for the obese, although the ventilatory challenges of the Trendelenburg position can be prohibitive in certain patients. An initial assessment of ventilator pressures in the Trendelenburg position is critical, especially in patients at risk of extended surgical times. Extra-long trocars may be helpful. Butt et al. showed outcomes were not different between BMI under 25 and those above 30, although they found the positive margin rate

to be higher for obese patients compared to non-obese when confronted with higher T-stage disease [21]. Results from one large database suggest a small but statistically significant additional risk of complication in those with a BMI over 30 [22]. Surgeon and institutional experience should guide patient selection.

Prior Surgery Prior surgery was initially viewed as a relative contraindication to laparoscopic abdominal entry and surgery [23]. As experience has grown, those relative contraindications have been overcome. Groups have reported success with robotic-assisted approaches in virtually all challenging situations, including cystectomy in the presence of prior ostomy [24].

Neoadjuvant Chemotherapy Neoadjuvant chemotherapy is a level 1 recommendation in many cases of MIBC [25]. Additional consideration for neoadjuvant chemotherapy should be given to those with high-grade T1 disease with lymphovascular invasion and variant histology. Robotic cystectomy may also allow for earlier initiation and increased usage of adjuvant therapy, although these measures have not been studied in a randomized trial.

The Elderly Muscle invasive cancer is primarily a disease of the elderly. Despite large series showing that radical cystectomy is feasible, safe, and remains the most effective modality for the treatment of MIBC in patients over the age of 80, use of this modality is lower than in younger counterparts [26]. While surgical selection is undoubtedly more challenging in the truly elderly, patients lacking severe co-morbidities should be considered for this operation. Paradoxically, some newer reports suggest that RARC may be particularly well suited to the elderly [27]. This may be directly related to the nearly universal finding of lower blood loss and presumably decreased fluid shifts with the robotic approach when compared to open.

Frailty Frailty in the older adult is closely related to surgical complications, including increased length of stay, readmission rates, increased health care needs, and mortality [28], and regardless of surgical approach, usage of one of the available frailty index tools is advisable for appropriate patient selection and counseling as all variables interact. The Fried Frailty Index (FFI) [29] and the Eastern Cooperative Oncology Group (ECOG) performance status have been shown to stratify cystectomy candidates to risk of complications. The FFI is based on five categories: grip strength, gait speed, physical activity, unintentional weight loss, and the feeling of exhaustion; 2–3 positives is moderately frail while 4–5 defines frail. Serum albumin and lumbar skeletal muscle index as a measure of sarcopenia have both been shown to function independently of the ECOG score to predict outcomes [30, 31]. Of note, the physical activity domain of the FFI was strongly associated with avoidance of complications; whether behavioral intervention in the preoperative period can improve outcomes is unclear but certainly seems unlikely to hurt.

Prior Radiotherapy Robot-assisted salvage prostatectomy after failed local radiotherapy has been shown to be not only feasible but in at least some hands able to produce results that are superior to open prostatectomy in similar conditions [32]. Salvage open cystectomy after failed curative radiotherapy for bladder cancer appears feasible but has been associated with a significant complication rate; one series found a 16% 3-month mortality rate and an tripling of anastomotic leaks at 9% compared to 3% in non-radiated patients [33]. In another series LND was performed in only 48% by surgeon preference and presumably represents the increased difficulty of perivascular dissection in the postradiation setting [34]. A report addressing ORC after 60Gy or more of pelvic radiation showed 32% likelihood of Clavien-Dindo Grade 3–5 complications at 90 days and an overall complication rate of 77% [35]. These are higher than most contemporary non-radiated series but appear reasonable in this setting.

Given the apparent feasibility of robot-assisted prostate surgery after radiation, the extension of the operation to include the bladder in this same situation seems reasonable, especially given the decreased need for urethral anastomotic reconstruction in the setting of conduit urinary diver-

sion. In experienced hands this may prove to be an appropriate therapy [36]. The International Robotic Cystectomy Consortium database recorded 15 cases of postradiation RARC representing just 2% of the total recorded patients [22]. Specific outcomes are not reported for these patients, however, preventing conclusions. In our experience, the operation is feasible but technically challenging; centers possessing experience with salvage robot-assisted prostatectomy will likely be comfortable with this operation.

Palliative Cystectomy Palliative cystectomy is a poorly studied area of this disease. Appropriate indications for this operation are poorly defined but include persistent hemorrhage and avoidance of pelvic morbidity. The balance of surgical risk to benefit for this major operation is difficult to calculate, but palliative cystectomy is generally best applied to younger patients with significant ongoing morbidity from localized tumor, in the setting of adequate functional and nutritional status. One smaller series addressing cystectomy in patients over 75 years of age included seven cystectomies for palliative indications such as intractable hematuria and pain. These patients experienced a much higher morbidity and a 29% in-hospital mortality when compared to the curative-intent cohort, but no attempt was made to compare them to non-operated counterparts [37]. Other reports in the open surgical literature show acceptable results for palliative cystectomy managed with cutaneous diversion and avoidance of bowel resection [38]; whether these challenging cases are appropriate for a robotic approach remains unstudied.

Lymph Node Dissection

Pelvic lymph node dissection (PLND) is a critical component of high-quality surgery for bladder cancer, serving as a diagnostic and therapeutic procedure [39]. Multiple large series have demonstrated that performing PLND contributes to improved survival in patients with bladder cancer, although one recent population-based report suggests that in those receiving neoadjuvant chemotherapy the survival benefit of lymphadenectomy may be obviated in comparison to those not receiving chemotherapy [40, 41]. The optimal extent of PLND and best outcome measures of PLND quality continue to be debated and studied: a standard PLND is defined as removal of lymph tissue up to the common iliac bifurcation to include the internal iliac, obturator, and external iliac lymph nodes [42]. Extended PLND is generally described to include the standard template as well as lymph nodes up to the aortic bifurcation, laterally to the genitofemoral nerve, distally to the node of Cloquet, and including the presacral lymph nodes [43].

Evidence of therapeutic benefit for extended vs. standard PLND remains unclear, given the many variables to consider. As of this writing, one prospective randomized trial of extended versus standard (aka "limited") lymphadenectomy template at cystectomy for urothelial carcinoma has been performed: 401 patients were randomized to limited versus extended LND, all without neoadjuvant chemotherapy. Despite substantially higher lymph node yield with extended template (31 extended vs. 19 with limited template) there was not a statistically significant difference in recurrence-free survival between groups [44]. Anatomical boundaries are depicted in Fig. 7.1; nomenclature of these boundaries in the literature varies. While data regarding outcomes continue to be gathered, the authors recommend at a minimum the standard template be carefully performed on all appropriate patients.

Many authors have proposed that lymph node yield may indeed be a surrogate of surgical quality since it correlates with survival outcomes [45]. However, consensus opinions on the superiority of survival outcomes in extended PLND note the low level of evidence, but cite the improved diagnostic results and trend toward improved disease-free survival in extended PLND [46].

The ability of robotic surgery to recapitulate the technique of open PLND has been investigated. In a study by Davis et al., the authors performed robotic extended PLND for bladder cancer in 11 patients with open extended PLND performed directly afterward in the same patients [47]. In 80% of patients, no additional lymph nodes were detected with the open technique,

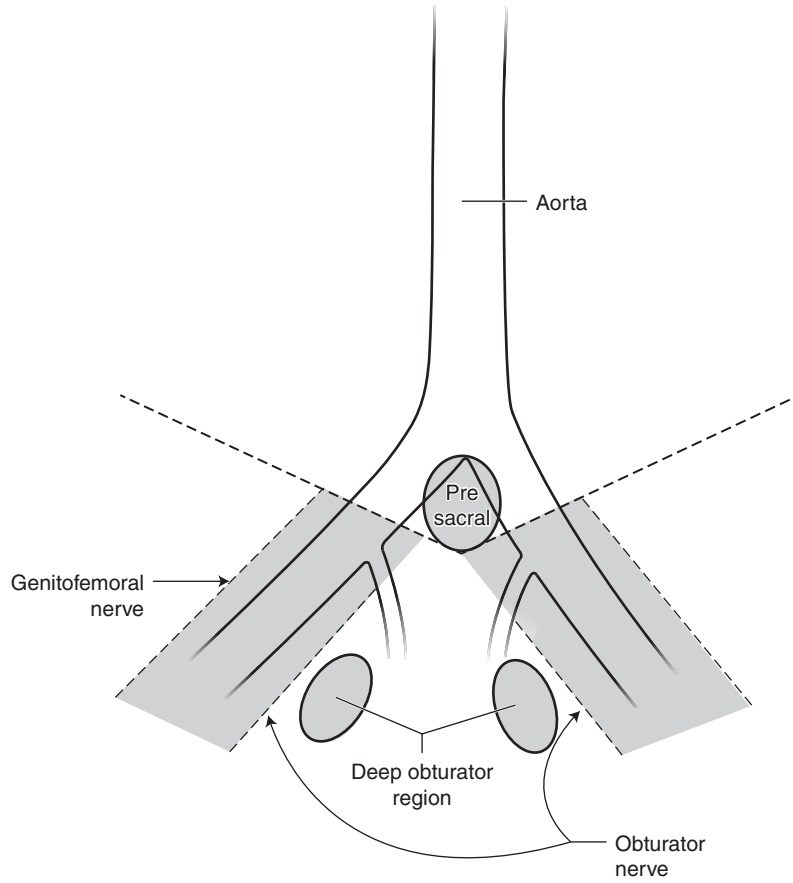

Fig. 7.1 Representation of the regions and boundaries of the recommended lymphadenectomy

verifying that a high-quality dissection is possible using a robotic technique. Although the indications and benefit of extended PLND will continue to be debated, it appears that robotic PLND can provide a similar lymph node dissection to open techniques.

Preoperative Assessment and Preparation

Enhanced recovery after surgery (ERAS) protocols have improved surgical outcomes in cystectomy. No specific protocol has been shown superior to others, but most share similar features. ERAS generally includes a combination of: pre-habilitation as possible, avoidance of bowel prep, carbohydrate and oral fluid loading up to 2 h before surgery, oral mu-opioid receptor blocker if available, immediate postoperative removal of nasogastric tube and minimization of drains, chewing gum, and rapid resumption of oral intake. Most of these interventions have been studied independently, and as an integrated protocol they appear to offer synergistic benefit [48, 49]. These interventions have been associated with decreases in LOS, complications and earlier return of bowel function, and the authors recommend an institutional adoption of such a program [50]. Core elements of our protocol are shown in Table 7.1.

Robot-Assisted Radical Cystectomy

Equipment List

(Note that requirements for intracorporeal diversion are not included here.)

1. Da Vinci surgical system (Intuitive Surgical, Sunnyvale, CA) – “Si” or “Xi” recommended

Table 7.1 Core elements of *enhanced recovery after surgery* (ERAS) program

Initial meetings	Smoking cessation Frailty assessment Social support assessment Nutritional assessment. Add one serving of nutritional shake per day in at-risk patient Encourage exercise, increased walking, steps, physical therapy/organized programs as possible Stomal therapy visit and marking
Perioperative	No bowel prep Carbohydrate loading. Clear sugary liquids up to 2 h before surgery Alvimopan per os in pre-op area SQ heparin
Intraoperative	Avoidance of fluid overload Remove gastric tube at end of operation Consider chewing gum in evening In chair in the evening Antimicrobial prophylaxis (cefoxitin) for 24 h only Low molecular weight heparin after surgery, continue for 30 days Long-acting local anesthetic in ports; transverse abdominus block or epidural if open Minimization of narcotic and sedative usage
Postoperative day 1–3+	Alvimopan bid Scheduled ketorolac 15 mg IV q 6 h × 3 days if renal function permits Send drain fluid for creatinine on postoperative day 2; if equivalent to serum, remove drain PT, OT consultation; vigorous and frequent walking

SQ Subcutaneous, *PT* physical therapy, *OT* occupational therapy

2. Veress needle or access device of choice, 2 × 10/12 mm disposable ports, 3 × 8 mm robotic ports, 5 mm assist port
3. Da Vinci instruments – Monopolar da Vinci scissors, bipolar fenestrated grasper, 2× da Vinci Large Needle Driver. Consider da Vinci vessel sealer if available Fourth arm – "Prograsp" graspers
4. Hem-o-lok clip appliers (2) with large clips
5. Laparoscopic vascular staplers, articulating, "45" and "60" as desired
6. Suture:
   (a) Male: 2-0 Vicryl (Ethicon, Somerville, NJ) on rb-1 and SH as needed and as surgeon preference for dorsal venous complex
   (b) Female: same as male, likely will need 9″ 2-0 Vicryl on SH for repair anterior vaginal wall
   (c) Other: we recommend having a 4-inch, 4-0 Prolene on Rb-1 with Lapra-Ty (Ethicon) pre-affixed in the event of vascular/venous injury during lymphadenectomy
7. 5 mm suction irrigator (long)
8. Appropriate open surgical equipment for performance of diversion.
9. Port closure device for 12 mm ports, if desired

Technique

Positioning

Patients are positioned supine. In order to secure the patient to the table in Trendelenburg position, the use of chest straps or direct skin-to-gel adhesion may be utilized; we prefer the Pink Pad system (Xodus Medical, New Kensington, PA). Skin-to-gel positioning is effective, but for longer cases can be associated with skin traction burns on the patient's back if steep Trendelenberg is used. If intracorporal diversion is contemplated, shallower Trendelenberg will facilitate bowel manipulation without gravitational effects pulling the bowel cephalad and out of the robotic operative field. Alternatively, surgical beds that

allow repositioning while docked may enhance surgical access during different phases of the operation if necessary (Trumpf Medical, Saalfeld, Germany).

If docking from between the legs, the legs are separated on orthopedic spreader bars or placed in low lithotomy in well-padded stirrups; the thighs should be close to parallel to the abdomen to minimize distortion of the pelvic floor. Alternatively, side docking with the Xi system may be performed with the patient supine. Orogastric/nasogastric tubes and bladder drainage catheter are placed.

Ports

When planning extracorporeal urinary diversion, port placement may be performed similarly to that utilized in robotic-assisted prostatectomy but modified a few centimeters cranially to give better access to the upper pelvic vessels for thorough lymph node dissection. If contemplating intracorporeal diversion, please refer to *Continent Urinary Diversion (Orthotopic Ileal Neobladder)* below for different port placement.

Our approach to male cystectomy occurs in a stepwise fashion as follows:

1. *Ureteral identification and dissection*

Beginning on the right, the ureters are identified at the level of the common iliac artery (Fig. 7.2). This may be used as the superior boundary for lymph node dissection template at a later point if desired. Using great care to preserve vascular tissue around the ureter as much as possible, the ureter is dissected free for a small distance above the vessels and followed into the deep pelvis to the ureterovesical junction (Fig. 7.3). Small feeder vessels originating from the iliac system are usually encountered and controlled with cautery; caution is important to avoid any cautery effect on or near the ureter and the associated extramural longitudinal blood supply. An identical procedure is completed on the contralateral side; maximization of length and blood supply on the left side are especially important given the need for tunneling at a later date. The left ureter should be mobilized a few centimeters above the common iliac artery to facilitate easy passage beneath the sigmoid colon later in the procedure.

2. *Completion of posterior plane*

Once the ureters are freed to their hiatus with the bladder, the peritoneal incisions are connected and the retrovesical space developed behind the bladder. Ureters may be tagged, clipped and cut at this point; we prefer to leave them intact to assist with orientation. Dissection proceeds carefully behind the bladder and seminal vesicles to the level of the prostate; the Denonvillier fascia is traversed and at the level of the prostate the pre-rectal yellow fat is identified, and the rectum carefully dissected free from the

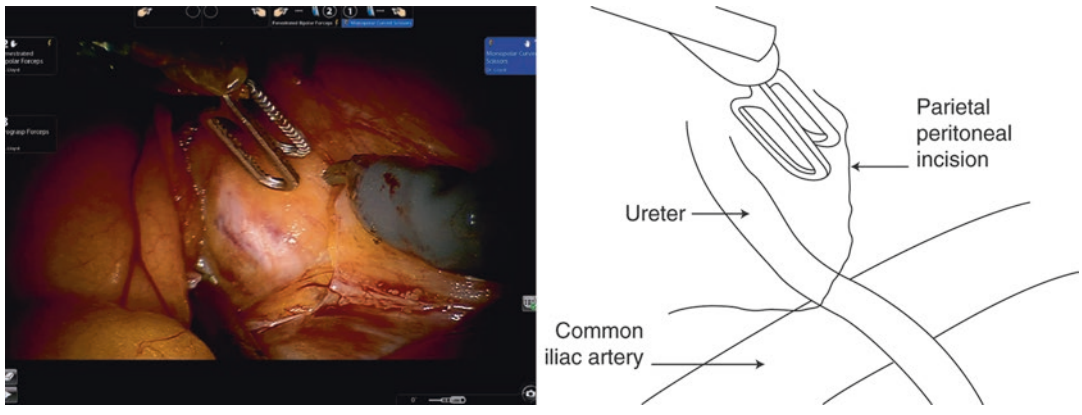

Fig. 7.2 The parietal peritoneum is incised and the ureter on the right is identified as it crosses the common iliac artery

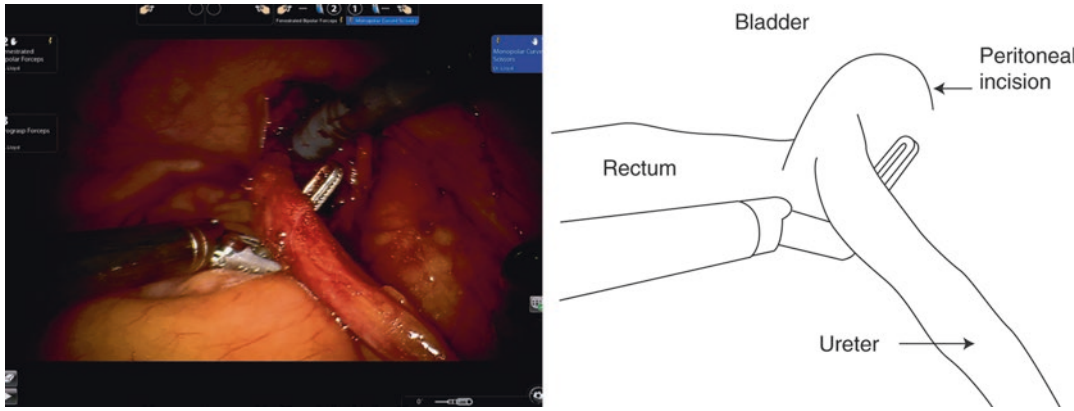

Fig. 7.3 The ureter is circumferentially freed with maximal preservation of periureteral tissue and dissected to the hiatus of with the bladder

prostate as far as possible in the distal direction. Vasa deferentia are clipped and cut, the small arterial branches to the seminal vesicles are carefully controlled with clips or cautery as appropriate. The lateral bounds of this dissection are the vascular pedicles of the bladder and prostate, beginning with the superior vesical artery. Great care is taken to widely establish separation between the rectum and bladder to minimize chances of rectal injury.

3. *Lateral space creation*

Delineation of the lateral aspects of the bladder and vascular pedicles is performed at this point. The goal of this step is the identification of the vascular pedicles. Peritoneal incision is performed along the lateral aspect of the medial collateral ligament, with care taken to leave the anterior suspension of the bladder intact. Early release of the anterior bladder support will significantly increase difficulty in posterior dissection from the loss of bladder support and should be avoided. The lateral incisions are connected to the posterior incision to form a "u" and the space lateral to the bladder freed distally to the endopelvic fascia and nerve sparing/prostatic fascial release performed if nerve sparing is desired. Even with anterior anatomical support intact, the "fourth arm" can be well utilized to additionally retract the bladder so as to provide stretch on the pedicles and facilitate dissection. The endopelvic fascia is released in the fashion of radical prostatectomy. Next, the medial umbilical ligaments are transected close to their junction with the internal iliac artery. The ureters are doubly clipped, divided and tucked into the upper abdomen well away from the operative field (Figs. 7.4 and 7.5). We recommend Hem-o-Lok clips (Teleflex Medical, Research Triangle Park, NC, USA) with a color-coded 10″ suture tied to the heel of the clip that is applied proximally to facilitate manipulation of the ureter through a smaller incision at diversion.

4. *Takedown of vascular pedicles*

Many different technologies are available for safe control of the superior vesical artery and vascular pedicles of the bladder. Clips, laparoscopic stapling devices and direct ablation with other hemostatic technology can be employed at surgeon discretion (Fig. 7.6). As in prostatectomy, adequate distal division of attachments facilitates mobility and completion of the apical dissection. A group at Vanderbilt compared the similar LigaSure Impact device (Medtronic, Minneapolis, MN) to stapler use and found no difference in blood loss and a simplification of vascular control during cystectomy [51].

5. *Control of dorsal venous complex*

The balance of anterior bladder suspension is now released and the anterior space of Retzius dissected. In men, the dorsal venous complex is controlled after placement of 1–2 securing

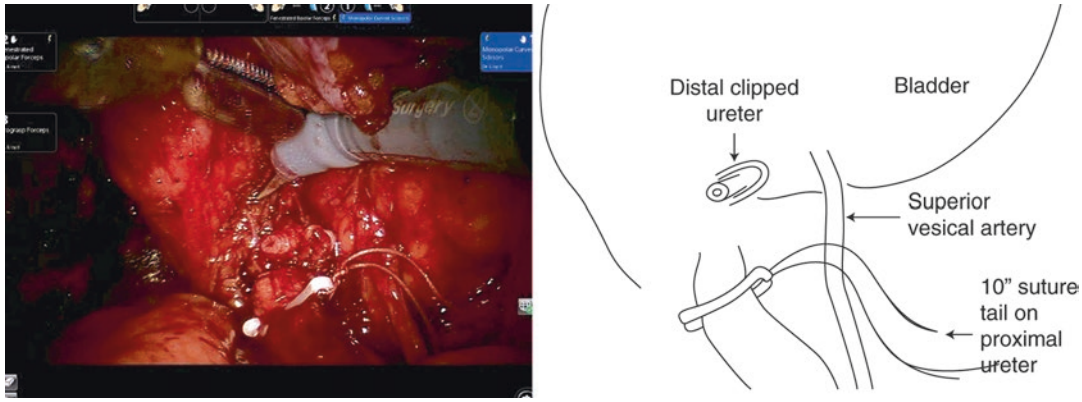

Fig. 7.4 Once the posterior and lateral spaces have been adequately developed, the ureter is doubly clipped and transected. For extracorporeal diversion, the clip on the proximal ureter is tagged with a 10″ 3-0 Vicryl for identification and manipulation

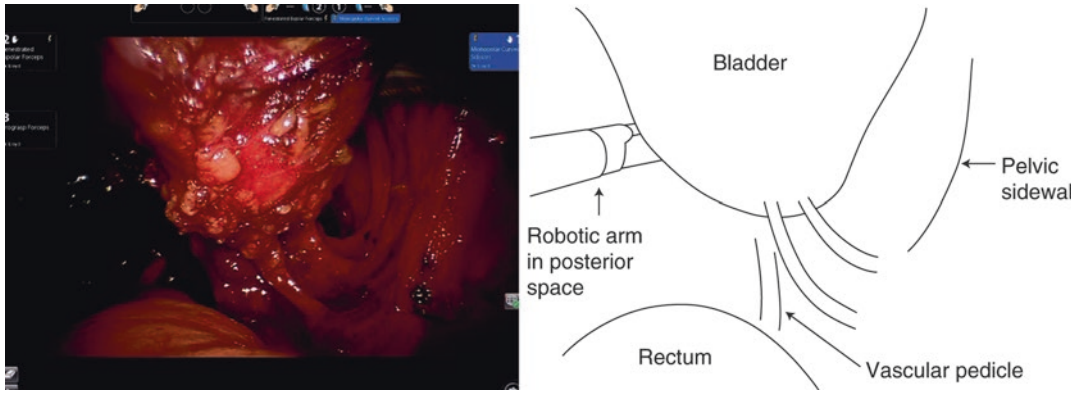

Fig. 7.5 With the ureter tucked into the upper abdomen, the rectum is dissected posteriorly away from the bladder and the vascular pedicle is identified

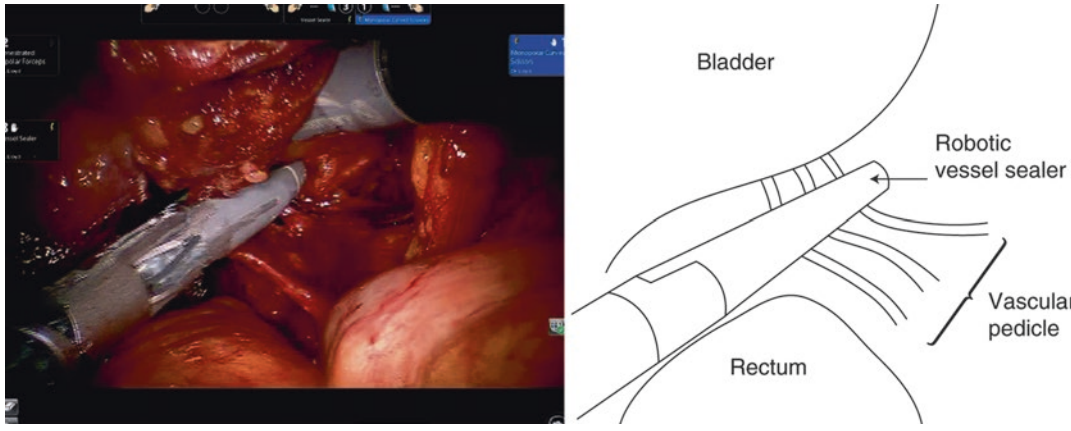

Fig. 7.6 Once the upper portion of the vascular pedicle is isolated, it can be clipped or cauterized at surgeon preference. This is shown here with the robotic vessel sealer

sutures in the fashion of a radical prostatectomy. Placement of the suture through the pubic ostium as during prostatectomy may stabilize the urethra for neobladder procedures. A vascular stapler may be utilized alternatively.

6. *Dissection of urethra*

The urethra is dissected free. If neobladder is planned, care is taken to preserve adequate urethral length. The urethral catheter is removed. The bladder side of the specimen is controlled with a Hem-o-Lok clip to prevent spillage of contents during transection. If ileal conduit is planned, the urethra is dissected as far distal as possible. The stump is carefully oversewn or clipped with a Hem-o-Lok clip to prevent persistent urethral leakage of peritoneal fluid or future urethrectomy if needed. The specimen is freed and placed in a large bag; we prefer the 12 mm Inzii device (Applied Medical, Rancho Santa Margarita, CA, USA) as it allows use of smaller 12 mm ports with full bag size.

7. *Lymph node dissection*

Lymph node dissection is completed as described above. The specimen is placed in a separate smaller bag or removed with via reusable endocatch bag. Clips and energy are utilized selectively to decrease risk of lymph leak. In high-risk cases, or those felt likely to benefit from extended dissection, LND can be carried as high as the level of the inferior mesenteric artery on the aorta.

Creation of Extracorporeal Urinary Diversion

For ileal conduit, diversion may be performed either intracorporeally or extracorporeally. For surgeons newer to RARC, extracorporeal diversion is familiar and expedient. Once the lymphadenectomy has been completed, the ureters are recovered from where they have been tucked in the upper quadrants and good mobility verified. Ideally, freedom that extends a short distance above the common iliac artery will be available, especially on the left side.

The ileum and ileocecal junction should be identified; a pre-measured suture can be utilized to march out 15–20 cm of terminal ileum and a long tagging suture of 3-0 silk placed in the serosa at the distal extent of the anticipated conduit. This is left full length to allow easy extraction through a small incision. Any attachments of the cecum that may hamper terminal ileal freedom are taken down.

Next, the ureter must be passed behind the sigmoid at roughly the level of the sacral promontory. With the colon gently retracted anteriorly, a passageway can usually be developed by gently manipulation behind the incised retroperitoneum. Care should be taken to avoid vascular injury when crossing the midline, especially in the setting of aneurysmal dilatation or ectasia. Once an instrument has been easily passed from right to left and a generously sized space created behind the colon, the left ureteral tagging suture is grasped, and the ureter pulled through to the right where it can be again assessed for adequate length and freedom. Alternatively, left ureteral passage can be accomplished open, although this often requires a larger abdominal incision.

Once both ureters lie in the right paracolic gutter and the terminal extent of planned conduit is tagged, all three tagging sutures are placed in a needle driver through an assist port and secured in place. The robot is undocked, and table taken out of Trendelenberg; a small incision is made in the sub-umbilical midline and all tagging sutures passed out it. The small bowel is pulled up, and bowel resection performed to provide an adequate conduit of roughly 15 cm without unnecessary redundancy. It has been our preference to mature the ostomy at the pre-marked site prior to performing the uretero-enteric implantation. Once this is done, spatulated ureteral implants of roughly 1.5 cm are made with urinary diversion stents inserted via the matured ostomy and up each ureter. Interrupted 4-0 Monocryl (Ethicon) used for implantation with great care taken to avoid any trauma to the distal ureter. A 4-0 chromic suture is used to secure the stent to the mucosa of the ostomy. At this point a closed-suction drain is gently placed in the pelvis through a lateral port site, the fascia and incision are closed, and the patient taken to recovery.

Creation of Intracorporeal Urinary Diversion

Setup

If the DaVinci Xi robot is available it is preferred for neobladders because repositioning is easier, although both can be done on the Si. Port placement and instrument positioning is key to successful urinary diversion, port placement is shown in Fig. 7.7. The most important port is the right robotic arm, placing this high/cranially allows for bowel work to be completed over the area of the distal ileum with minimal instrument clashing.

The stoma should be marked preoperatively. It is not necessary to have a port site be the same at the stoma site.

Mobilization of the colon, including cecum, at the beginning of the case is useful later on when preparing to perform urinary diversion.

The presacral dissection allows for the urinary diversion to be done with ease later on. If no presacral dissection has been done, then the area between the sigmoid mesentery and bifurcation of the aorta needs to be developed in order to facilitate the urinary diversion.

The bowel should be brought into the pelvis and splayed out such that the mesentery is in the center and the bowel is surrounding (Fig. 7.8).

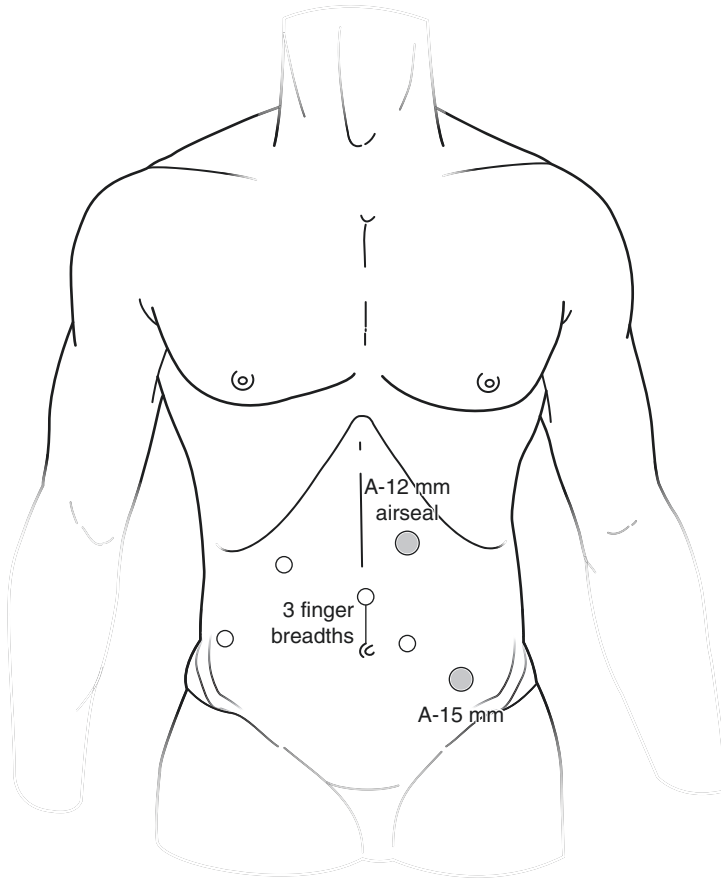

Fig. 7.7 Port placement for robot-assisted cystectomy. Note the cranial placement of especially the right surgical arm to facilitate intracorporeal diversion. This may not be necessary if extracorporeal diversion is planned

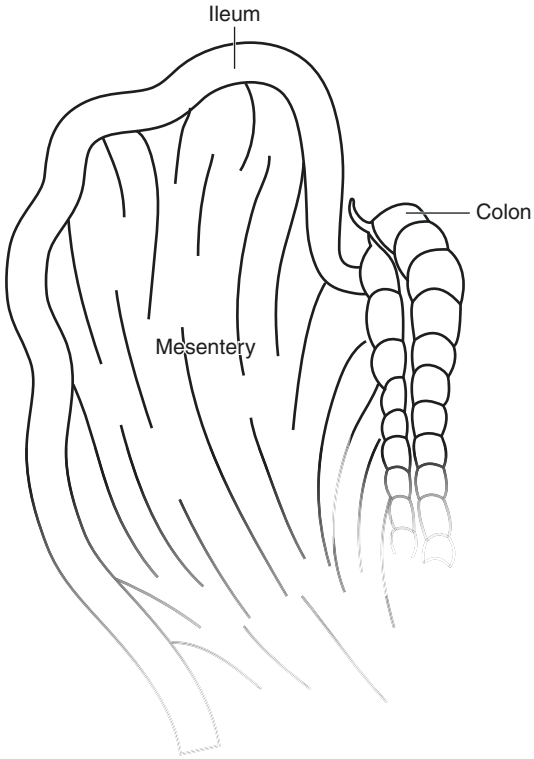

Fig. 7.8 Bowel is carefully arranged for measurement and selection of segment that will easily reach the abdominal wall. A premeasured segment of free suture may be used for selection

All staplers may be brought in from the lateral assistant port.

Non-Continent Urinary Diversion (Ileal Conduit)

The ileal conduit steps can be divided into the following steps:

1. Bowel segment harvest
2. Reestablishment of bowel continuity
3. Passage of the conduit posterior to the sigmoid
4. Ureteral anastomosis
5. Stomal delivery and maturation

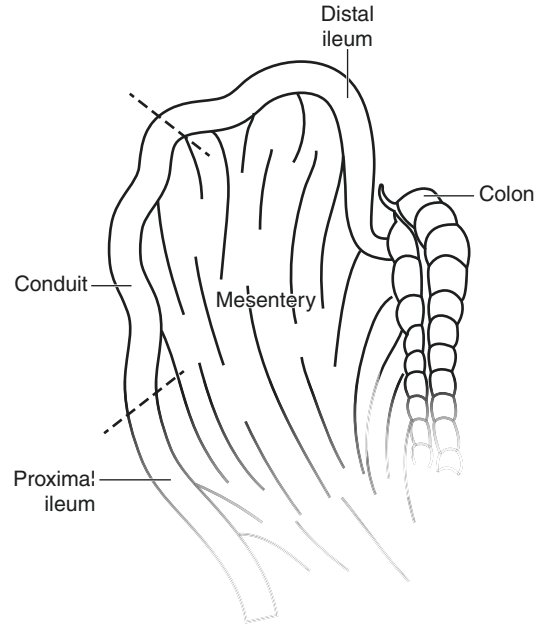

Fig. 7.9 Initial section of bowel chosen for ileal conduit is selected and distal aspect stapled with the 60 mm stapler. Additional mobility can be achieved with additional stapling into mesentery while using care not to devitalize other segments

1. The ileal conduit is harvested at or greater than 15 cm from ileocecal valve, with preference to the section that reaches the ostomy site and ureters most easily. A measured purple absorbable suture is placed in the abdomen. This suture should be pre-cut to 10–15 cm depending on the length needed to make the conduit (a little longer for larger patients).
2. Once the conduit segment is isolated, the proximal portion is taken with a 60 mm load of a three-row stapler (Endo GIA, Medtronic). This is taken into the mesentery. If additional mesentery mobilization is needed one can use a second 45 mm load of staples. Ensure that the mesentery is straight (see Fig. 7.9).
3. Place a Hem-o-Lok clip on the side that will be the stoma portion to mark the conduit. Then take the distal ileal portion with an additional 60 mm staple load (Fig. 7.10).

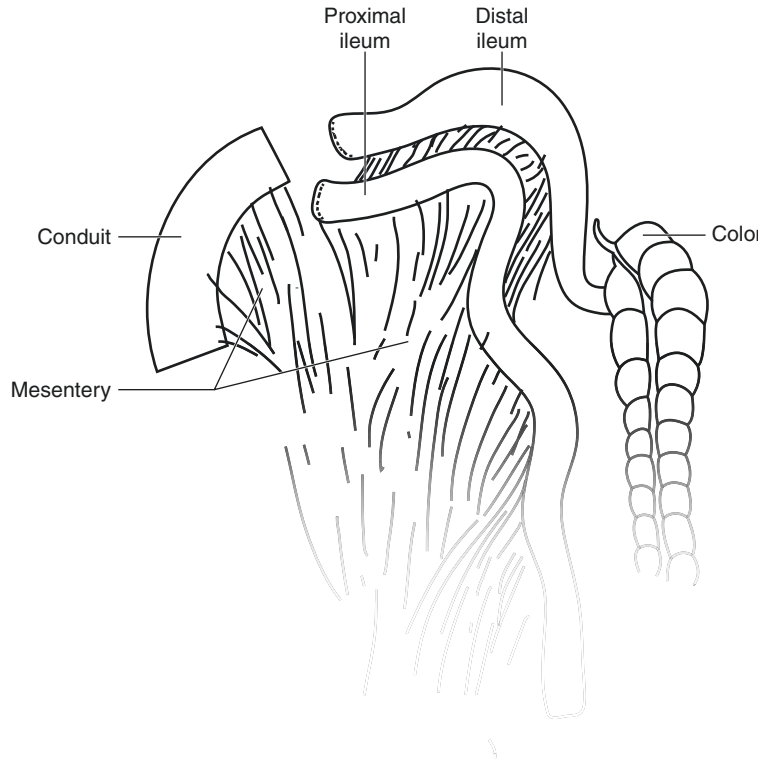

Fig. 7.10 Mark the distal/stomal end of the conduit with a Hem-o-Lok clip and subsequently divide the proximal end of the conduit with a stapler

4. Next place the conduit inferiorly and prepare to do the bowel anastomosis to reinstate continuity (Fig. 7.11). Cut into the staple line, for both the proximal and distal bowel, close to the anti-mesenteric border to make a small triangle to use as a handle to place the bowel onto the stapler. Pull the bowel onto the stapler so that it is lined up and the stapling is as close to the anti-mesenteric border as possible.
5. Close the mesenteric trap with a 3-0 Vicryl running suture. This is debatable as to whether this actually needs to be done, however many centers still practice closure [52].
6. Once the bowel is back in continuity, the incision for the left ureter is made in the conduit. The stoma portion of the conduit is open, and the first stent is brought through where the incision for the left ureter is made with cutting current.
7. The 12-inch 3-0 Vicryl is placed through the butt end of the conduit. The conduit is then brought under the sigmoid for the left ureteral anastomosis to be performed on the left side [53].
8. The suture is then given to the assistant with a needle driver to help hold the conduit in place for the anastomosis.

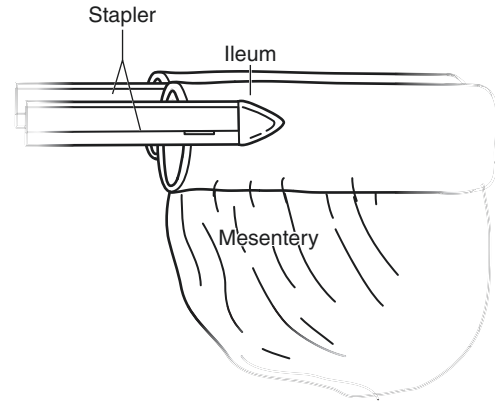

Fig. 7.11 Place the conduit segment inferiorly into the pelvis. Excise staples at the anti-mesenteric aspect of the bowel, carefully orient the bowel on the stapler, and perform a side-to-side stapled bowel anastomosis

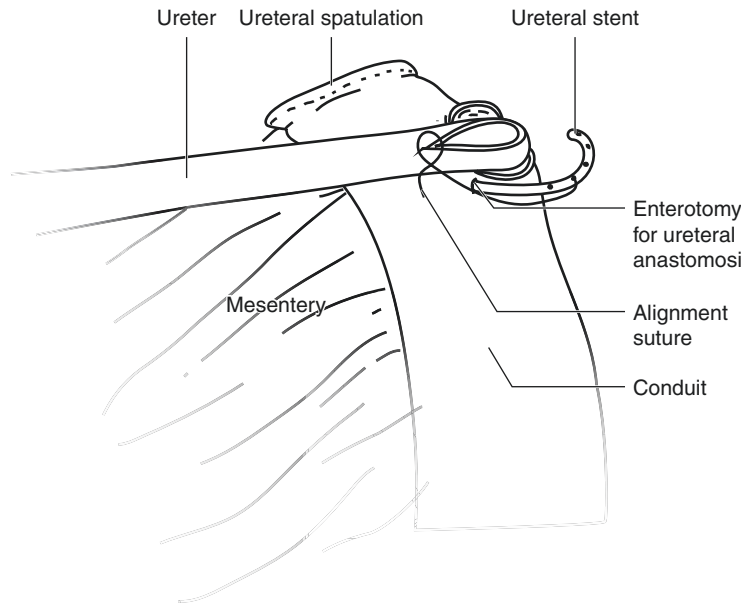

Fig. 7.12 After creating a generous incision in the bowel for implantation with cutting current, the ureter is trimmed, spatulated, and anastomosed to the bowel with 4-0 absorbable suture. The stent is re-wired and fed up the ureter once the first few stitches of the anastomosis are secure

9. The ureter is spatulated and as much as possible is removed to be sent for permanent specimen. The left side is then aligned with a 4-0 Vicryl bringing periureteral tissue in apposition to adventitial tissue around the ureteral insertion site on the bowel (Fig. 7.12).
10. 4-0 Monocryl is then used to begin the anastomosis. The wire is replaced in the stent and the stent threaded up the ureter after a few stitches have been taken on each side. Once the wire is removed the ureteral handle is sent off for final pathology and the anastomosis is finished. The same procedure is performed on the right side for the ureteral anastomosis.

Subsequently, an uncut 3-0 Vicryl is placed in the stoma end and brought through a right sided port and grasped with a hemostat on the outside. A bowel grasper is used to hold the stoma in place. The robot is undocked, and the camera is held by the assistant. The incision for the stoma is made at the previously marked spot and the fascia incised in a cruciate fashion, two fingers are placed through the incision into the peritoneum. A Babcock clamp is then passed and under direct vision the stomal end is brought to the Babcock. The 3-0 Vicryl is released. If insufflation is lost or the conduit dropped this 3-0 Vicryl can be grabbed and used to bring the stoma through to the skin. Once the stoma is grasped, insufflation is turned off and pneumoperitoneum is allowed to escape. The stoma is then matured as per surgeon preference.

Continent Urinary Diversion (Orthotopic Ileal Neobladder)

Multiple techniques of intracorporeal orthotopic neobladder construction have been described previously [54–62]. In this section, we highlight the key technical point for the commonly performed intracorporeal Studer orthotopic neobladder.

Studer Neobladder

The neobladder is started by doing the urethral anastomosis. In order to begin the anastomosis, the most dependent portion of bowel is identified.

The most dependent portion is brought to the urethra using two atraumatic forceps such as a Cadiere or Tip-Up (Intuitive Surgical, Sunnyvale, CA, USA). Once the neourethra location is identified the bowel is entered with cutting current. The urethra is reinforced with a 3-0 Vicryl. The urethral anastomosis is done with two interlocked 3-0 V-Loc sutures (Medtronic). The anastomosis is started at the 6 o'clock position with both needles brought from outside to the inside of the bowel side. Then the needle is brought through inside to outside on the urethra side. Perineal pressure can be helpful to bridge any gaps. Additional maneuvers include a buttress suture to the rectourethralis muscle and positioning the table out of Trendelenburg.

The above principles are used as detailed in the conduit section for the bowel resection and ureteral anastomosis.

1. Once the anastomosis is complete measure the distal ileum at 15–20 cm with a precut suture. Perform the bowel resection as above. The proximal ileum should be measured from the urethral anastomosis and a total of 35–40 cm proximal ileum. The bowel anastomosis is the same as with the conduit.
2. The bowel is then detubularized preserving 12 cm for the ileal chimney.
3. The posterior plate is then brought together at seromuscular level. A 3-0, 6-inch V-Loc is used in a running fashion. The entire posterior plate is brought together (Fig. 7.13).
4. Once the anterior plate is partially completed the catheter is placed and directly visualized in the neobladder, the balloon inflated to 10 ml. Once this is half way the bowel is folded over to create a spherical pouch reservoir [63].
5. Before the neobladder is completely closed the ureteral anastomosis is performed as above with the conduit. The stents are brought out the anterior neobladder and this exit is reinforced with a 3-0 Vicryl suture.
6. The stents are brought through a right robotic trocar arm and an ostomy pouch is placed at the end of the case.

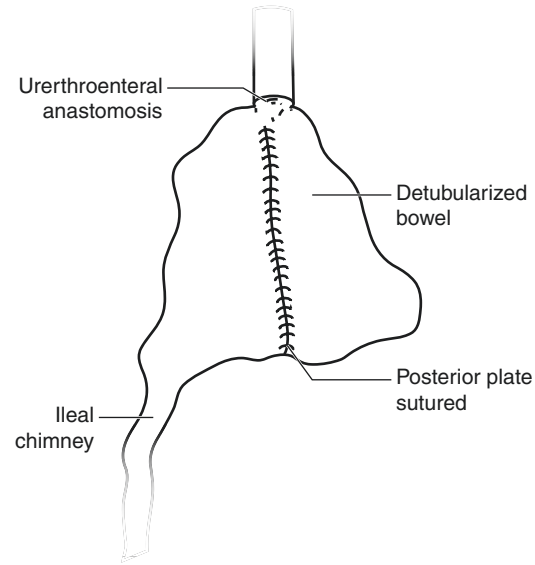

Fig. 7.13 The posterior plate of the neobladder is closed with a running 3-0 V-Loc suture

7. The neobladder is completely closed. The neobladder is leak tested with 120 ml of saline. Any leaks should be fixed if they are found with additional sutures.

Complications and Cost Analysis

Thorough doctor-patient discussion of complications relevant to RARC should include all the complications seen in ORC and the possibility of access-related injury to bowel or vasculature and need for conversion to open surgery should be noted. Meticulous recording and tracking of surgical metrics is critical to a successful cystectomy program and the provision of superior care as well as accurate patient counseling. It has become apparent that many complications, including a fair amount of those termed major (Clavien Grade 3–5), occur more than 30 days after surgery; thus, 90-day complication rates ought to be recorded. Kauffman et al. showed that while 16% of their RARC had major complications by this definition, fully half of those occurred between 31 and 90 days of surgery [64].

In the modern era, no discussion is complete without a cost analysis, and this is especially focused regarding the high expense of the DaVinci platform. Multiple factors contribute to the overall expense of an operation: direct surgical costs in the operating room that include time and technology, hospital costs that are largely related to length of stay, and costs incurred by complications in the hospital as well as after discharge. It bears noting the previously cited data suggesting that a large number of complications occur after 30 days and are only captured on 90-day postoperative follow-up.

Within the domain of direct costs, RARC is more costly: amortization of the robotic system itself, disposable goods and OR time generally all exceed the in-room costs of ORC, although since few if any high-volume centers in the United States or Europe lack a surgical robot system, allowing that cost to be ignored. At one institution that produces open cystectomy outcomes that are closely comparable to RARC (equivalent complication rates and hospital stay; ORC showing higher transfusion rates) costs were nearly equivalent with RARC consuming $1640 more in direct hospital costs [18].

Cost-effectiveness occurs if a new technology decreases the rate of other more expensive medical events. Cystectomy, by nature rife with complications, is an excellent venue for such assessment. The cost of complications associated with cystectomy is impressive: a 2007 analysis of these costs from the National Inpatient database showed costs from each complication incurred another 29% in costs above baseline, and two complications added 65% to the bill [65]. A 2012 analysis that was limited to hospital-acquired complications by Kim et al., found that a single significant complication doubled the in-hospital costs of the operation (from $26,306 to $54,242) [17]. Any significant decrease in events of this cost magnitude clearly opens the door for expensive equipment to easily pay for itself.

Assessments directly comparing ORC to RARC cost are limited. Cost modeling is difficult to do and can be influenced by geography, baseline robotic volume, robot-associated costs, surgeon and team experience, accuracy of complication capture, presence of cystectomy pathway and countless other factors that influence true total cost. One comparison of 100 ORC to 100 RARC showed estimated ORC blood loss of 986 ml compared to RARC losses of 423 ml, with transfusion rates of 47% and 15%, respectively [66]. In this series, complications were substantially more common in the ORC cohort, including more than twice as common in the severe Clavien Grade III–V major complications (10% vs. 22%). Conversely, a report from Memorial Sloan-Kettering in New York found no difference in hospitalization or 90-day complication rates [67], and the larger RAZOR multicenter trial of 302 randomized patients also showed no difference in complication rates, although blood loss and transfusion rates were much lower in the robotic arm [10]. Cost benefit of this technology will best be seen through avoidance of complication and transfusion.

Conclusion

RARC has rapidly emerged as an effective treatment for advanced bladder. In virtually all published reports to date, it demonstrates lower blood loss and transfusion rates, but longer surgical times when compared to its open radical cystectomy. Oncologic outcomes and essentially all other important parameters appear to remain equivalent when the urinary diversion is performed extracorporeally. The expense of the robotic technology must be considered with the potential for decreased surgical morbidity, which will remain a focus of research as further data report benefits of intracorporeal urinary diversion and impact of other advances. Whether robot-assisted laparoscopy will become the future standard approach for radical cystectomy remains to be proven, but it certainly at this point it appears likely.

References

1. Marshall VJ, Whitemore WF. A technique for the extension of radical surgery in the treatment of vesical cancer. Cancer. 1949;2(3):424–8.
2. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg. 2004;240(2):205–13.
3. Shabsigh A, Korets R, Vora KC, Brooks CM, Cronin AM, Savage C, et al. Defining early morbidity of radical cystectomy for patients with bladder cancer using a standardized reporting methodology. Eur Urol. 2009;55(1):164–74.
4. Lowrance WT, Rumohr JA, Chang SS, Clark PE, Smith JA Jr, Cookson MS. Contemporary open radical cystectomy: analysis of perioperative outcomes. J Urol. 2008;179(4):1313–8; discussion 1318.
5. Sánchez de Badajoz E, Gallego Perales JL, Reche Rosado A, Gutierrez de la Cruz JM, Jimenez Garrido A. Laparoscopic cystectomy and ileal conduit: case report. J Endourol. 1995;9(1):59–62.
6. Puppo P, Perachino M, Ricciotti G, Bozzo W, Gallucci M, Carmignani G. Laparoscopically assisted transvaginal radical cystectomy. Eur Urol. 1995;27(1):80–4.
7. Gettman MT, Blute ML, Peschel R, Bartsch G. Current status of robotics in urologic laparoscopy. Eur Urol. 2003;43(2):106–12.
8. Hanna N, Leow JJ, Sun M, Friedlander DF, Seisen T, Abdollah F, et al. Comparative effectiveness of robot-assisted vs. open radical cystectomy. Urol Oncol. 2018;36(3):88.e1–9.
9. Sathianathen NJ, Kalapara A, Frydenberg M, Lawrentschuk N, Weight CJ, Parekh D, Konety BR. Robotic-assisted radical cystectomy vs open radical cystectomy: systematic review and meta-analysis. J Urol. 2019;201(4):715–20.
10. Parekh DJ, Reis IM, Castle EP, Gonzalgo ML, Woods ME, Svatek RS, et al. Robot-assisted radical cystectomy versus open radical cystectomy in patients with bladder cancer (RAZOR): an open-label, randomised, phase 3, non-inferiority trial. Lancet. 2018;391(10139):2525–36.
11. Nix J, Smith A, Kurpad R, Nielsen ME, Wallen EM, Pruthi RS. Prospective randomized controlled trial of robotic versus open radical cystectomy for bladder cancer: perioperative and pathologic results. Eur Urol. 2010;57(2):196–201.
12. Khan MS, Gan C, Ahmed K, Ismail AF, Watkins J, Summers JA, et al. A single-Centre early phase randomised controlled three-arm trial of open, robotic, and laparoscopic radical cystectomy (CORAL). Eur Urol. 2016;69(4):613–21.
13. Hayn MH, Hussain A, Mansour AM, Andrews PE, Carpentier P, Castle E, et al. The learning curve of robot-assisted radical cystectomy: results from the International Robotic Cystectomy Consortium. Eur Urol. 2010;58(2):197–202.
14. Ahmed K, Khan SA, Hayn MH, Agarwal PK, Badani KK, Balbay MD, 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.
15. Simone G, Tuderti G, Misuraca L, Anceschi U, Ferriero M, Minisola F, et al. Perioperative and mid-term oncologic outcomes of robotic assisted radical cystectomy with totally intracorporeal neobladder: results of a propensity score matched comparison with open cohort from a single-centre series. Eur J Surg Oncol. 2018;44(9):1432–8.
16. Catto JW, Khetrapal P, Ambler G, Sarpong R, Khan MS, Tan M, et al. Robot-assisted radical cystectomy with intracorporeal urinary diversion versus open radical cystectomy (iROC): protocol for a randomised controlled trial with internal feasibility study. BMJ Open. 2018;8(8):e020500.
17. Kim SP, Shah ND, Karnes RJ, Weight CJ, Frank I, Moriarty JP, et al. The implications of hospital acquired adverse events on mortality, length of stay and costs for patients undergoing radical cystectomy for bladder cancer. J Urol. 2012;187(6):2011–7.
18. Smith A, Kurpad R, Lal A, Nielsen M, Wallen EM, Pruthi RS. Cost analysis of robotic versus open radical cystectomy for bladder cancer. J Urol. 2010;183(2):505–9.
19. Richards KA, Kader K, Pettus JA, Smith JJ, Hemeal AK. Does initial learning curve compromise outcomes for robot-assisted radical cystectomy? A critical evaluation of the first 60 cases while establishing a robotics program. J Endourol. 2011;25(9):1553–8.
20. Guru KA, Perlmutter AE, Butt ZM, Piacente P, Wilding GE, Tan W, et al. The learning curve for robot-assisted radical cystectomy. JSLS. 2009;13(4):509–14.
21. Butt ZM, Perlmutter AE, Piacente PM, Wilding G, Tan W, Kim HL, et al. Impact of body mass index on robot-assisted radical cystectomy. JSLS. 2008;12(3):241–5.
22. Johar RS, Hayn MH, Stegemann AP, Ahmed K, Agarwal P, Balbay MD, et al. Complications after robot-assisted radical cystectomy: results from the International Robotic Cystectomy Consortium. Eur Urol. 2013;64(1):52–7.
23. Gadacz TR, Talamini MA. Traditional versus laparoscopic cholecystectomy. Am J Surg. 1991;161(3):336–8.
24. Lloyd G, Rashid H, Wu G. Complex pelvic surgery in the setting of prior ostomy. 29th World Congress of Endourology from 30 Nov – 3 Dec 2011, Kyoto, Japan; 2011.
25. Meeks JJ, Bellmunt J, Bochner BH, Clarke NW, Daneshmand S, Galsky MD, et al. A systematic review of neoadjuvant and adjuvant chemotherapy for muscle-invasive bladder cancer. Eur Urol. 2012;62(3):523–33.
26. Hollenbeck BK, Miller DC, Taub D, Dunn RL, Underwood W 3rd, Montie JE, Wei JT. Aggressive treatment for bladder cancer is associated with

improved overall survival among patients 80 years old or older. Urology. 2004;64(2):292–7.
27. Knox ML, El-Galley R, Busby JE. Robotic versus open radical cystectomy: identification of patients who benefit from the robotic approach. J Endourol. 2013;27(1):40–4.
28. Robinson TN, Walston JD, Brummel NE, Deiner S, Brown CH 4th, Kennedy M, Hurria A. Frailty for surgeons: review of a National Institute on Aging conference on frailty for specialists. J Am Coll Surg. 2015;221(6):1083–92.
29. Burg ML, Clifford TG, Bazargani ST, Lin-Brande M, Miranda G, Cai J, et al. Frailty as a predictor of complications after radical cystectomy: a prospective study of various preoperative assessments. Urol Oncol. 2019;37(1):40–7.
30. Bhalla RG, Wang L, Chang SS, Tyson MD. Association between preoperative albumin levels and length of stay after radical cystectomy. J Urol. 2017;198(5):1039–45.
31. Psutka SP, Carrasco A, Schmit GD, Moynagh MR, Boorjian SA, Frank I, et al. Sarcopenia in patients with bladder cancer undergoing radical cystectomy: impact on cancer-specific and all-cause mortality. Cancer. 2014;120(18):2910–8.
32. Kaffenberger SD, Keegan KA, Bansal NK, Morgan TM, Tang DH, Barocas DA, et al. Salvage robotic assisted laparoscopic radical prostatectomy: a single institution, 5-year experience. J Urol. 2013;189(2):507–13.
33. Chahal R, Sundaram SK, Iddenden R, Forman DF, Weston PM, Harrison SC. A study of the morbidity, mortality and long-term survival following radical cystectomy and radical radiotherapy in the treatment of invasive bladder cancer in Yorkshire. Eur Urol. 2003;43(3):246–57.
34. Eswara JR, Efstathiou JA, Heney NM, Paly J, Kaufman DS, McDougal WS, et al. Complications and long-term results of salvage cystectomy after failed bladder sparing therapy for muscle invasive bladder cancer. J Urol. 2012;187(2):463–8.
35. Eisenberg MS, Dorin RP, Bartsch G, Cai J, Miranda G, Skinner EC. Early complications of cystectomy after high dose pelvic radiation. J Urol. 2010;184(6):2264–9.
36. Lee DJ, Rothberg MB, McKiernan JM, Benson MC, Badani KK. Robot-assisted radical cystoprostatectomy in complex surgical patients: single institution report. Can J Urol. 2009;16(3):4664–9.
37. Zebic N, Weinknecht S, Kroepfl D. Radical cystectomy in patients aged > or = 75 years: an updated review of patients treated with curative and palliative intent. BJU Int. 2005;95(9):1211–4.
38. Nogueira L, Reis RB, Machado RD, Tobias-Machado M, Carvalhal G, Freitas C Jr, et al. Cutaneous ureterostomy with definitive ureteral stent as urinary diversion option in unfit patients after radical cystectomy. Acta Cir Bras. 2013;28(Suppl 1):43–7.
39. Karl A, Carroll PR, Gschwend JE, Knüchel R, Montorsi F, Stief CG, Studer UE. The impact of lymphadenectomy and lymph node metastasis on the outcomes of radical cystectomy for bladder cancer. Eur Urol. 2009;55(4):826–35.
40. Buscarini M, Josephson DY, Stein JP. Lymphadenectomy in bladder cancer: a review. Urol Int. 2007;79(3):191–9. Review.
41. von Landenberg N, Speed JM, Cole AP, Seisen T, Lipsitz SR, Gild P, et al. Impact of adequate pelvic lymph node dissection on overall survival after radical cystectomy: a stratified analysis by clinical stage and receipt of neoadjuvant chemotherapy. Urol Oncol. 2018;36(2):78.e13–9.
42. Mills RD, Fleischmann A, Studer UE. Radical cystectomy with an extended pelvic lymphadenectomy: rationale and results. Surg Oncol Clin N Am. 2007;16(1):233–45.
43. Stein JP. The role of lymphadenectomy in patients undergoing radical cystectomy for bladder cancer. Curr Oncol Rep. 2007;9(3):213–21.
44. Gschwend JE, Heck MM, Lehmann J, Rübben H, Albers P, Wolff JM, et al. Extended versus limited lymph node dissection in bladder cancer patients undergoing radical cystectomy: survival results from a prospective, randomized trial. Eur Urol. 2019;75(4):604–11.
45. Youssef RF, Raj GV. Lymphadenectomy in management of invasive bladder cancer. Int J Surg Oncol. 2011;2011:758189. https://doi.org/10.1155/2011/758189.
46. Tilki D, Brausi M, Colombo R, Evans CP, Fradet Y, Fritsche HM, et al. Lymphadenectomy for bladder cancer at the time of radical cystectomy. Eur Urol. 2013;64(2):266–76.
47. Davis JW, Gaston K, Anderson R, Dinney CP, Grossman HB, Munsell MF, Kamat AM. Robot assisted extended pelvic lymphadenectomy at radical cystectomy: lymph node yield compared with second look open dissection. J Urol. 2011;185(1):79–83.
48. Sultan S, Coles B, Dahm P. Alvimopan for recovery of bowel function after radical cystectomy. Cochrane Database Syst Rev. 2017;5:CD012111. https://doi.org/10.1002/14651858.CD012111.pub2.
49. Pereira Gomes Morais E, Riera R, Porfírio GJ, Macedo CR, Sarmento Vasconcelos V, de Souza Pedrosa A, Torloni MR. Chewing gum for enhancing early recovery of bowel function after caesarean section. Cochrane Database Syst Rev. 2016;10:CD011562.
50. Baack Kukreja JE, Kiernan M, Schempp B, Siebert A, Hontar A, Nelson B, et al. Quality improvement in cystectomy care with enhanced recovery (QUICCER) study. BJU Int. 2017;119(1):38–49.
51. Thompson IM 3rd, Kappa SF, Morgan TM, Barocas DA, Bischoff CJ, Keegan KA, et al. Blood loss associated with radical cystectomy: a prospective, randomized study comparing impact LigaSure vs. stapling device. Urol Oncol. 2014;32(1):45.e11–5.
52. Cho M, Pinto D, Carrodeguas L, Lascano C, Soto F, Whipple O, et al. Frequency and management of internal hernias after laparoscopic antecolic antegastric Roux-en-Y gastric bypass without division of

the small bowel mesentery or closure of mesenteric defects: review of 1400 consecutive cases. Surg Obes Relat Dis. 2006;2(2):87–91.
53. Ficarra V, Giannarini G, Crestani A, Palumbo V, Rossanese M, Valotto C, et al. Retrosigmoid versus traditional ileal conduit for urinary diversion after radical cystectomy. Eur Urol. 2019;75(2):294–9.
54. Pruthi RS, Nix J, McRackan D, Hickerson A, Nielsen ME, Raynor M, Wallen EM. Robotic-assisted laparoscopic intracorporeal urinary diversion. Eur Urol. 2010;57(6):1013–21.
55. Collins JW, Tyritzis S, Nyberg T, Schumacher M, Laurin O, Khazaeli D, et al. Robot-assisted radical cystectomy: description of an evolved approach to radical cystectomy. Eur Urol. 2013;64(4):654–63.
56. Collins JW, Wiklund PN, Desai MM, Goh AC, Gill IS. Total intracorporeal robotic cystectomy: are we there yet? Curr Opin Urol. 2013;23(2):135–40.
57. Goh AC, Gill IS, Lee DJ, de Castro Abreu AL, Fairey AS, Leslie S, et al. Robotic intracorporeal orthotopic ileal neobladder: replicating open surgical principles. Eur Urol. 2012;62(5):891–901.
58. Hosseini A, Adding C, Nilsson A, Jonsson MN, Wiklund NP. Robotic cystectomy: surgical technique. BJU Int. 2011;108(6. Pt 2):962–8.
59. Johnson D, Castle E, Pruthi RS, Woods ME. Robotic intracorporeal urinary diversion: ileal conduit. J Endourol. 2012;26(12):1566–9.
60. Jonsson MN, Adding LC, Hosseini A, Schumacher MC, Volz D, Nilsson A, et al. Robot-assisted radical cystectomy with intracorporeal urinary diversion in patients with transitional cell carcinoma of the bladder. Eur Urol. 2011;60(5):1066–73.
61. Josephson DY, Chen JA, Chan KG, Lau CS, Nelson RA, Wilson TG. Robotic-assisted laparoscopic radical cystoprostatectomy and extracorporeal continent urinary diversion: highlight of surgical techniques and outcomes. Int J Med Robot. 2010;6(3):315–23.
62. Murphy DG, Anderson P. Robotic radical cystectomy with intracorporeal neobladder: ready for prime time? Eur Urol. 2013;64(5):742–3.
63. Koie T, Ohyama C, Yoneyama T, Nagasaka H, Yamamoto H, Imai A, et al. Robotic cross-folded U-configuration intracorporeal ileal neobladder for muscle-invasive bladder cancer: initial experience and functional outcomes. Int J Med Robot. 2018;14(6):e1955.
64. Kauffman EC, Ng CK, Lee MM, Otto BJ, Portnoff A, Wang GJ, Scherr DS. Critical analysis of complications after robotic-assisted radical cystectomy with identification of preoperative and operative risk factors. BJU Int. 2010;105(4):520–7.
65. Konety BR, Allareddy V. Influence of post-cystectomy complications on cost and subsequent outcome. J Urol. 2007;177(1):280–7; discussion 287.
66. Kader AK, Richards KA, Krane LS, Pettus JA, Smith JJ, Hemal AK. Robot-assisted laparoscopic vs open radical cystectomy: comparison of complications and perioperative oncological outcomes in 200 patients. BJU Int. 2013;112(4):E290–4.
67. Bochner BH, Dalbagni G, Sjoberg DD, Silberstein J, Keren Paz GE, Donat SM, et al. Comparing open radical cystectomy and robot-assisted laparoscopic radical cystectomy: a randomized clinical trial. Eur Urol. 2015;67(6):1042–50.

Robotic Pyeloplasty

8

Naveen Kachroo, Sri Sivalingam, and Sara L. Best

Introduction

Although open Anderson-Hynes dismembered pyeloplasty was historically the criterion standard for the definitive treatment of ureteropelvic junction obstruction (UPJO), minimally invasive approaches such as laparoscopic pyeloplasty (LP) and robot-assisted laparoscopic pyeloplasty (RAP) are arguably the current gold standard [1]. The first purely laparoscopic pyeloplasty was reported in 1993 [2, 3]. However, the technical nuances and steep learning curve associated with laparoscopic pyeloplasty made the rapid adoption of laparoscopy for this procedure difficult, primarily due to the technical complexity of intracorporeal suturing. Since its approval in 2000 by the US Food and Drug Administration, the introduction of the da Vinci robotic system (Intuitive Surgical, Inc., Sunnyvale, CA) facilitated the adoption of minimally invasive pyeloplasty and gained rapid popularity by significantly simplifying and shortening intracorporeal suturing time [4]. The robotic system has undergone several upgrades and modifications from the original S® and Si® systems with the development in 2014 of the da Vinci Xi® platform and more recently the evolution of the fourth generation SP® system which is a purpose built platform for single-site, single-port surgery. Robotic approaches to pyeloplasty continue to evolve, and as experience with the technique and technology grows, RAP may ultimately become the reference gold standard approach.

Minimally invasive pyeloplasty has similar functional outcomes compared to the open approach but with the advantages of improved postoperative convalescence, cosmesis, and lower short-term morbidity [5, 6]. Several studies have shown that laparoscopic dismembered pyeloplasty has equivalent efficacy compared to open pyeloplasty [7, 8]. Similarly, RAP has demonstrated therapeutic equivalence to LP [9, 10] with a faster learning curve and easier adoption than standard laparoscopy due to its distinct advantage with intracorporeal suturing. The increase in degrees of freedom, wristed instrumentation, and 3D vision unique to the robotic platform facilitates reconstruction, decreases the learning curve for the procedure, and reduces surgeon fatigue, thus popularizing RAP over standard laparoscopy in a trend similar to that of the robotic prostatectomy [11, 12]. Overall, there has been a dramatic shift from open to minimally invasive pyeloplasty since 2005 [13]. Specifically, one study showed a

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S. L. Best, S. Y. Nakada (eds.), *Minimally Invasive Urology*,
https://doi.org/10.1007/978-3-030-23993-0_8

23-fold increase from 2.4% to 55.3% in minimally invasive pyeloplasty from 1998 to 2009 [14]. This trend favoring minimally invasive pyeloplasty was primarily driven by the increased use of RAP, which accounted for 45% of all cases in comparison to 10% for pure laparoscopy in 2009 [14]. Assessing trends from the Nationwide Inpatient Sample, Monn et al. identified a statistically significant increase specifically in the number of RAPs performed between 2005 and 2010 ($p < 0.001$) especially among those performed at a teaching hospital [13]. This dramatic shift in approach has been mirrored in a recent analysis of pyeloplasty trends in the US pediatric population identified from the Premier Database, which showed a 29% annual growth in RAP utilization, with 84% of cases in adolescents being performed robotically at the end of the study period [15].

This chapter will detail the application of RAP, with specific details on operative technique. Contemporary outcomes and complications of this procedure will also be presented.

Robotic Versus Laparoscopic Pyeloplasty

The first detailed report of laparoscopic pyeloplasty was in 1993 [3], and although it was shown to be a feasible procedure, the technique demanded advanced laparoscopic skills for the intracorporeal suturing in the reconstruction. Despite these challenges, in many centers, laparoscopic pyeloplasty took the lead over open pyeloplasty, highlighting the demand for more minimally invasive approaches [1]. With the introduction of the da Vinci robotic surgical system, intracorporeal suturing became much easier and tempered the learning curve. Consequently, multiple trials have emerged comparing the two approaches (Table 8.1).

Four systematic reviews comparing RAP and LP have been published [9, 32–34]. The systematic review and meta-analysis by Braga et al. in 2009 analyzed eight available studies at that time and compared the outcomes of the two approaches [9]. They noted that although there was a 10-min advantage with the RAP, this did not translate into statistical significance. Five of the eight studies had a shorter hospital stay (by 0.5 days) for the robotic approach, which was statistically (if not clinically) significant. Both RAP and LP had similar complication rates and success rates. A more recent meta-analysis comparing RAP to LP reviewed 12 studies with 347 and 299 cases of RAP and LP, respectively [32]. This meta-analysis noted advantages of a shorter suturing time and hospital stay with the robotic approach. Interestingly, while there was no significant difference in total operative times, a subgroup analysis of suturing time found an 18 min advantage with RAP, based on a meta-analysis of four studies. It is conceivable that the time gained with suturing is balanced by docking and undocking of the robot [30] and the potentially faster dissection to expose the retroperitoneum and ureter with pure laparoscopy. Hospital stay was significantly shorter by 0.75 days in the RAP group, and again, there were no differences in success or complication rates. Conversely, another systematic review and meta-analysis by Autorino et al. of nine studies (277 RAP and 196 LP cases) found that RAP was associated with a significantly shorter operative time with no significant difference in hospital stay, complication, or success rates [33]. The most recent analysis by Light et al. [34], specifically focusing on those studies exclusively performing the dismembered technique, included 17 studies and confirmed a 27-min shorter operative time for RAP ($p = 0.003$) potentially reflecting increased efficiency in operative performance as well as robotic set up/undocking with experience of the technique to compound the effect on overall operative time observed in earlier analyses. RAP was also shown to have a 1.2-day shorter hospital stay ($p < 0.001$) and significantly lower complication rate ($p = 0.005$) and higher success rate ($p = 0.008$). This study did highlight the tremendous study heterogeneity and deemed the level of evidence to be "low" based on the quality of the studies (using a modified Newcastle-Ottawa scale) with a high-quality randomized controlled trial required to strengthen these conclusions.

Despite some of the conflicting data from these meta-analyses, the literature to date suggests that both LP and RAP provide excellent outcomes with low complication rates. However,

Table 8.1 Comparative series of robotic versus laparoscopic pyeloplasty

		N	Mean age	Mean follow up (mo)	OR time (min)	Hospital LOS (d)	Complications	Success rates (%)	Definition of success
Song et al. 2017 [16]	LP RAP	30 10	Peds Peds	20.1 16.6	197.4 ± 38.9 254.1 ± 46.0	5.8 ± 1.4 3.2 ± 1.0	13.3 0	90 100	Symptoms, US, renogram
Silay et al. 2016 [17]	LP RAP	390 185	Peds Peds	45.2 12.8	173.8 ± 55.2 173.1 ± 50.7	4.6 ± 2.4 2.1 ± 2.1	15.1 7	97.7 99.5	Symptoms, US, renogram
Patel et al. 2016 [18]	LP RAP	13 55	Peds Peds	NR NR	259.8 237	1.67 1.17	0 3.6	91.7 100	Symptoms, US, renogram
Ganpule et al. 2015 [19]	LP RAP	25 19	Peds Peds	24.8 18.3	167.4 ± 49.7 155 ± 46.6	5.0 ± 1.6 3.5 ± 1.5	4 5.3	96 94.6	Symptoms, IVU, renogram
Pahwa et al. 2014 [20]	LP RAP	30 30	34.4 32	18 13.5	191.6 141.7	3 2.5	NR NR	96.7 96.7	Symptoms, renogram
Basatac et al. 2014 [21]	LP RAP	16 15	34.3 32.9	12 36	130 ± 45 114 ± 26	2.8 ± 0.75 2 ± 1	6.3 6.7	93.8 93.3	Symptoms, renogram
Danuser et al. 2014 [22]	LP RAP	33 131	42.8 45.4	34.1 19.2	277.7 ± 72.3 181.6 ± 46.8	7.3 ± 2.8 5.1 ± 1.4	18.2 16.8	100 98.5	Symptoms, IVU, renogram
Riachy et al. 2013 [23]	LP RAP	18 46	Peds Peds	43 22	298 209	1 2	11.1 4.3	94.4 100	Symptoms, US, renogram
Kumar et al. 2013 [24]	LP	11	25	1.4–2.8	150	2.9	0	100	Renogram
	RAP	19	21	1.4–2/8	129	2.8	0	100	–
Olweny et al. 2012[a] [25]	LP	10	35.8	9.2	188 ± 12.4	2.6	20	87.5	Symptoms, renogram
	RAP	10	40.3	2.76	226 ± 36.7	2.6	10	100	
Subotic et al. 2012 [26]	LP RAP	20 19	Peds Peds	21 10	248 165	7 6	25 31.6	100 100	Symptoms, US, renogram
Garcia-Galisteo 2011 [27]	LP	33	33.9	20.6	152.1 ± 23.3	4.5 ± 1.5	51.5	93.9	Symptoms, creatinine, renogram
	RAP	17	33.9	42.5	121.6 ± 13.3	2.4 ± 0.5	23.5	94.1	
Hemal 2010 [28]	LP	30	28.1		145 ± 44	5.5 ± 3.8	10	97	–
	RAP	30	24.9		99 ± 29	2.5 ± 0.8	3.3	93	–
Kim et al. 2008 [29]	LP	58	Peds	18.1	196 ± 38	0.9 ± 0.23	3.4	97	Symptoms, renogram
	RAP	84	Peds	10.1	188 ± 45.8	1.5 ± 0.55	0	99	
Link et al. 2006 [30]	LP	10	38.0	5.6	80.7 ± 21.9	NR	0	90	NR
	RAP	10	46.5	5.6	100.2 ± 9.1	NR	10 (1 delayed urine leak)	90	–
Weise and Winfield 2006 [31]	LP	14	24.5	10	271	2	0	100 (T), 64 (S)	"Technical" (T) – renogram
	RAP	31	26	6	299	2	0	97 (T), 66 (S)	"Strict" (S) – symptoms and renogram

Abbreviations: *Peds* pediatric cases only, *NR* not reported, *OR* operating room, *LOS* length of stay, *US* ultrasonography, *IVU* intravenous urogram

[a]Laparoendoscopic single-site surgery (LESS) laparoscopic pyeloplasty versus LESS robot-assisted pyeloplasty

the shorter learning curve associated with RAP is likely responsible for its rapid adoption in many minimally invasive practices including pyeloplasties, as demonstrated by one national surgical trend analysis where open and RAP was each performed in 45% of cases, while only 10% of cases were done laparoscopically [14].

Retroperitoneal Versus Transperitoneal Approach

The UPJ can be accessed via a transperitoneal or retroperitoneal route. Although most laparoscopic or robot-assisted urological surgeries are performed transperitoneally, there may be unique advantages with the retroperitoneal approach as it provides direct access to the renal pelvis and hilar vessels without the need for colonic reflection, avoids urine leak into the peritoneal cavity, and potentially hastens recovery. This may also be the approach of choice in obese patients or those who have had multiple prior abdominal surgeries. Outcomes of both retroperitoneal and transperitoneal approaches appear similar. The original description of retroperitoneal RAP was in the pediatric population in 2004 [35]. Subsequently the first report in adults was by Kaouk and colleagues in 2008 [36]. In this series, all cases were performed by a single surgeon with prior experience in retroperitoneal LP. Retroperitoneal access was achieved through a 1.2-cm incision at the tip of the 12th rib and subsequently, the lumbodorsal fascia incised and retroperitoneal space developed by balloon dissection. The authors indicate that although the transperitoneal approach affords the advantage of familiarity of the operative field, and a larger working space, there are significant benefits for the retroperitoneal approach such as lower risk of bowel injury and direct approach to the UPJ. In retroperitoneal LP series, the technical challenge of intracorporeal suturing was exacerbated by the smaller working space in the retroperitoneum and finding a potential crossing vessel was also more challenging. However according to Kaouk and coauthors, the wristed instrumentation of the da Vinci system helped overcome the limitation of working in a confined space. The outcomes and complications were also similar to that of standard transperitoneal RAP. Cestari et al. published their series of retroperitoneal versus transperitoneal RAP in 36 and 19 patients, respectively [37]. These authors also found similar outcomes in the two groups but noted similar challenges for the retroperitoneal approach, namely, gaining access, limited working space, and the loss of familiar anatomic landmarks. The confined space can also make identification of crossing vessels more difficult as evidenced by a recurrence caused by failure of recognition of one within the retroperitoneal cohort. The authors also noted that antegrade stent placement is more challenging during retroperitoneal RAP [37]. This, however, can be overcome with retrograde placement with flexible cystoscopy without any interruption in the procedure. A recently published randomized comparison of the two approaches performed robotically by a single surgeon (40 patients in each group) showed no significant difference in operative time, hospital stay, success or complication rates [38].

Given the paucity of literature comparing the two approaches, no conclusive statements regarding the superiority of one approach versus the other cannot be made at this time. The choice to pursue the retroperitoneal approach remains largely based upon the surgeon's preference and experience with the technique and could be considered advantageous in certain situations such as in the presence of extensive intraperitoneal adhesions. The remainder of this chapter will focus on the transperitoneal approach.

LESS Robotic Pyeloplasty

With the emergence of a LP and RAP, laparoendoscopic single-site surgery (LESS) has been of interest in an effort to further minimize surgical invasiveness and potentially recovery. In the pursuit of a "scarless" surgery and given the non-extirpative nature of pyeloplasty surgery, this may represent an ideal setting for a LESS approach as it offers patients improved cosmesis by decreasing the number of ports from 3 to 5 to a single periumbilical incision that is often concealed

[39]. Although this approach further raises the level of complexity in performing the procedure, in experienced hands, complication rates are similar to those with other minimally invasive approaches [39]. Early reports with LESS have demonstrated equivalent outcomes compared to conventional LP, with no differences in hospital stay, analgesic requirements, and minor and major complications [40]. LESS can be performed using either laparoscopic or robotic approaches, but some surgeons have found the ergonomic challenges of LESS to be better addressed using the robotic platform. In particular, the wristed instrumentation, surgeon-controlled camera, and ability to electronically reassign the hand controls ("masters") after crossing the instruments have been cited as particular advantages of robotic LESS. Technical feasibility of LESS in RAP has been demonstrated in a number of case series [41–43] with good short-term outcomes and the authors uniformly highlighting the reduced technical complexity and improved learning curve over LESS LP. A comparison of LESS LP with LESS RAP showed no difference in hospital stay, complications, or outcome except for a longer operative time in the robotic LESS cohort (226 vs. 188 min, $p = 0.007$) [25]. Despite the initial enthusiasm created with this approach, a lack of universal adoption and recent decline in the performance of LESS surgery was demonstrated in a survey of Endourological Society members [44]. The survey responders highlighted the need for a new robotic platform with modified instrumentation that allows improved suturing ability and reduced robotic arm clashing. The development of the purpose driven da Vinci SP® platform for single-port surgery may specifically circumvent some of these technical challenges to renew interest in LESS RAP and studies assessing this are eagerly awaited.

Robot-Assisted Laparoscopic Pyeloplasty: Equipment List

1. da Vinci surgical system (Intuitive Surgical, Inc., Sunnyvale, CA) – Si® or Xi®
2. Veress needle, 2–10-/12-mm disposable ports, 8-mm robotic ports, GelPOINT® (for LESS)
3. Right arm – monopolar da Vinci Curved Scissors (Hot Shears™), da Vinci Potts Scissors, da Vinci Large Needle Driver
4. Left arm – fenestrated bipolar forceps ProGrasp Forceps, da Vinci Fine Tissue Forceps, da Vinci Large Needle Driver
5. Fourth arm – not typically employed for pyeloplasty
6. Assistant – 5-mm suction irrigator
7. Liver retraction port – atraumatic locking grasper (right-sided procedures only)

Technical Description

Patient Preparation

After a thorough preoperative evaluation of the patient's suitability for the procedure, any anticoagulant medications are stopped a week prior to the procedure. Urinalysis and urine culture are performed before surgery and any urinary tract infection treated accordingly, and preoperative antibiotics are given prior to commencing the procedure. In our practice, a routine ureteral stent is not placed preoperatively to avoid ureteral edema and potential masking of an intraureteral stenosis; therefore, the following will highlight antegrade stent placement. However, the stent can be placed prior to the robotic positioning and a retrograde pyelogram can be performed at this time if required to delineate the ureteral anatomy further and rule out any distal stricture or filling defect.

Patient Positioning

After induction of anesthesia, a Foley catheter is placed and, after draining the initial bladder contents, is clamped so that the bladder will fill during the procedure, facilitating antegrade stent placement. The patient is placed in a modified lateral decubitus position with the affected flank facing upward. All pressure points are carefully padded; the lower leg is flexed and the upper leg is kept straight. Pillows are secured in between the legs and secured with tape. The patient is well secured to the operating table to allow for ample

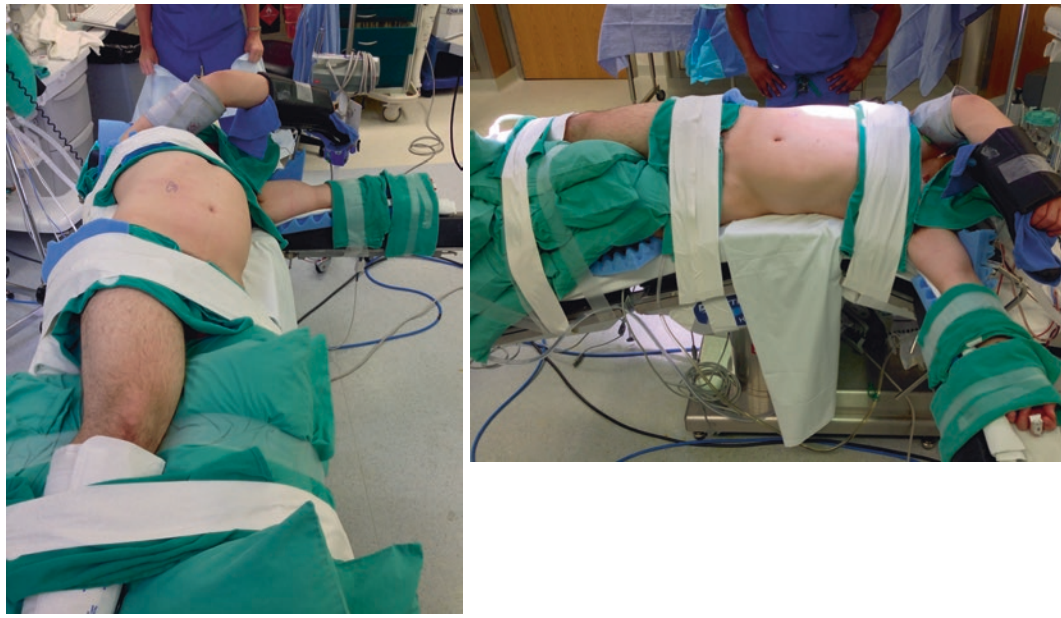

Fig. 8.1 Patient positioning in modified lateral decubitus with careful padding of pressure points. Patient is secured with cloth tape to enable airplaning the table for port placement and subsequent docking of the robot

airplane rotation. The operating table is then gently flexed to elevate the kidney and open the space between the ipsilateral hip and ribs (Fig. 8.1).

Port Placement (Standard RAP)

The table is rotated maximally to position the patient in a near-supine orientation. A small skin incision is made below the inner crease of the umbilicus to allow for Veress needle placement (alternatively the Hasson technique may be used to obtain initial entry dependent upon surgeon preference). After confirmation of safe intraperitoneal Veress entry with aspiration and drop test, pneumoperitoneum is established to 15 mmHg. A 10-mm incision is then made around the umbilicus and a visual optical dilating trocar is used to insert the first 10-mm port using a zero degree lens. In larger or more obese patients, it may be helpful to lateralize the trocar sites, including the camera port, few centimeters lateral and superior to the umbilicus. The two 8-mm robotic ports are placed under direct vision in the upper and lower quadrants. Care must be taken to ensure the remote centers of the ports lie within the fascia to avoid unnecessary enlargement of the fascial defects. For right-sided procedures, a 5-mm subxiphoid trocar can be placed and an atraumatic locking grasper can be used to elevate the liver by clipping the grasper to the sidewall, though this is not necessary unless the liver edge drapes over the UPJ. A 12-mm assistant port is then placed in the midline between the umbilicus and the xiphoid (Fig. 8.2). Port placement is largely similar between the Si® and Xi® platforms with some specific differences as highlighted in Fig. 8.2a and b. The table is then rotated so that the patient lies on his/her side and the robot is docked over the ipsilateral shoulder.

Port Placement (LESS RAP)

The patient is positioned and the table maximally rotated as above. A 2.5-cm intraumbilical incision is then made. The fascia is then elevated with 0 Vicryl stitches and is incised sharply and the peritoneum is lifted and incised. The fascial incision is extended to the length of the skin incision, and a GelPOINT® LESS port device (Applied Medical, Rancho Santa Margarita, CA,

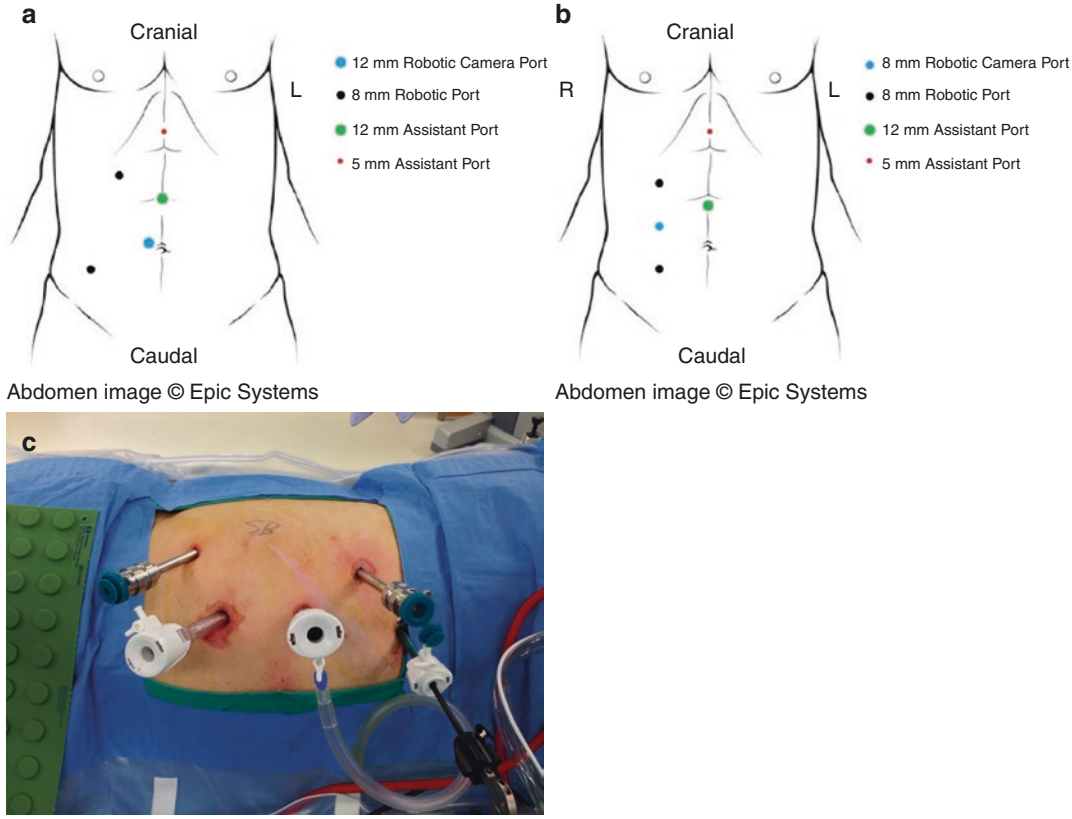

Fig. 8.2 Optimal port placement for right robot-assisted pyeloplasty. Left-sided port placement would be a mirror image. Port placements may be modified based on the size and anatomy of the patient, usually lateralizing the port placements in obese patients. (**a**) Transperitoneal port placement template for the Si® system. A 12-mm camera port is placed around the umbilicus and the 8-mm robotic ports are placed about 8 cm cranial in the right upper quadrant and 8 cm caudal in the right lower quadrant as shown. A 5-mm midline subxiphoid assistant port is required for placement of a liver retractor locking grasper (right side only). (**b**) Transperitoneal port placement template for the Xi® system. All robotic ports are 8 mm and are placed in a line 8 cm apart, along the lateral border of the rectus muscle. (**c**) Photograph of port placement for a right robot-assisted pyeloplasty with a single 12-mm assist port and a 5-mm liver retraction port

USA) is placed through the incision, ensuring that loops of bowel are not caught within the ring [25]. Two 5-mm robotic trocars are placed, along with a 12-mm robotic camera trocar and a 12-mm assistant trocar through the GelPOINT® port (Fig. 8.3a) and the abdomen is insufflated to 15 mmHg. On some robotic platforms, it may be necessary to use one 8-mm robotic trocar instead of a 5-mm to accommodate an articulating cautery scissors. The table is rotated back to the initial position and robot is docked (Fig. 8.3b). The camera is loaded in the "30-degrees up" orientation to diminish clashing of instruments. A left 5-mm robotic hook cautery (or scissors) and a right 5-mm tissue grasper are deployed in the respective robotic ports, crisscrossing at the level of the fascia. The robotic console is programmed so that the surgeon's left hand controls the instrument on the left side of the screen and vice versa, resulting in intuitive manipulation of the instruments. This ability to reassign the masters at the console for LESS procedures is yet another unique advantage of the robotic platform.

Exposure of Renal Pelvis and Ureter

The colon is reflected medially along the white line of Toldt. The peritoneum overlying the inferior aspect of the kidney is then carefully dissected

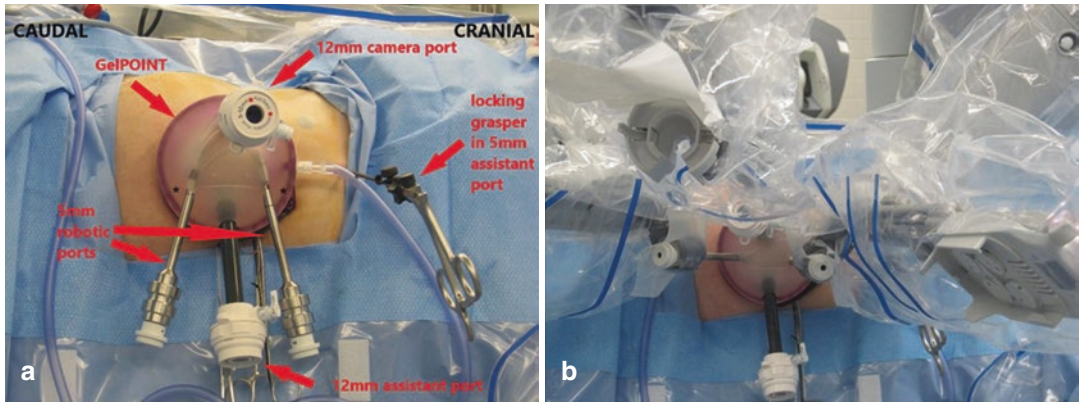

Fig. 8.3 (**a**) Port positioning and (**b**) Docking of the robot for a robotic LESS pyeloplasty using a GelPOINT® device that was placed through a 2.5 cm umbilical incision

and mobilized off Gerota's fascia, which is then incised to locate the ureter which is carefully dissected free of the surrounding tissues (Fig. 8.4a). The ureter is traced cranially toward the renal pelvis (Fig. 8.4b), and meticulous efforts are made to avoid excessive handling/manipulation of the ureter and to leave tissue surrounding it to maintain perfusion. As dissection of the ureter approaches the renal pelvis (Fig. 8.4c), care should be taken to identify and preserve any crossing vessels (Fig. 8.4d, e). Since the goal is to preserve any crossing arteries, as these are "end vessels" that provide the sole perfusion for a portion of the kidney, the ureter and renal pelvis should be gently dissected free from these arteries (Fig. 8.4f).

Periodically during the dissection, the surgeon must assess the "slack" on the ureter to obtain an eventual tension-free anastomosis. This is usually not problematic, but occasionally, additional mobilization of the renal pelvis and more distal ureter must be performed. Once the ureter and renal pelvis are adequately mobilized, the ureter is sharply transected at the UPJ (Fig. 8.4g), often using Potts scissors. The ureter is then laterally speculated to about 1.5–2 cm after excision of any scarred tissue (Fig. 8.4h), and the corresponding area of the renal pelvis is spatulated medially. The renal pelvis and ureter are brought anterior to any crossing vessels.

Stone Removal (If Indicated)

If stones are present within the renal collecting system, a flexible nephroscope can be introduced through the assistant trocar and advanced into the renal pelvis. The renal pelvis incision can be compressed around the scope to minimize the leakage of irrigant into the abdominal cavity and the suction irrigator can be used to remove any excess irrigant fluid within the peritoneal cavity. Of note, care must be taken if grasping the scope with robotic instruments as the scope cladding can be damaged. Stones can be removed with an appropriate basket and extracted through the port. If stones are particularly numerous or large, in some cases, it may be helpful to place them in a laparoscopic retrieval sac for removal at the end of the case.

Antegrade Stent Placement

A 14-gauge angiocatheter is passed percutaneously through the anterior abdominal wall through a small scalpel puncture in the subcostal region and a stiff wire passed through it, which is advanced down the spatulated ureter with robotic assistance. The angiocatheter is removed leaving the wire in place, and a double-J stent is then passed over the wire down through the ureter

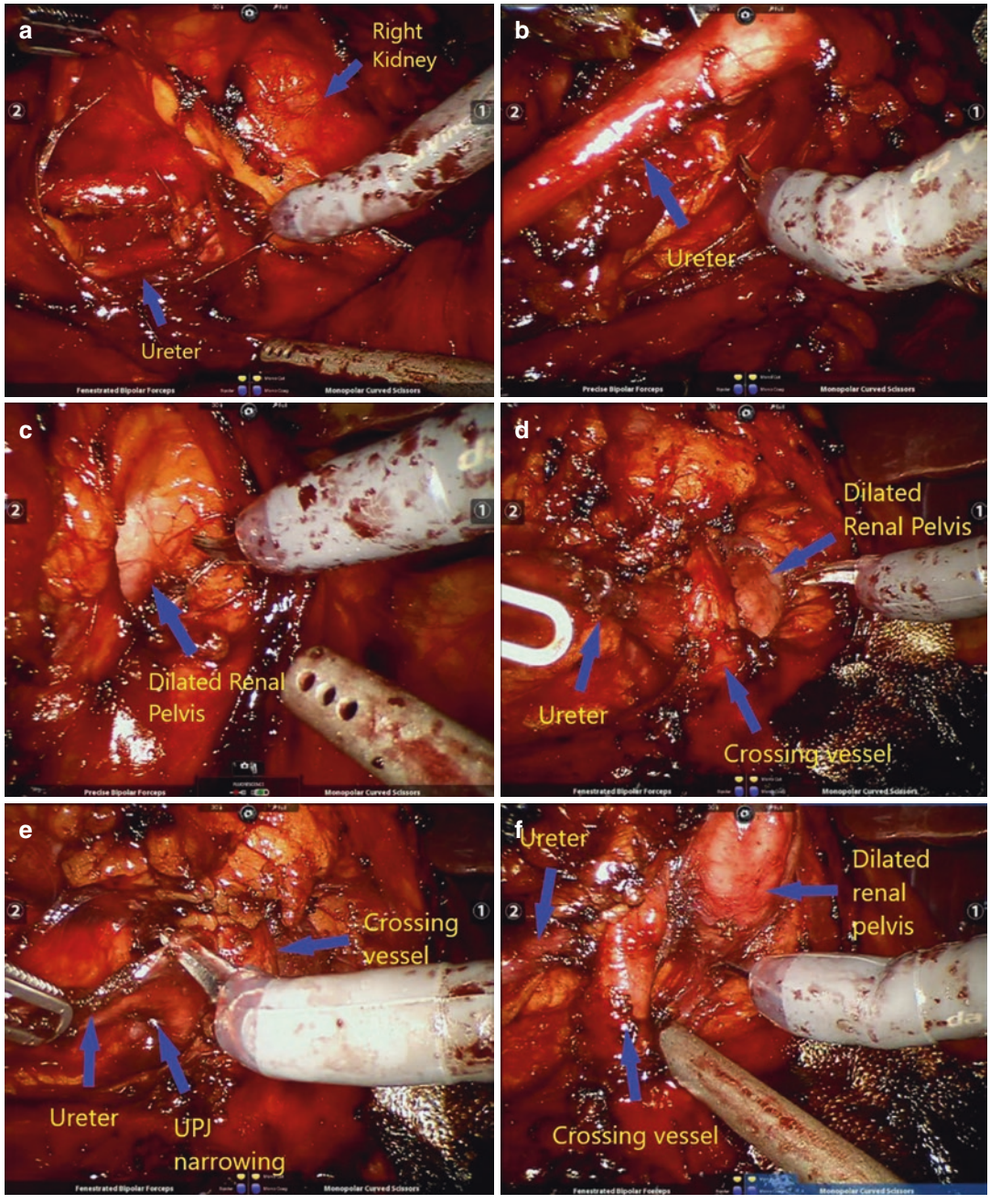

Fig. 8.4 Operative steps of a robotic pyeloplasty. Images taken from a right robotic pyeloplasty. (**a**) Identification of the ureter. (**b**) Tracing the ureter cephalad towards the renal pelvis. (**c**) Dissecting out the dilated renal pelvis. (**d**) Identification of any crossing vessels. (**e**) Release of crossing vessel and dissection of the fibrous rind around the UPJ obstruction. (**f**) Further dissection of the dilated renal pelvis. (**g**) Transection of the UPJ. (**h**) Lateral spatulation of the ureter. (**i**) Antegrade stent placement. (**j**) Ureteral anastomosis after transposing ureter and renal pelvis anterior to crossing vessel and placing the stent curl within the renal pelvis. (**k**) Completed ureteropelvic anastomosis

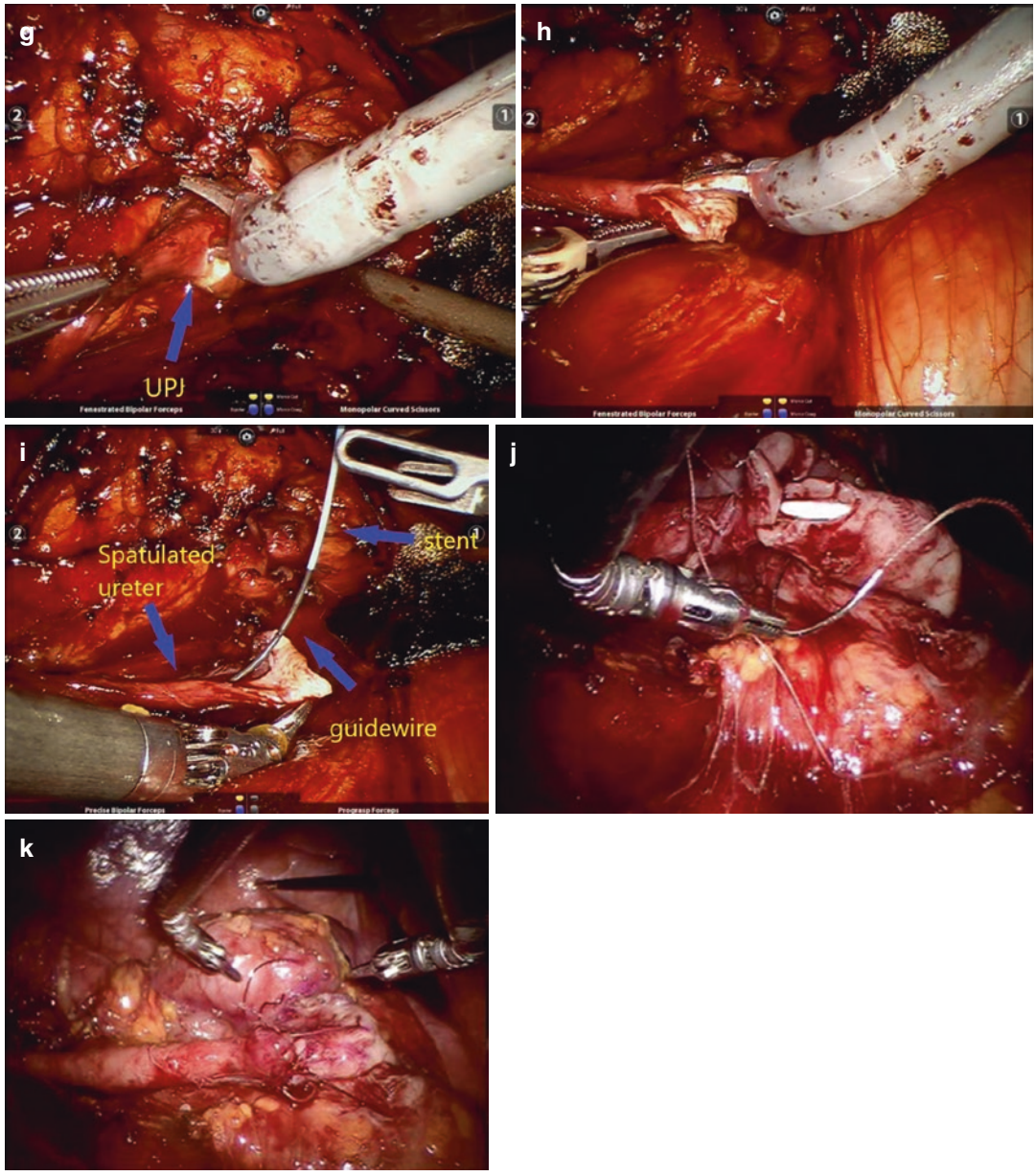

Fig. 8.4 (continued)

(Fig. 8.4i) and then the wire removed, leaving a curl in the proximal end. Confirmation that the distal end of the stent lies within the bladder can be made if the Foley was clamped at the beginning of the case by looking for urine dripping out the proximal end.

Anastomosis

The anastomosis is performed with two running stitches along the anterior and posterior aspects of the closure. A 3-0 Vicryl suture (cut to approximately 6–8 inches) is used to perform the initial

anastomotic stitch between the ureter (at the bottom of the spatulation) and the lateral tip of the renal pelvis. The anastomosis is made anterior to any crossing vessels, if present. The posterior aspect of the anastomosis is then sewn in a running fashion with this 3-0 Vicryl suture. It is helpful to use a dyed and undyed suture to differentiate the anterior and posterior closures. Before closing the anterior aspect, the curl of the stent is placed within the renal pelvis. The anterior aspect of the anastomosis is closed with a separate running stitch (Fig. 8.4j). The closure is then examined to ensure a tension-free, water-tight anastomosis (Fig. 8.4k). The anastomosis is then covered with a small amount of fibrin tissue sealant. Pneumoperitoneum is briefly dropped to 5 mmHg and hemostasis is confirmed, and subsequently reestablished to 15 mmHg.

Drain Placement and Closure

A 19-French round drain is placed in the perinephric region through the lower quadrant robotic trocar site and sutured to the skin. The remaining 10/12 mm trocars are removed under direct vision closed under direct laparoscopic vision using a Carter-Thomason device. The 8-mm robotic trocar sites typically do not need to be closed unless the fascia is felt to have become over-dilated.

Complications

The complication rate for robotic pyeloplasty has been comparable with the standard open approach. A meta-analysis of 12 studies revealed an overall complication rate of 8.9% with RAP. Although there are variations in technique and experience, the reported overall complications rates are within 15% and this decreases further if Clavien grade 1 complications are excluded [32]. The reported treatment-specific complications include postoperative hemorrhage, infection, urine leak (requiring percutaneous drainage and/or prolonged stenting), stent migration (requiring ureteroscopy for stent extraction), and sewn-in stent.

The complication rate associated with LESS RP and conventional LESS pyeloplasty is comparable, between 10% and 20% [25, 39]. Specific complications reported in the LESS approach include urine leak requiring nephrostomy tube placement or conversion to multiport pyeloplasty. In comparative studies, it is noteworthy that the complication rate in initial series of conventional LESS pyeloplasty was higher than that of robotic LESS pyeloplasty, suggesting perhaps a faster learning curve for robotic LESS [25].

Table 8.2 highlights select contemporary series with associated complication rates.

Follow-Up

Typically, the patient may be started on clear fluids the day of surgery and advanced appropriately based on the patient's recovery. Ambulation is encouraged by post-op day 1, and if drain output is minimal, the Foley catheter may be removed for a voiding trial 24 h after surgery. The drain output must be monitored during this period ensure any potential urine leak is not exacerbated by reflux during voids. If the drain fluid is noted to increase, it may be sent for a creatinine measurement to confirm a urine leak, and if present, the Foley catheter should be reinserted and the drain maintained. If no such increase is noted, or fluid creatinine is negative, the drain may be removed and the patient may be discharged. Stent removal is typically arranged in 4–6 weeks, and follow-up imaging may be obtained in 4–8 weeks after stent removal to establish a postoperative baseline.

Outcomes

As discussed previously and shown in Table 8.1, the success rates for RAP are reported as >94%, and as such, it is difficult to ascertain the specific causes for treatment failures. While most studies

Table 8.2 Table of complications from select studies

Study	*N*	Complication rate (overall)	Conversion	Clavien 1	Clavien 2	Clavien 3a	Clavien 3b	Comment
Kumar et al. 2013 [24]	19	0	0	–	–	–	–	Comparison of RAP vs LP; no complications in either group
Moreno-Sierra et al. 2013 [45]	10	1 (10%)	0	1	0	0	0	Initial experience with RAP, 1 complication of lower pole ischemia
Sivaraman et al. 2012 [46]	168	11 (6.6%)		0	11 (6.6%)	0	6 (5.4%)	Comparison of 1° vs 2° RAP; 5% vs 14% complication rates in 1° vs 2° repair, respectively
Olweny et al. 2012 [25][a]	10	1 (10%)	0	0	0	1	0	Comparison of LESS RAP vs LESS LP; no significant differences in complications observed
Niver et al. 2012 [47][a]	117	18 (15.3%)	0	2	2	0	14	Comparison of 1° vs 2° RAP; 15% complications in each group
Etafy et al. 2011 [48]	61	7 (11.4%)	0	3	2[b]	1	2[b]	Review of 61 consecutive patients at a single institution
Sethi et al. 2011 [49][a]	41	3 (7.3%)	0	0	0	1	2	Comparison of stented vs unstented RAP; no clinically significant differences
Bird et al. 2011 [10]	98	5 (5.1%)	0	–	–	–	–	Comparison of RAP vs LP; complications for both groups infrequent
Erdeljan et al. 2010 [50]	88	5 (5.7%)		0	0	1	4	A comparison of experienced surgeons and trainees; no significant differences
Cestari et al. 2010 [37][a]	55	1	0	1	0	0	0	Comparison of transperitoneal vs retroperitoneal RAP

RAP robot-assisted pyeloplasty, *LP* laparoscopic pyeloplasty
[a]Key paper
[b]Repeat patient

indicate that RAP and LP have similar outcomes, the Laparoscopic and Robotic Pyeloplasty Collaborative Group was assembled to further elucidate any subtle determinants of outcomes [51]. In this multi-institutional collaboration, 759 cases from 15 centers were evaluated, comparing 274 LP and 465 RAP with a mean follow-up of 11 months. Although overall there were no significant differences in outcomes between the LP and RAP groups, in bivariate analysis, RAP was associated with a decreased need for secondary procedures than LP (3.2% vs 9.5%, $p = 0.001$). In this series, Lucas et al. showed that the 2 years freedom from secondary procedures was 87% for LP versus 95% for RAP, 81% versus 93% for patients with versus without previous endopyelotomy, and 88% versus 95% for patients with versus without intraoperative crossing vessels, respectively. However, on multivariate analysis, the use of RAP versus LP was no longer found to be related to freedom from secondary procedures.

In the 1–6% of failures with RAP, secondary treatment may be necessary, which may include endopyelotomy, repeat pyeloplasty, extensive reconstruction with ureteral substitution, long-term stent or NT placement, or rarely, nephrectomy.

References

1. Winfield HN. Management of adult ureteropelvic junction obstruction--is it time for a new gold standard? J Urol. 2006;176(3):866–7.
2. Kavoussi LR, Peters CA. Laparoscopic pyeloplasty. J Urol. 1993;150(6):1891–4.
3. Schuessler WW, Grune MT, Tecuanhuey LV, Preminger GM. Laparoscopic dismembered pyeloplasty. J Urol. 1993;150(6):1795–9.
4. Gettman MT, Neururer R, Bartsch G, Peschel R. Anderson-Hynes dismembered pyeloplasty performed using the da Vinci robotic system. Urology. 2002;60(3):509–13.
5. Klingler HC, Remzi M, Janetschek G, Kratzik C, Marberger MJ. Comparison of open versus laparoscopic pyeloplasty techniques in treatment of uretero-pelvic junction obstruction. Eur Urol. 2003;44(3):340–5.
6. Bauer JJ, Bishoff JT, Moore RG, Chen RN, Iverson AJ, Kavoussi LR. Laparoscopic versus open pyeloplasty: assessment of objective and subjective outcome. J Urol. 1999;162(3 Pt 1):692–5.
7. Brooks JD, Kavoussi LR, Preminger GM, Schuessler WW, Moore RG. Comparison of open and endourologic approaches to the obstructed ureteropelvic junction. Urology. 1995;46(6):791–5.
8. Baldwin DD, Dunbar JA, Wells N, McDougall EM. Single-center comparison of laparoscopic pyeloplasty, Acucise endopyelotomy, and open pyeloplasty. J Endourol. 2003;17(3):155–60.
9. Braga LH, Pace K, DeMaria J, Lorenzo AJ. Systematic review and meta-analysis of robotic-assisted versus conventional laparoscopic pyeloplasty for patients with ureteropelvic junction obstruction: effect on operative time, length of hospital stay, postoperative complications, and success rate. Eur Urol. 2009;56(5):848–57.
10. Bird VG, Leveillee RJ, Eldefrawy A, Bracho J, Aziz MS. Comparison of robot-assisted versus conventional laparoscopic transperitoneal pyeloplasty for patients with ureteropelvic junction obstruction: a single-center study. Urology. 2011;77(3):730–4.
11. Kawachi MH. Counterpoint: robot-assisted laparoscopic prostatectomy: perhaps the surgical gold standard for prostate cancer care. J Natl Compr Cancer Netw. 2007;5(7):689–92.
12. Willis DL, Gonzalgo ML, Brotzman M, Feng Z, Trock B, Su LM. Comparison of outcomes between pure laparoscopic vs robot-assisted laparoscopic radical prostatectomy: a study of comparative effectiveness based upon validated quality of life outcomes. BJU Int. 2012;109(6):898–905.
13. Monn MF, Bahler CD, Schneider EB, Sundaram CP. Emerging trends in robotic pyeloplasty for the management of ureteropelvic junction obstruction in adults. J Urol. 2013;189(4):1352–7.
14. Sukumar S, Sun M, Karakiewicz PI, Friedman AA, Chun FK, Sammon J, et al. National trends and disparities in the use of minimally invasive adult pyeloplasty. J Urol. 2012;188(3):913–8.
15. Varda BK, Wang Y, Chung BI, Lee RS, Kurtz MP, Nelson CP, et al. Has the robot caught up? National trends in utilization, perioperative outcomes, and cost for open, laparoscopic, and robotic pediatric pyeloplasty in the United States from 2003 to 2015. J Pediatr Urol. 2018;14(4):336.e1–8.
16. Song SH, Lee C, Jung J, Kim SJ, Park S, Park H, et al. A comparative study of pediatric open pyeloplasty, laparoscopy-assisted extracorporeal pyeloplasty, and robot-assisted laparoscopic pyeloplasty. PLoS One. 2017;12(4):e0175026.
17. Silay MS, Spinoit AF, Undre S, Fiala V, Tandogdu Z, Garmanova T, et al. Global minimally invasive pyeloplasty study in children: results from the Pediatric Urology Expert Group of the European Association of Urology Young Academic Urologists working party. J Pediatr Urol. 2016;12(4):229.e1–7.
18. Patel A, Pickhardt MW, Littlejohn N, Zamilpa I, Rettiganti M, Luo C, et al. Shortened operative time

for pediatric robotic versus laparoscopic dismembered pyeloplasty. Can J Urol. 2016;23(3):8308–11.
19. Ganpule A, Jairath A, Singh A, Mishra S, Sabnis R, Desai M. Robotic versus conventional laparoscopic pyeloplasty in children less than 20 kg by weight: single-center experience. World J Urol. 2015;33(11):1867–73.
20. Pahwa M, Pahwa AR, Girotra M, Abrahm RR, Kathuria S, Sharma A. Defining the pros and cons of open, conventional laparoscopy, and robot-assisted pyeloplasty in a developing nation. Adv Urol. 2014;2014:850156.
21. Basatac C, Boylu U, Onol FF, Gumus E. Comparison of surgical and functional outcomes of open, laparoscopic and robotic pyeloplasty for the treatment of ureteropelvic junction obstruction. Turk J Urol. 2014;40(1):24–30.
22. Danuser H, Germann C, Pelzer N, Ruhle A, Stucki P, Mattei A. One- vs 4-week stent placement after laparoscopic and robot-assisted pyeloplasty: results of a prospective randomised single-centre study. BJU Int. 2014;113(6):931–5.
23. Riachy E, Cost NG, Defoor WR, Reddy PP, Minevich EA, Noh PH. Pediatric standard and robot-assisted laparoscopic pyeloplasty: a comparative single institution study. J Urol. 2013;189(1):283–7.
24. Kumar R, Nayak B. Robotic versus conventional laparoscopic pyeloplasty: a single surgeon concurrent cohort review. Indian J Urol. 2013;29(1):19–21.
25. Olweny EO, Park SK, Tan YK, Gurbuz C, Cadeddu JA, Best SL. Perioperative comparison of robotic assisted laparoendoscopic single-site (LESS) pyeloplasty versus conventional LESS pyeloplasty. Eur Urol. 2012;61(2):410–4.
26. Subotic U, Rohard I, Weber DM, Gobet R, Moehrlen U, Gonzalez R. A minimal invasive surgical approach for children of all ages with ureteropelvic junction obstruction. J Pediatr Urol. 2012;8(4):354–8.
27. Garcia-Galisteo E, Emmanuel-Tejero E, Navarro Vilchez P, Garcia-Galisteo J, Baena-Gonzalez V. [Comparison of the operation time and complications between conventional and robotic-assisted laparoscopic pyeloplasty]. Actas Urol Esp. 2011;35(9):523–8. [Article in Spanish].
28. Hemal AK, Mukherjee S, Singh K. Laparoscopic pyeloplasty versus robotic pyeloplasty for ureteropelvic junction obstruction: a series of 60 cases performed by a single surgeon. Can J Urol. 2010;17(1):5012–6.
29. Kim S, Canter D, Leone N, Patel R, Casale P. A comparative study between laparoscopic and robotically assisted pyeloplasty in the pediatric population. J Urol. 2008;179:357.
30. Link RE, Bhayani SB, Kavoussi LR. A prospective comparison of robotic and laparoscopic pyeloplasty. Ann Surg. 2006;243(4):486–91.
31. Weise ES, Winfield HN. Robotic computer-assisted pyeloplasty versus conventional laparoscopic pyeloplasty. J Endourol. 2006;20(10):813–9.
32. Wang F, Xu Y, Zhong H. Robot-assisted versus laparoscopic pyeloplasty for patients with ureteropelvic junction obstruction: an updated systematic review and meta-analysis. Scand J Urol. 2013;47(4):251–64.
33. Autorino R, Eden C, El-Ghoneimi A, Guazzoni G, Buffi N, Peters CA, et al. Robot-assisted and laparoscopic repair of ureteropelvic junction obstruction: a systematic review and meta-analysis. Eur Urol. 2014;65(2):430–52.
34. Light A, Karthikeyan S, Maruthan S, Elhage O, Danuser H, Dasgupta P. Peri-operative outcomes and complications after laparoscopic vs robot-assisted dismembered pyeloplasty: a systematic review and meta-analysis. BJU Int. 2018;122(2):181–94.
35. Olsen LH, Jorgensen TM. Computer assisted pyeloplasty in children: the retroperitoneal approach. J Urol. 2004;171(6 Pt 2):2629–31.
36. Kaouk JH, Hafron J, Parekattil S, Moinzadeh A, Stein R, Gill IS, et al. Is retroperitoneal approach feasible for robotic dismembered pyeloplasty: initial experience and long-term results. J Endourol. 2008;22(9):2153–9.
37. Cestari A, Buffi NM, Lista G, Sangalli M, Scapaticci E, Fabbri F, et al. Retroperitoneal and transperitoneal robot-assisted pyeloplasty in adults: techniques and results. Eur Urol. 2010;58(5):711–8.
38. Khoder WY, Waidelich R, Ghamdi AMA, Schulz T, Becker A, Stief CG. A prospective randomised comparison between the transperitoneal and retroperitoneoscopic approaches for robotic-assisted pyeloplasty in a single surgeon, single centre study. J Robot Surg. 2018;12(1):131–7.
39. Best SL, Donnally C, Mir SA, Tracy CR, Raman JD, Cadeddu JA. Complications during the initial experience with laparoendoscopic single-site pyeloplasty. BJU Int. 2011;108(8):1326–9.
40. Tracy CR, Raman JD, Bagrodia A, Cadeddu JA. Perioperative outcomes in patients undergoing conventional laparoscopic versus laparoendoscopic single-site pyeloplasty. Urology. 2009;74(5):1029–34.
41. Tobis S, Houman J, Thomer M, Rashid H, Wu G. Robot-assisted transumbilical laparoendoscopic single-site pyeloplasty: technique and perioperative outcomes from a single institution. J Laparoendosc Adv Surg Tech A. 2013;23(8):702–6.
42. Rais-Bahrami S, Rizkala ER, Cadeddu JA, Tugcu V, Derweesh IH, Abdel-Karim AM, et al. Laparoendoscopic single-site pyeloplasty: outcomes of an international multi-institutional study of 140 patients. Urology. 2013;82(2):366–72.
43. Buffi NM, Lughezzani G, Fossati N, Lazzeri M, Guazzoni G, Lista G, et al. Robot-assisted, single-site, dismembered pyeloplasty for ureteropelvic junction obstruction with the new da Vinci platform: a stage 2a study. Eur Urol. 2015;67(1):151–6.
44. Sorokin I, Canvasser NE, Irwin B, Autorino R, Liatsikos EN, Cadeddu JA, et al. The Decline of laparoendoscopic single-site surgery: a survey of the endourological society to identify shortcomings and guidance for future directions. J Endourol. 2017;31(10):1049–55.

45. Moreno-Sierra J, Castillon-Vela I, Ortiz-Oshiro E, Galante-Romo I, Fernandez-Perez C, Senovilla-Perez JL, et al. Robotic Anderson-Hynes dismembered pyeloplasty: initial experience. Int J Med Robot. 2013;9(2):127–33.
46. Sivaraman A, Leveillee RJ, Patel MB, Chauhan S, Bracho JE 2nd, Moore CR, et al. Robot-assisted laparoscopic dismembered pyeloplasty for ureteropelvic junction obstruction: a multi-institutional experience. Urology. 2012;79(2):351–5.
47. Niver BE, Agalliu I, Bareket R, Mufarrij P, Shah O, Stifelman MD. Analysis of robotic-assisted laparoscopic pyleloplasty for primary versus secondary repair in 119 consecutive cases. Urology. 2012;79(3):689–94.
48. Etafy M, Pick D, Said S, Hsueh T, Kerbl D, Mucksavage P, et al. Robotic pyeloplasty: the University of California-Irvine experience. J Urol. 2011;185(6):2196–200.
49. Sethi AS, Regan SM, Sundaram CP. Robot-assisted laparoscopic pyeloplasty with and without a ureteral stent. J Endourol. 2011;25(2):239–43.
50. Erdeljan P, Caumartin Y, Warren J, Nguan C, Nott L, Luke PP, et al. Robot-assisted pyeloplasty: follow-up of first Canadian experience with comparison of outcomes between experienced and trainee surgeons. J Endourol. 2010;24(9):1447–50.
51. Lucas SM, Sundaram CP, Wolf JS Jr, Leveillee RJ, Bird VG, Aziz M, et al. Factors that impact the outcome of minimally invasive pyeloplasty: results of the Multi-institutional Laparoscopic and Robotic Pyeloplasty Collaborative Group. J Urol. 2012;187(2):522–7.

Robotic Abdominal Sacrocolpopexy

9

Sarah McAchran and Courtenay K. Moore

Introduction

Urologic and urogynecologic surgeons specializing in female pelvic medicine and reconstructive surgery have been early adapters of new and minimally invasive techniques to treat both urinary incontinence and pelvic organ prolapse (POP) with the goal of improving both anatomic and subjective outcomes while minimizing morbidity. Robotic approaches to POP have gained a strong foothold as surgeons have adapted this technology to the abdominal sacrocolpopexy (ASC) procedure, the universally considered "gold-standard" procedure to treat POP [1]. The utilization of robotic technology has led to decreased intraoperative morbidity as well as decreased convalescence.

Abdominal surgery for pelvic organ prolapse (POP) has a long history, originating with the Mayo procedure which described securing the uterus to the anterior abdominal wall. Eventually, attempts to create a more natural vaginal axis and to prevent enterocele formation led to the suturing of the vaginal apex directly to the anterior longitudinal ligament of the sacrum. The subsequent addition of a piece of material, either autologous or synthetic, to bridge the gap between the vaginal apex and the sacrum led to the contemporary version of the abdominal sacrocolpopexy.

The first minimally invasive alternative to the open ASC was the laparoscopic sacrocolpopexy (LSC) [2]. This enabled the performance of a highly successful abdominal procedure while avoiding a large abdominal incision, abdominal packing and retracting, and extensive bowel manipulation. This translates into shorter recovery time, reduction in postoperative pain, and a lower rate of postoperative ileus. LSC and ASC procedures have demonstrated similar success rates [3–5]. However, the rigidity of laparoscopic instrumentation limits surgical dexterity with suturing as well as sacral and apical vaginal dissection. Robotic technology alleviates these limitations by improving visualization of the surgical field with three-dimensional imaging. Additionally, the 7° of freedom in articulation as well as the stability of the instrument (tremor control) enable the surgeon to perform complex procedures with precision and accuracy.

Given the relatively recent adoption of this technology, true evaluation of long-term outcomes are decades away; however, one center has published data comparing outcomes for 51 patients who underwent either an open ASC or robotic abdominal sacrocolpopexy (RASC)

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S. L. Best, S. Y. Nakada (eds.), *Minimally Invasive Urology*,
https://doi.org/10.1007/978-3-030-23993-0_9

procedure between 2006 and 2007, giving a mean follow-up of 44 months [6]. Anatomic improvement, based on Pelvic Organ Prolapse Quantification (POP-Q) examination and subjective improvement based on questionnaire data was similar between the two groups suggesting that the addition of robotic technology does not hinder outcomes. The Mayo Clinic group evaluated all of their patients who had surgery for post-hysterectomy vault prolapse from 2000 to 2012 to compare outcomes between the Mayo-McCall culdoplasty (MMC), open abdominal sacrocolpopexy (ASC), and robotic sacrocolpopexy (RSC) [7]. The 5 years survival free of retreatment rate was not significant at 94.0%, 95.5%, and 92.1%, respectively. Ten-year data was not available for RSC comparisons. It should be noted that the long-term durability for open ASC for relieving symptoms is less than previously thought with a large multicenter trial finding 71–76% at 7 years [8]. Time will tell if the addition of robotic technology improves these numbers.

It is estimated that the lifetime risk of surgical intervention for POP is 11% for women who reach 80 years of age [9]. As the population ages, the prevalence of this problem will continue to increase and the need to find a minimally invasive, durable repair that can be widely adopted by a reconstructive specialists continues to grow.

Indications/Contraindications

Commonly accepted indications for sacrocolpopexy include multicompartment pelvic organ prolapse, symptomatic prolapse in younger women, recurrent prolapse after failed vaginal prolapse repair, severe vaginal vault prolapse, and vaginal vault prolapse in women with significant vaginal shortening as a result of prior surgeries. It is an appropriate procedure for women who wish to remain sexually active.

Relative contraindications for RASC are similar to those for most laparoscopic procedures and depend on the surgeon's experience and the complexity of the case. These include a history of multiple prior abdominal or pelvic procedures, severe chronic obstructive pulmonary disease, and morbid obesity. RASC traditionally requires a steep Trendelenburg position that may put patients with morbid obesity, pulmonary disease, and gastroesophageal reflux disease at higher risk for increased airway pressures, poor ventilation, and aspiration pneumonia. Prolonged surgical procedures in the steep Trendelenberg position can increase intraocular pressure, with case reports of retinal detachment and blindness [10]. Both open and laparoscopic approaches can be achieved with less steep Trendelenberg and thus should be considered for patients with the aforementioned comorbidities, or for those with retinal disease.

Sacrocolpopexy With Concomitant Hysterectomy

Strictly speaking, ASC describes the repair of post-hysterectomy vaginal vault prolapse. However, many with POP still have their uterus, necessitating concomitant hysterectomy. There are conflicting data regarding mesh erosion with concurrent total hysterectomy and open ASC [11–13]. The rate of erosion of the vaginal portion of the suspending mesh into the vagina varies between studies from 2% to 10%. Patients suffering from this complication generally present with granulation tissue and a seropurulent or serosanguinous discharge per vagina. This can be accompanied by pain or tenderness and dyspareunia. Any combination of mesh and/or suture material may be extruded. The pathophysiology of this process is not known and the term "erosion" is used simply to describe the unplanned presence of mesh in the vagina. Erosion may be the result of inflammatory reaction to the foreign body, or infection of the foreign body. Alternatively, it may be due to the host's own immune response to the graft. Management of these erosions can be quite complicated with associated morbidity [14, 15].

Because mesh erosion tends to occur along suture lines, concomitant hysterectomy performed at the time of ASC is a logical risk factor given the proximity of the vaginal cuff closure to

the suspended mesh. The risk is amplified by the potential for cuff dehiscence, which one study placed as an incidence of 4.1% for robotic procedures [16]. Perhaps the most convincing study evaluating risk factors for mesh erosion is the subset analysis of the CARE trial performed by the members of the Pelvic Floor Disorders Network [12]. The CARE trial was a randomized surgical trial of 322 stress-continent women with stages II-IV POP conducted to investigate the benefit of an adjuvant Burch colposuspension at the time of ASC. This prospectively designed study followed 322 patients out to 2 years with 93% of the patients completing the 2-year assessment. 83 patients had a concomitant hysterectomy. There was a 6% mesh/suture erosion rate within 2 years of surgery. In this study, concurrent hysterectomy was a modifiable risk factor for mesh/suture erosion.

For this reason, if hysterectomy is to be performed at the time of robotic-assisted repair of prolapse, then a cervical sparing procedure is preferred. The cervical sparing procedure obviates the need for vaginal cuff closure and leads to shorter operative time and less blood loss [17]. The remainder of this chapter will focus on repair of post-hysterectomy vaginal vault prolapse with the RASC.

Robotic Abdominal Sacrocolpopexy Equipment List

- Non-disposable
  - Da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA)
  - Veress needle
  - 12-mm robotic port
  - Three 8-mm robotic ports (2 optional)
  - 10/12-mm laparoscopic port
  - 0° and 30° down robotic camera
  - Robotic monopolar curved scissors
  - Robotic grasping forceps
  - Robotic double fenestrated grasper
  - Two robotic needle drivers
  - Laparoscopic scissors
  - Laparoscopic grasping forceps
  - Handheld vaginal retractor
  - Polypropylene mesh
  - Cystoscope with 30° and 70° lenses
- Disposable
  - Laparoscopic suction

Technical Description

Patient Preparation and Positioning

As previously noted, steep Trendelenberg position is required for adequate pelvic visualization and dissection. Anti-skid devices such as a gel pad or bean bag should be employed. Sequential compression devices are placed on the patient's legs. The patient's arms are padded and tucked taking care to protect all the bony prominences. The legs are placed in low-profile Allen stirrups in a low lithotomy position with the thighs roughly parallel to the floor when the table is level. The knees should not be flexed more than 60° to prevent femoral nerve compression. The buttocks are placed so that they extend approximately 1 inch beyond the end of the table. To further insure against patient movement once the Trendelenberg position is employed, cross straps can be placed across the patient's chest. Prior to beginning the procedure, the table should then be placed into steep Trendelenberg position and observation for and remediation of any patient movement can occur. The patient is prepped from the nipples to the proximal thigh, including the vagina. Either an orogastric or nasogastric tube is placed. Once the patient is draped, a 16-French foley catheter is inserted.

Placement of Instruments

The robotic ports are placed in a W configuration with the camera port placed at the level of the umbilicus (Fig. 9.1). When the distance between the umbilicus and the pubic symphysis is less than 15 cm, the camera port should be placed above the umbilicus to allow for adequate visualization of the sacral promontory. Pneumoperitoneum is obtained after gaining access to the peritoneal cavity using a Veress

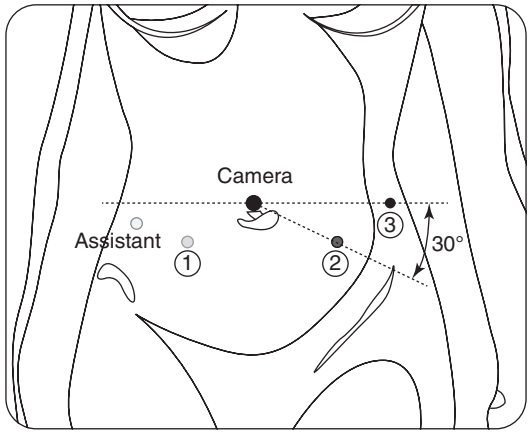

Fig. 9.1 Port placement placement for robotic abdominal sacrocolpopexy (using the 4-arm Da Vinci)

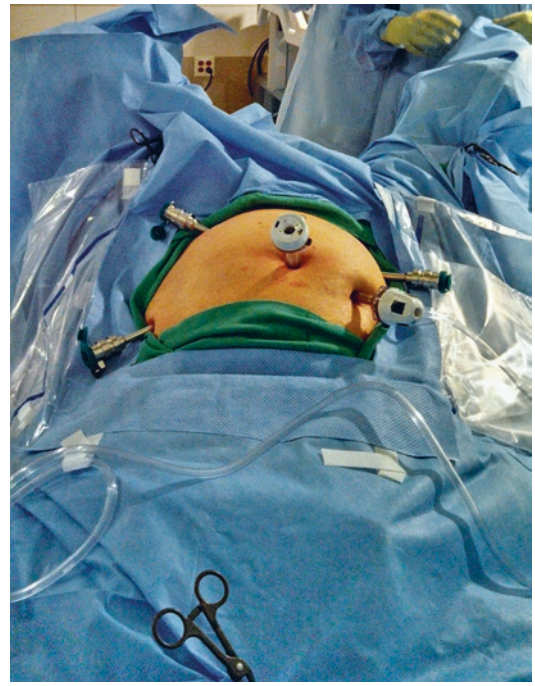

Fig. 9.2 Port in place after insufflation. In this view from the head looking toward the legs, the 10/12 camera port and accessory port are easily distinguished from the three robotic arm port. The third robotic port, the most cephalad of the three, is placed as far lateral as possible to the patient's left side, approximately 3 cm from the iliac crest and at least 10 cm from the left instrument port, at the level of the camera port

needle at the umbilicus. After confirmation of safe intraperitoneal entry with aspiration and drop test, pneumoperitoneum is established to 15 mmHg. A 10 mm incision is then made within the umbilicus and a visual optical dilating trocar is used to insert the first 10 mm port using a 0° lens. Using a 0° or 30° up robotic camera, four additional ports are placed under direct vision. A total of three 8-mm robotic ports are placed as well as an additional 10/12-mm accessory laparoscopic port in the right lateral abdominal wall to allow passage of instruments, mesh, and sutures. The right and left robotic ports are placed 10 cm to the right or left of the umbilicus and approximately 30° inferior to the camera port. The third robotic port is placed as far lateral as possible to the patient's left side, approximately 3 cm from the iliac crest and at least 10 cm from the left instrument port, at the level of the camera port. The final laparoscopic port is placed on the patient's far right side, approximately 8 cm from the right instrument port, just below the level of the camera port (Fig. 9.2).

The OR table is lowered and the patient is placed in steep Trendelenberg position to allow bowel contents to retract naturally cephalad and the robot is docked. RASC can be accomplished with traditional docking between the legs at the foot of the bed. However, with the robotic cart side-docked 45° lateral to the patient's left leg, vaginal access during the procedure is improved (Fig. 9.3) [18, 19]. The bedside surgeon stands on the patient's right as does the scrub assistant.

Gaining Exposure

If not already in use, the 0° robotic camera is placed. The abdomen and pelvis are inspected and adhesions are addressed robotically. The sigmoid colon is identified. A fenestrated bipolar forceps can be used in the third robotic arm to retract the sigmoid colon laterally. If one is using the 2-arm robot, then a suture can be used to retract the sigmoid colon. There are several methods for doing this. A Keith needle can be used to pass a retracting suture into the abdomen through the skin. Using the robotic arms the retracting suture is then passed through an epiploic

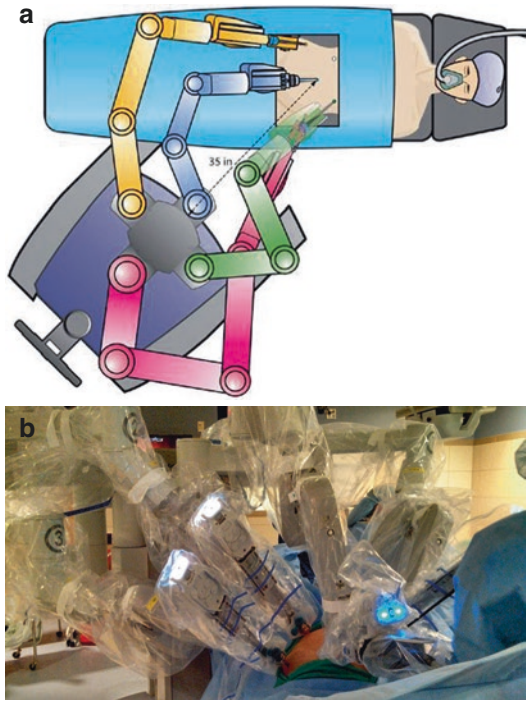

Fig. 9.3 (**a**) Side docking allows for easier access to the vagina and easier manipulation of the vaginal obturator by the bedside assistant (Arm #3, *red*; arm #2, *green*; camera, *blue*; arm #1, *yellow*). (**b**) Note that arm #3 is almost parallel to the floor

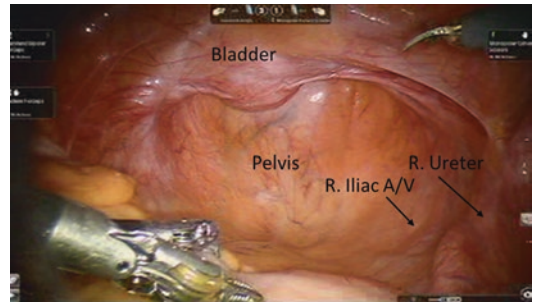

Fig. 9.4 Pelvic anatomy. Prior to any dissection, one can identify the bladder, iliac artery and vein, and right ureter

appendage or the tenia of the sigmoid colon and then back through the skin near the entry site. This is gently secured at the skin level with a clamp.

The following structures should be identified: the sacral promontory which is just below the bifurcation of the iliac arteries, the right ureter which is approximately 3 cm lateral to the sacral promontory, the vagina, bladder, and rectum (Fig. 9.4) [20]. To identify the vagina, a vaginal obturator is placed and manipulated by the bedside assistant. A round tipped endoanal, or EEA sizer may be placed transvaginally (Fig. 9.5). Alternatively, a customized handheld vaginal retractor can be used. CooperSurgical (Trumbull CT, USA) manufactures a two disposable Sacro tips that attach to their RUMI® handle, one of which is used for sacrocolpopexy and the other which can be used for sacrocervicopexy.

With the vaginal obturator in place, the plane between the anterior wall of the vagina and the bladder is developed (Fig. 9.6). The peritoneum over the vaginal apex is incised with cautery applied via the monopolar curved scissors in the right hand and the Maryland bipolar forceps in the left hand. This should be a relatively bloodless plane, and after the initial use of cautery to incise the peritoneum, the remaining dissection is performed sharply without cautery to prevent devascularization of the vaginal wall (Fig. 9.7). The bladder can be filled to help demarcate the appropriate plane, or a cystoscopic light can be introduced into the bladder. This plane should be dissected for a minimum of 3 cm distal to the vaginal apex to allow space for placement of the mesh. The lack of direct tactile feedback can make this dissection challenging, particularly in patients who have undergone prior reconstructive procedures. In a series of 85 cases performed by an experienced robotic surgeon, the rate of inadvertent cystotomy was 4.7% [17].

The rectovaginal space is similarly developed. The peritoneum over the posterior vaginal wall is elevated and the vagina is separated from the rectum posteriorly. An EEA sizer placed per rectum can help to identify the rectovaginal septum.

After adequate vaginal mobilization, attention is then turned to the sacral promontory and to exposure of the anterior longitudinal ligament of the sacrum (Fig. 9.8). The 30° down scope allows for better visualization of the sacrum. The peritoneum overlying the sacral promontory is grasped and incised with the monopolar endoshears. Blunt dissection can then be used to clearly identify the anterior longitudinal ligament in preparation for suture placement. Extreme care is taken

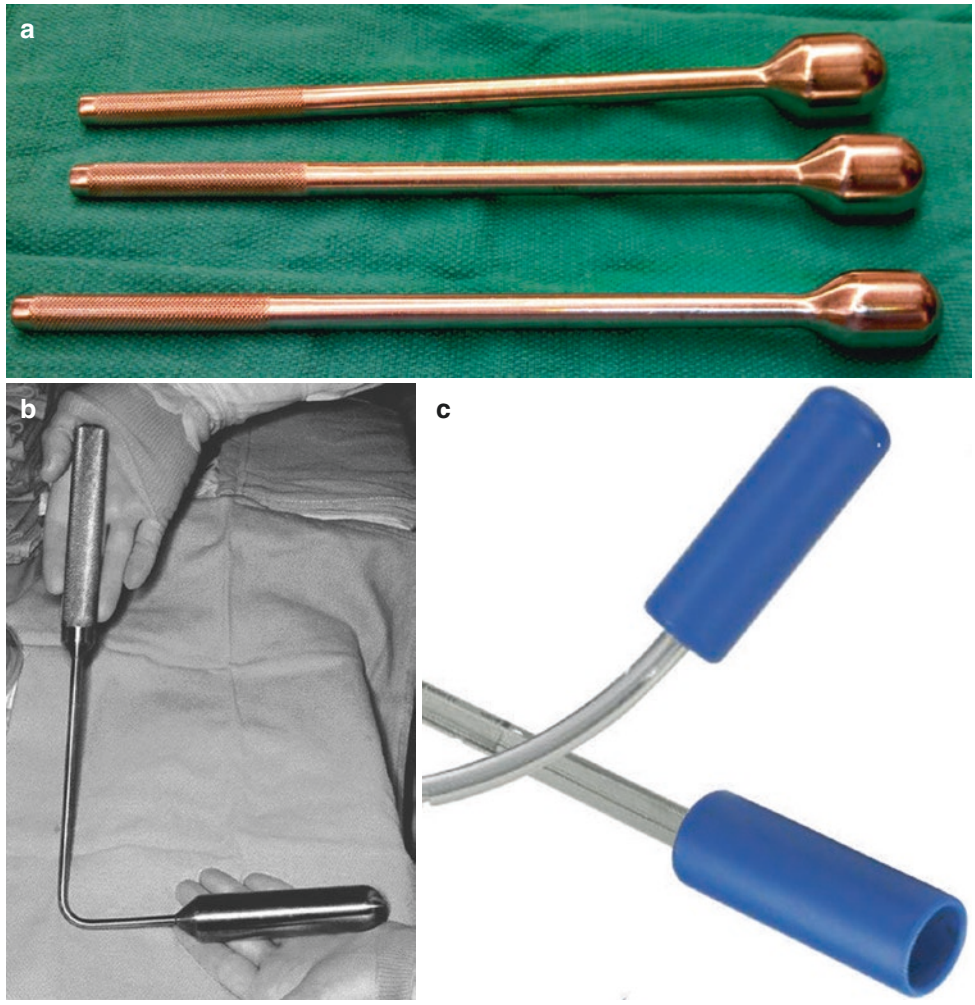

Fig. 9.5 Various options to use as the vaginal obturator: (**a**) EEA sizers, (**b**) customized vaginal retractor used at the Mayo Clinic, (**c**) CooperSurgical disposable Sacrocolpopexy tips and Sacrocervicopexy tips for RUMI® System Handle. (Courtesy of CooperSurgical, Trumbull, CT, USA)

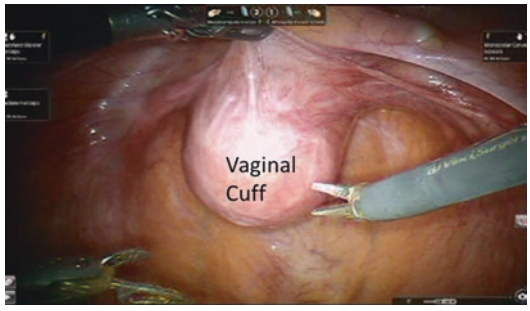

Fig. 9.6 Using the third robotic arm to retract the bladder anteriorly, the peritoneum over the vaginal cuff is exposed. Note the grasper in the left hand and the endoshears in the right hand

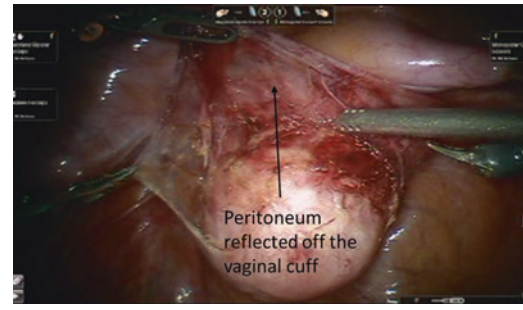

Fig. 9.7 The peritoneum overlying the anterior vagina has been disseted allowing a place to develop between the vagina and the bladder. This will be site for the anterior mesh attachment

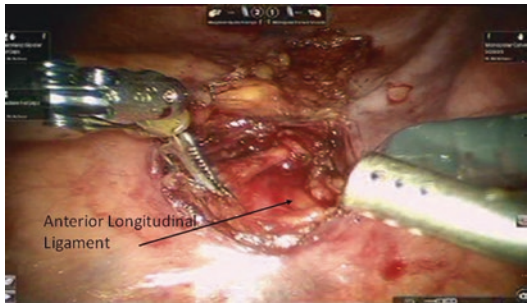

Fig. 9.8 Sacral dissection with the posterior peritoneum incised and the anterior longitudinal ligament exposed

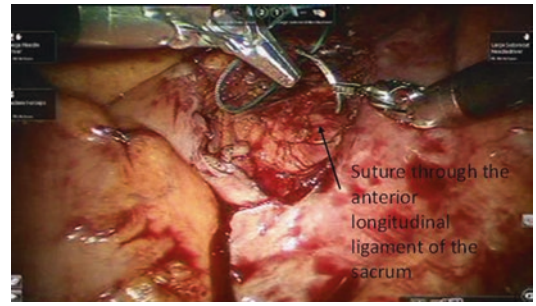

Fig. 9.9 The anchoring suture for the sacral portion of the mesh is placed through the anterior longitudinal ligament

to avoid injury to the presacral veins, as this can cause life-threatening bleeding. The magnification and 3-D visualization afforded by the robotic technique provide enhanced visualization of the pre-sacral vasculature. The peritoneal incision can then be extended in a caudal direction towards the posterior cul-de-sac and vaginal cuff to allow for retroperitonealization of the mesh at completion of the procedure. Alternatively, a peritoneal tunnel can be created using blunt dissection from the promontory to the cul-de-sac [17]. This eliminates the need for a peritoneal closure at the end of the case, which can be time-consuming.

Mesh Placement

Next, two or three nonabsorbable sutures, cut to approximately 7 cm, are placed into the exposed portion of the sacral promontory (Fig. 9.9). These sutures with needles attached are left in the abdomen for mesh fixation. 2.0 Gore-Tex, 0.0 or 2.0 Ethibond, and 2.0 Prolene have all been described [17, 21–24].

The polypropylene mesh, either in two separate strips (3–5 cm × 12–15 cm) or prefashioned in a Y configuration, is passed into the field through the assistant port and sutured to the posterior and anterior vaginal wall. Several companies have a precut macroporous Y-shaped mesh designed specifically for ASC (Fig. 9.10). Alternatively, the anterior and posterior arms of the self-cut mesh can be sewn together with permanent suture before introduction into the abdomen.

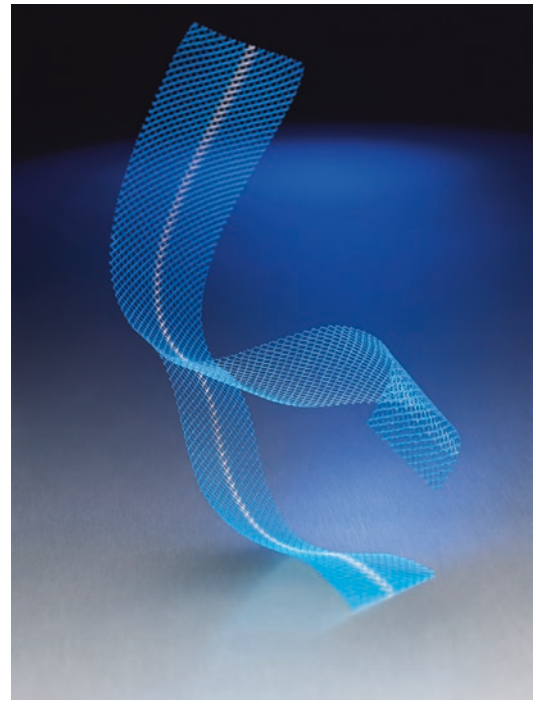

Fig. 9.10 Macroporous Y-shaped prefabricated mesh. Pictured is the Upsylon™ Y-shaped Mesh. (Courtesy of Boston Scientific, Marlborough, MA, USA)

With the vaginal obturator in place and the endoshears swapped for a needle driver, the mesh is affixed to the anterior vaginal wall with a series of 4–8 interrupted sutures cut to 6.0 inches in length (Fig. 9.11). Placing the distal and lateral corner sutures first facilitates placement of the remaining sutures. Traditionally, nonabsorbable sutures, often 2.0 Gore-Tex, have been used to affix the mesh to the vagina. Because Gore-Tex is

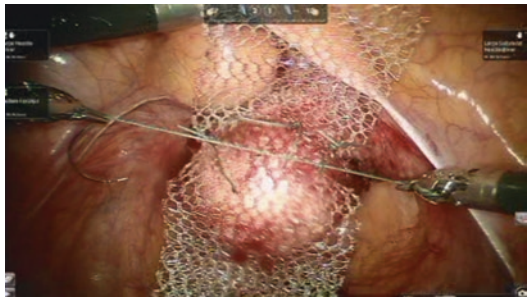

Fig. 9.11 With an obturator in the vagina, the mesh is attached to the anterior vaginal wall

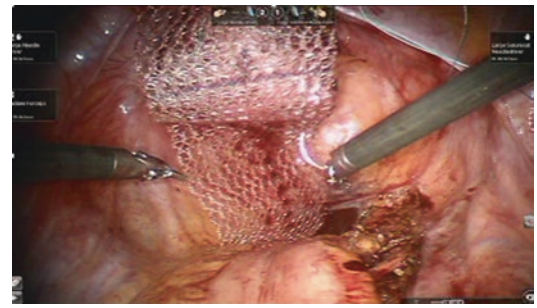

Fig. 9.12 Using the third robotic arm to retract the sacral portion of the mesh, the posterior arm of the mesh is affixed to the vagina. Note that the vaginal obturator is used to deflect the vagina anteriorly

a monofilament suture, it is thought to be less likely to extrude vaginally. Recently, the procedure has been described using 2-0 polyglactin suture for this portion of the procedure [24, 25]. In two small series, both of which had 2-year follow-up, the rate of vaginal mesh erosion was less than 3%. It is proposed that polyglactin suture which is completely absorbed in 56–70 days, will retain its strength in the first few weeks while tissue ingrowth incorporates the mesh into the vaginal wall and then absorb, eliminating the risk of suture extrusion in the long term. The effect this may have on prolapse recurrence rates in the long term remains unknown.

The posterior arm of the mesh is then affixed to the posterior vaginal wall (Fig. 9.12). The third robotic arm can be used to grasp the apical end of the mesh, allowing the posterior arm to drape over the posterior vaginal wall. Excess mesh from the anterior and posterior limbs is trimmed with either robotic scissors or the scissor portion of the SutureCut™ needle driver.

Finally, the apical portion of the mesh is held in place against the sacral promontory while the console or bedside surgeon examines the vagina to assess the degree of prolapse reduction. The mesh tension should be adjusted appropriately to reduce the prolapse without putting excess tension on the vaginal walls. The previously placed sutures in the anterior longitudinal ligament of the sacrum are then passed through the mesh at the chosen location (Fig. 9.13). Excess apical mesh is trimmed and the mesh is retroperitonealized by reapproximating the peritoneum over the mesh with 2-0 Vicryl suture (Figs. 9.14 and 9.15).

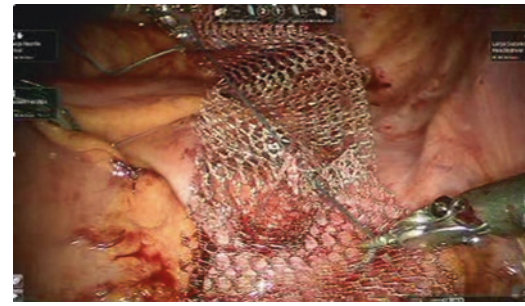

Fig. 9.13 The mesh is secured to the sacrum with at least two fixating sutures

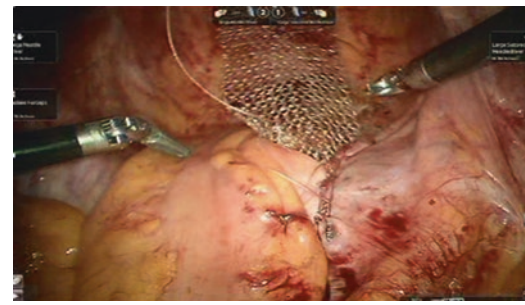

Fig. 9.14 The posterior peritoneum is reapproximated over the mesh using a 2-0 Vicryl suture

Additional sutures can be used to approximate the peritoneum overlying the bladder to cover the mesh near the vaginal cuff. The LAPRA-TY® (Ethicon) device can be helpful in securing the suture for this portion of the procedure.

At this point, it is prudent to perform cystoscopy after the intravenous administration of indigo carmine. This allows the surgeon to assess for ureteral patency and bladder integrity prior to

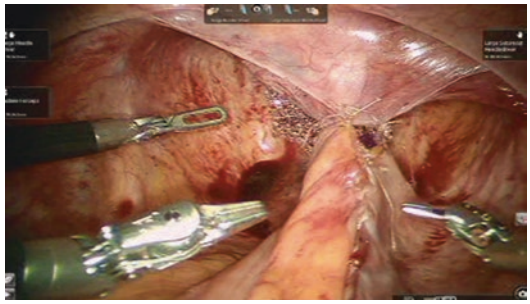

Fig. 9.15 The mesh is almost completely retroperitonealized

completing the procedure. Once completed, the ports are removed. Fascial closures are performed on the 10-/12-mm ports. The 8-mm robotic ports do not require fascial closure. Skin is closed with subcuticular sutures and ports sites are covered with skin glue.

Outcomes

Multiple studies, some prospective, have demonstrated reduced hospital stay, reduced blood loss when compared to open sacrocolpopexy and comparable patient outcomes when compared to open and laparoscopic techniques [6, 7, 17, 23–32]. The majority of prolapse recurrences are either anterior or posterior wall recurrences and were treatable with vaginal repairs.

Kenton et al. randomized 78 patients to either laparoscopic ($n = 38$) or robotic ($n = 40$) ASC and assessed 66 of them at 1 year with both physical exams and pelvic floor symptom questionnaires [33]. Overall, patients had significant improvement in all pelvic floor symptoms and quality of life measures and this did not differ significantly between the laparoscopic and robotic groups. They found no significant differences between anatomic outcomes as evaluated by POP-Q scores or sexual function at 1 year, suggesting that the two minimally invasive approaches are equivalent with respect to outcomes.

Geller et al. have the longest and most detailed follow-up of their RASC patients at 44.2 months; however, the study population is only 23 patients [6]. In that series they reported no recurrence of apical prolapse but 21% of patients with recurrent anterior or posterior wall prolapse. They do not comment on whether or not the recurrent prolapse was symptomatic or how it was addressed. The mesh erosion rate was 8%. Siddiqui et al. included Geller's 23 patients in his study of 125 RASC with 12 months of follow-up [30]. In this larger cohort with shorter follow-up, the recurrent prolapse rate was 8%. Anand et al. report their 5-year survival free of re-treatment rate for 101 patients who underwent RASC as 92.1%, but do not have details about anatomic outcomes or complications [7].

Both the Geller and Siddiqui papers compare their RASC patients with open patients who were subjects of the Colpopexy and Urinary Reduction Efforts, or CARE trial. This was a prospective randomized multicenter trial of women with stress continence who underwent open abdominal sacrocolpopexy between 2002 and 2005 for symptomatic POP and also received either concomitant Burch urethropexy or no urethropexy. A recent long-term follow-up of the CARE cohort of patients was published by Nygaard et al. [8]. These patients were followed at 2, 5, and 7 years with a robust 126 of the original 233 patients completing 7-year follow-up. For this study, anatomic failure was defined as failure requiring retreatment or POP-Q evaluation demonstrating descent of the vaginal apex below the upper third of the vagina, or anterior or posterior vaginal wall prolapse beyond the hymen. Symptomatic failure was defined as failure requiring retreatment or self-reported bulge. Using this composite outcomes criteria, by the 5-year follow-up study, nearly one-third of women met the composite failure definition. However, 95% had no retreatment for POP. This suggests that, with time, even with the gold-standard open ASC, there is progressive loss of anatomic support. Despite this progressive loss of anatomic support, ASC generally provides relief of POP symptoms.

Additionally, in this study, by year 2, 3 of the 322 women enrolled in CARE had suture erosion and 17 had mesh erosion. There were six additional cases of mesh erosion and one suture erosion in the extended CARE population by year 7. Erosions occurred with all mesh types placed.

This data provided the basis for an estimated probability of mesh erosion at 10.5%.

It is safe to say that this is likely the most objective, least biased data available on long-term outcomes after ASC and it demonstrates a significant anatomic failure rate in the long-term as well as a 10.5% risk of mesh complications that continue to accrue over time. While outcomes of robotic procedures should be expected to be comparable to the open procedures, they are unlikely to be better and this data on both prolapse recurrence and mesh erosion rate should be factored into patient counseling when discussing this procedure.

Complications

The major complications of recurrence and mesh erosion have been reviewed; however, several other intraoperative and postoperative complications can occur.

Intraoperative Complications

The dissection of the sacral promontory can be fraught with difficulty if care is not taken to identify the presacral veins. If these are injured, they can be a source of significant bleeding. If bleeding does occur, this can be controlled with electrocautery or placement of Hem-o-lock applied clips by the bedside assistant. If bleeding persists, then open conversion may be required.

Inadvertent injury to the vagina, bladder, and rectum can all occur during the vaginal dissection. Two studies have demonstrated an increased rate of bladder injury with RASC when compared to either laparoscopic [34] or open [35] ASC, with the highest reported rate at 10%. When bladder injury occurs and is identified, Mitchell et al. recommend meticulous closure of the bladder in two layers to ensure a watertight closure [21]. If successful closure is achieved then the procedure does not need to be aborted. They do recommend maintaining Foley catheter drainage for 1–2 weeks postoperatively. Belsante et al. report on five vaginotomies which were oversewn with 2-0 polyglactin sutures [24]. The mesh was then placed away from the vaginotomy repair to minimize the risk of secondary mesh erosion. One of these patients was noted to have an apical mesh erosion at 6-month follow-up, and this was treated with excision and vaginal closure. Matthews comments on her four cystotomies and two proctotomies [17]. Both rectal injuries occurred in the distal rectum near the perineal body in women who had undergone prior repair. The rectal injury was repaired in two layers, and patients were kept on a low-residue diet for 2 weeks' postsurgery. No further complications were noted.

Postoperative Complications

Mesh erosion has been discussed. Other complications include urinary tract or wound infection. Port site hernias may occur and often require open reduction and repair. As with any abdominal surgery, small bowel obstruction may occur. Vahanian et al. have reported on two of their patients who presented with small bowel obstruction about 1 month after RASC [36]. In both cases, the bowel was found to be adhered to barbed suture used to retroperitonealize the mesh, suggesting that it might be best to avoid this type of suture in this location.

Finally, sacral osteomyelitis has been reported as a rare, but very serious, complication of RASC. The offending organisms have been both bacterial and fungal [37–42]. Patients who present postoperatively with low back pain, even in the absence of other constitutional symptoms should be taken seriously and are best evaluated with either CT or MRI. Treatment involves long-term IV antibiotics or antifungals and surgical excision of the involved mesh. Unger et al. found the rate to be significantly higher if a concomitant rectopexy was performed [34]. The use of absorbable sutures to affix the mesh to the sacrum has been proposed to reduce the risk of osteomyelitis. In a small retrospective study by Linder et al., 132 patients underwent robotic sacrocolopexy using polyglactin for the sacral fixation [43]. At a mean follow-up of 33 months, two patients had

apical recurrences, one due to mesh detachment from the sacral promontory. Given the small numbers of patients and short follow-up, additional data is needed to determine long-term recurrence rates.

In the largest cohort to date, Linder et al. evaluated the 30-day perioperative morbidity of abdominal versus minimally invasive (laparoscopic or robotic) sacrocolpopexy of 4362 women using the American College of Surgeons NSQIP (National Surgical Quality Improvement Program) database from 2010 to 2016 [44]. Of the 4362 women, 1179 (27%) underwent abdominal versus 3183 (73%) minimally invasive sacrocolpopexy. Minimally invasive sacrocolpopexy had lower 30 days complication rates and fewer blood transfusions, thromboembolic events, surgical site infections, prolonged hospitalizations, and hospital readmissions compared to abdominal sacrocolpopexy.

Future

ASC with synthetic mesh remains the gold-standard POP repair; however, the need for general anesthesia, longer operative time, and increased invasiveness compared with vaginal approaches limit its use. The addition of robotic technology is appealing to both the patient and surgeon as a minimally invasive alternative with acceptable morbidity and complication rates. Several prospective series have demonstrated the safety and feasibility of RASC with outcomes comparable to the open approach. Randomized prospective studies with long-term follow-up are needed to determine the efficacy, morbidity, and patient satisfaction of RASC.

References

1. Nygaard IE, McCreery R, Brubaker L, Connolly A, Cundiff G, Weber AM, Zyczynski H, Pelvic Floor Disorders Network. Abdominal sacrocolpopexy: a comprehensive review. Obstet Gynecol. 2004;104(4):805–23.
2. Nezhat CH, Nezhat F, Nezhat C. Laparoscopic sacral colpopexy for vaginal vault prolapse. Obstet Gynecol. 1994;84(5):885–8.
3. Paraiso MF, Walters MD, Rackley RR, Melek S, Hugney C. Laparoscopic and abdominal sacral colpopexies: a comparative cohort study. Am J Obstet Gynecol. 2005;192(5):1752–8.
4. Klauschie JL, Suozzi BA, O'Brien MM, McBride AW. A comparison of laparoscopic and abdominal sacral colpopexy: objective outcome and perioperative differences. Int Urogynecol J Pelvic Floor Dysfunct. 2009;20(3):273–9.
5. Hsiao KC, Latchamsetty K, Govier FE, Kozlowski P, Kobashi KC. Comparison of laparoscopic and abdominal sacrocolpopexy for the treatment of vaginal vault prolapse. J Endourol. 2007;21(8):926–30.
6. Geller EJ, Parnell BA, Dunivan GC. Robotic vs abdominal sacrocolpopexy: 44-month pelvic floor outcomes. Urology. 2012;79(3):532–6.
7. Anand M, Weaver AL, Fruth KM, Trabuco EC, Gebhart JB. Symptom relief and retreatment after vaginal, open, or robotic surgery for apical vaginal prolapse. Female Pelvic Med Reconstr Surg. 2017;23(5):297–309.
8. Nygaard I, Brubaker L, Zyczynski HM, Cundiff G, Richter H, Gantz M, et al. Long-term outcomes following abdominal sacrocolpopexy for pelvic organ prolapse. JAMA. 2013;309(19):2016–24.
9. Olsen AL, Smith VJ, Bergstrom JO, Colling JC, Clark AL. Epidemiology of surgically managed pelvic organ prolapse and urinary incontinence. Obstet Gynecol. 1997;89(4):501–6.
10. Awad H, Santilli S, Ohr M, Roth A, Yan W, Fernandez S, et al. The effects of steep trendelenburg positioning on intraocular pressure during robotic radical prostatectomy. Anesth Analg. 2009;109(2):473–8.
11. Brizzolara S, Pillai-Allen A. Risk of mesh erosion with sacral colpopexy and concurrent hysterectomy. Obstet Gynecol. 2003;102(2):306–10.
12. Cundiff GW, Varner E, Visco AG, Zyczynski HM, Nager CW, Norton PA, Pelvic Floor Disorders Network, et al. Risk factors for mesh/suture erosion following sacral colpopexy. Am J Obstet Gynecol. 2008;199(6):688.e1–5.
13. Wu JM, Wells EC, Hundley AF, Connolly A, Williams KS, Visco AG. Mesh erosion in abdominal sacral colpopexy with and without concomitant hysterectomy. Am J Obstet Gynecol. 2006;194(5):1418–22.
14. Quiroz LH, Gutman RE, Fagan MJ, Cundiff GW. Partial colpocleisis for the treatment of sacrocolpopexy mesh erosions. Int Urogynecol J Pelvic Floor Dysfunct. 2008;19(2):261–6.
15. South MM, Foster RT, Webster GD, Weidner AC, Amundsen CL. Surgical excision of eroded mesh after prior abdominal sacrocolpopexy. Am J Obstet Gynecol. 2007;197(6):615.e1–5.
16. 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(2 Pt 1):231–5.
17. Matthews CA, Carroll A, Hill A, Ramakrishnan V, Gill EJ. Prospective evaluation of surgical outcomes

of robot-assisted sacrocolpopexy and sacrocervicopexy for the management of apical pelvic support defects. South Med J. 2012;105(5):274–8.
18. Woods DL, Hou JY, Riemers L, Gupta D, Kuo DY. Side-docking in robotic-assisted gynaecologic cancer surgery. Int J Med Robot. 2011;7(1):51–4.
19. 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.
20. McCullough M, Valceus J, Downes K, Hoyte L. The ureter as a landmark for robotic sacrocolpopexy. Female Pelvic Med Reconstr Surg. 2012;18(3):162–4.
21. Mitchell CR, Gettman M, Chow GK, Elliott D. Robot-assisted sacrocolpopexy: description and video. J Endourol. 2012;26(12):1596–9.
22. Rosenblum N. Robotic approaches to prolapse surgery. Curr Opin Urol. 2012;22(4):292–6.
23. Akl MN, Long JB, Giles DL, Cornella JL, Pettit PD, Chen AH, Magtibay PM. Robotic-assisted sacrocolpopexy: technique and learning curve. Surg Endosc. 2009;23(10):2390–4.
24. Belsante M, Murray S, Dillon B, Zimmern P. Mid term outcome of robotic mesh sacrocolpopexy. Can J Urol. 2013;20(1):6656–61.
25. Kramer BA, Whelan CM, Powell TM, Schwartz BF. Robot-assisted laparoscopic sacrocolpopexy as management for pelvic organ prolapse. J Endourol. 2009;23(4):655–8.
26. Moreno Sierra J, Ortiz Oshiro E, Fernandez Pérez C, Galante Romo I, Corral Rosillo J, Prieto Nogal S, et al. Long-term outcomes after robotic sacrocolpopexy in pelvic organ prolapse: prospective analysis. Urol Int. 2011;86(4):414–8.
27. Tan-Kim J, Menefee SA, Luber KM, Nager CW, Lukacz ES. Robotic-assisted and laparoscopic sacrocolpopexy: comparing operative times, costs and outcomes. Female Pelvic Med Reconstr Surg. 2011;17(1):44–9.
28. Elliott DS, Krambeck AE, Chow GK. Long-term results of robotic assisted laparoscopic sacrocolpopexy for the treatment of high grade vaginal vault prolapse. J Urol. 2006;176(2):655–9.
29. Ploumidis A, Spinoit AF, De Naeyer G, Schatteman P, Gan M, Ficarra V, et al. Robot-assisted sacrocolpopexy for pelvic organ prolapse: surgical technique and outcomes at a single high-volume institution. Eur Urol. 2014;65(1):138–45.
30. Siddiqui NY, Geller EJ, Visco AG. Symptomatic and anatomic 1-year outcomes after robotic and abdominal sacrocolpopexy. Am J Obstet Gynecol. 2012;206(5):435.e1–5.
31. 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.
32. Gupta P, Ehlert M, Bartley J, Gilleran J, Killinger KA, Boura JA, et al. Perioperative outcomes, complications, and efficacy of robotic-assisted prolapse repair: a single institution study of 196 patients. Female Pelvic Med Reconstr Surg. 2018;24(6):408–11.
33. Kenton K, Mueller ER, Tarney C, Bresee C, Anger JT. One-year outcomes after minimally invasive sacrocolpopexy. Female Pelvic Med Reconstr Surg. 2016;22(5):382–4.
34. 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.
35. Anand M, Woelk JL, Weaver AL, Trabuco EC, Klingele CJ, Gebhart JB. Perioperative complications of robotic sacrocolpopexy for post-hysterectomy vaginal vault prolapse. Int Urogynecol J. 2014;25(9):1193–200.
36. Vahanian SA, Finamore PS, Lazarou G. Delayed small bowel obstruction after robotic-assisted sacrocolpopexy. Female Pelvic Med Reconstr Surg. 2015;21(1):e11–3.
37. Feng TS, Thum DJ, Anger JT, Eilber KS. Sacral osteomyelitis after robotic sacrocolpopexy. Female Pelvic Med Reconstr Surg. 2016;22(1):e6–7.
38. Boyd B, Pratt T, Mishra K. Fungal lumbosacral osteomyelitis after robotic-assisted laparoscopic sacrocolpopexy. Female Pelvic Med Reconstr Surg. 2018;24(6):e46–8.
39. Apostolis CA, Heiselman C. Sacral osteomyelitis after laparoscopic sacral colpopexy performed after a recent dental extraction: a case report. Female Pelvic Med Reconstr Surg. 2014;20(6):e5–7.
40. Grimes CL, Tan-Kim J, Garfin SR, Nager CW. Sacral colpopexy followed by refractory Candida albicans osteomyelitis and discitis requiring extensive spinal surgery. Am J Obstet Gynecol. 2012;120(2 Pt 2):464–8.
41. Iavazzo C, Gkegkes ID. Osteomyelitis after robotically assisted laparoscopic sacral colpopexy. Acta Inform Med. 2013;21(2):143.
42. Muffly TM, Diwadkar GB, Paraiso MF. Lumbosacral osteomyelitis after robot-assisted total laparoscopic hysterectomy and sacral colpopexy. Int Urogynecol J. 2010;21(12):1569–71.
43. Linder BJ, Anand M, Klingele CJ, Trabuco EC, Gebhart JB, Occhino JA. Outcomes of robotic sacrocolpopexy using only absorbable suture for mesh fixation. Female Pelvic Med Reconstr Surg. 2017;23(1):13–6.
44. Linder BJ, Occhino JA, Habermann EB, Glasgow AE, Bews KA, Gershman B. A national contemporary analysis of perioperative outcomes of open versus minimally invasive sacrocolpopexy. J Urol. 2018;200(4):862–7.

10 Standard and Robot-Assisted Laparoendoscopic Single-Site Urologic Surgery

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Standard Laparoendoscopic Single-Site Surgery

Laparoendoscopic single-site surgery (LESS) represents an evolution in laparoscopic surgery to potentially further reduce morbidity and improve cosmesis [1, 2]. The term LESS has been recently coined to incorporate a group of related techniques that perform laparoscopic surgery through a single access site in the abdomen typically concealed in the umbilical scar [3]. LESS came in vogue due to a perceived impression that reducing the number of ports would naturally result in reduced morbidity and improve cosmesis of conventional multiport laparoscopy. Since its initial report by Raman and colleagues, LESS surgery has increasingly been used to perform various urological procedures, including those on the kidney, ureter, bladder, and prostate. At the time of this writing, a total of 1023 manuscripts written have been reported on LESS, of which 328 have been from urology. The aim of the current chapter is to describe specialized instrumentation and technical nuances with respect to LESS renal surgery.

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Access Instrumentation

LESS can be performed by inserting conventional laparoscopic ports through a single umbilical incision or with the use of one of the commercially available multichannel trocars. The advantage of the single-site approach of using typically three low-profile laparoscopic trocars minimizes the need for specialized instrumentation as relates to access (Fig. 10.1). In contrast, the single-port approach utilizes a variety of purpose-specific ports that have multiple channels for the use of the optic and instruments [4]. Some of the clinically used industry-driven access devices for LESS are TriPort TM and QuadPort TM (Olympus Medical, Tokyo, Japan), Uni-X Single Port TM (Pnavel Systems, Cleveland, OH, USA), and GelPort™ (Applied Medical, Rancho Santa Margarita, CA). These trocars are all typically inserted through a single umbilical incision, although extra umbilical sites have also been utilized. The TriPort™ and QuadPort™ (Olympus Medical, Tokyo, Japan) are the most commonly used and known FDA-approved, first-generation access system. The TriPort and TriPort Plus have a smaller ring compared to the larger QuadPort. Each device consists of a retractor component and a valve component, where the instruments are inserted. The design advantages of this port are as follows: tight seal, complete flexibility, no internal profile, and compatibility with curved, straight, and articulating instruments.

S. L. Best, S. Y. Nakada (eds.), *Minimally Invasive Urology*,
https://doi.org/10.1007/978-3-030-23993-0_10

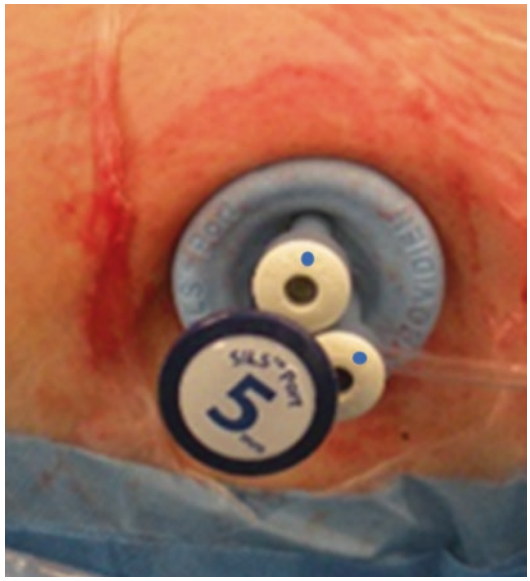

Fig. 10.1 Low-profile laparoscopic trocars (*blue circles*) can be used with a single-port device or a single-skin incision through multiple aponeurosis accesses

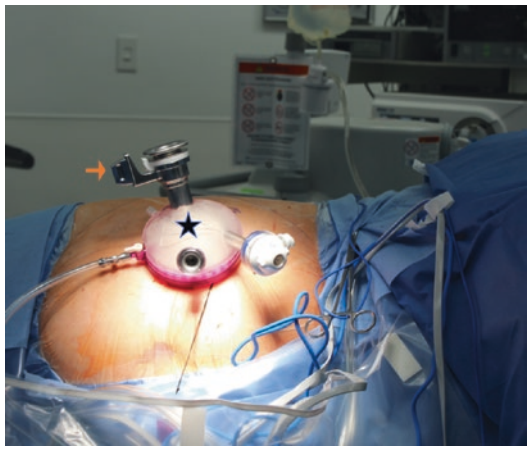

Fig. 10.2 GelPORT/GelPOINT™ (*black star*), low-profile trocar (*orange arrow*), comes with the device. It can be used for laparoscopic or robotic technique

Additionally, specimens can be easily retrieved through the TriPort and QuadPort by detaching the valve without the need to remove the ring.

The GelPort™ (Applied Medical, USA) was already in use in hand-assisted laparoscopic surgery and is now modified for use in LESS (Fig. 10.2). It has a GelSeal cap that provides a pseudo abdomen for a larger platform for triangulation, incorporates insufflation and smoke evacuation capabilities, provides a flexible fulcrum for improved instrument articulation, and maintains pneumoperitoneum. There is an Alexis wound protector/retractor that accommodates 1.5–7 cm incisions. GelPort™ also facilitates extracorporeal anastomosis and specimen retrieval while protecting the incision site.

The low-profile sleeves accommodate 5–12 mm instrumentation and offers greater freedom of movement due to low-profile design. The advantage of the GelPort is that the exact location of the ports can be selected by the surgeon, as is the length of the fascial incision. Thus, for procedures that require extraction, one can make a larger incision and position the working ports to achieve triangulation in the small space. Other access devices (SILS Port™ (Covidien), X-Cone™ (Karl Storz), Air Seal™ (SurgiQuest), SLASS™ (Ethicon), and Octoport™ (Daikin Surgical, Korea)) and a detailed description of them are beyond the scope of this chapter.

Optics with LESS

Optics has also been optimized to accommodate the needs of LESS. Conventional laparoscopes result in external clashing because of their large camera head and light cable exiting at 90° (Fig. 10.3). Newer scopes combine light and camera systems to keep the camera head and

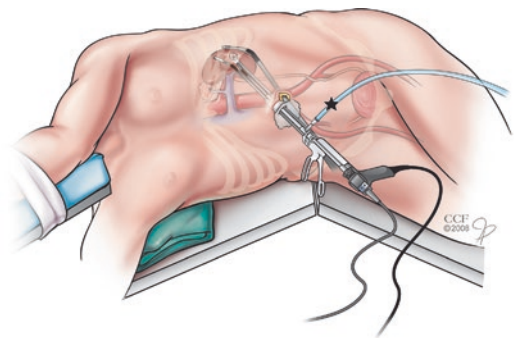

Fig. 10.3 Conventional laparoscope during a kidney single-site surgery. Camera head (*blue circle*), light cable (*black star*). Associated with crowded space and frequent instrument clashing. (© Cleveland Clinic Foundation, used with permission)

light cord out of the operative field. In addition, extra-long scopes allow the camera operator to work outside of the operative space, providing the surgeon with more room to operate.

Most recently, endoscopes with a deflectable tip have been developed to provide the adequate angle of view while keeping the assistants' hand outside the already cramped working space during LESS surgery. In addition to technologic developments, many technical tips may help minimize clashing between the camera assistant and the surgeon (e.g., combination of instruments: (1) large and short, (2) curved and straight, (3) straight and articulated; extra-large and flexible endoscopes, and also putting camera assistant in a sit-down position or in a different ground level).

LESS Instruments

Clashing of hands and instruments is inherent to LESS, and much of the instrument development is aimed at minimizing clashing and restoring triangulation. LESS procedures can be performed using a combination of conventional straight, bent rigid, and actively articulating instruments. In straight instruments, the parallel and close distance of the right-hand and left-hand instrument shafts of standard laparoscopic instruments through a single access site results in the crowding of the laparoscope and the instruments. The surgeon can hold instruments in a different axis and use variable length instruments, which help to keep away the working hand from the retracting hand to partially offset this limitation. With regard to rigid-bent instruments, those with a single bend or multiple bends are available. The advantage is that these are generally reusable, resulting in a minimum increase in disposable cost. The bends are strategically located to improve triangulation and/or increase space external to the port to reduce clashing. Limitations of these instruments are that the bends are fixed and not always optimal.

Additionally, these instruments require specialized trocars to be inserted. For articulating instruments, several of them that have a wristed internal motion are available for LESS surgery. The articulation is typically controlled by intuitively manipulating the handle around a pivot point. The advantages of articulating instruments are that the angle of articulation can be changed, and these instruments can be inserted through standard straight, rigid trocars. Limitations include relative lack of robustness, cost, and a learning curve to control articulation. Experts have varied in their choice of instruments, and often surgeons use a combination of straight, bent, and articulating instruments during LESS procedures.

New Technologies in LESS

Magnetic anchoring and guidance system (MAGS) is a novel technique that may alleviate many of the current challenges of LESS. The system centers around intracorporeal instruments that are delivered through the single access site and anchored through the abdominal wall with extracorporeal magnetic devices. The theoretical benefits of this system are the following: ability to be externally controlled, continuously adjustable positioning without the need for external incisions or dedicated ports, reduction of internal and external collisions, restoration of triangulation, and improvements in visualization. Recently, the initial clinical experience with the MAGS camera for LESS nephrectomy and appendectomy was described [5].

During these procedures, the entire dissection was carried out with rigid, straight instruments with only MAGS camera visualization. The authors found that the use of MAGS camera resulted in fewer instrument collisions and improved surgical working space and provided an image comparable to conventional laparoscopy. Although currently limited by a fixed 0° lens, fixed focus, external wires, magnets requiring a thin abdominal wall, and limited light delivery, innovations on the horizon aim to address each of these issues [5, 6].

Another area of development is the use of in vivo robotic instruments with the potential to provide a stable platform while providing precise tip maneuverability [7]. Similar to MAGS, these robots are delivered through the single incision

and come in two types: either independently mobile or fixed to a base that extends through the port. Several examples have been described such as pan and tilt cameras, 3D-imaging systems, mobile adjustable-focus robotic cameras (MARC), and mobile biopsy graspers [6, 7].

These instruments seek to minimize internal and external clashing while providing improved dexterity and intuitive tissue manipulation, which could be used alone or in conjunction with standard LESS instrumentation, as well as with each other. Although their applications are currently limited, further developments aim to increase battery life, increase the complexity of allowable maneuvers, and include transition to wireless technology for control [7].

Common LESS Clinical Procedures

In general, standard LESS surgery has been performed for extirpative and reconstructive renal surgery, including transperitoneal and retroperitoneal nephrectomy (radical and partial), nephroureterectomy, donor nephrectomy, and pediatric LESS interventions. The majority of pelvic LESS has been performed using robotic assistance and will be described elsewhere in the text. When it comes to patient selection, in general, patients of average build and height should be preferred so that the kidney is within the reach of the umbilicus. For obese patients, the incision can be moved outside the umbilicus. For the extraction of larger specimens, a larger incision should be used from the outset to improve mobility and to have some triangulation. Finally, the threshold for adding ports should be minimal.

Conclusions

LESS is appropriate for patients interested in better cosmesis. Ablative and reconstructive renal procedures are appropriate, and the threshold for converting to standard laparoscopy should be low. Better instrumentation, especially dedicated robotic platforms, may enable the wider use of LESS.

Robotic LESS Approaches

Introduction

It has been established that robotic-assisted laparoscopic surgery has several advantages when compared to standard laparoscopic surgery. Optics, ergonomics, dexterity, and precision are all enhanced with use of the robotic platform for a number of urologic procedures. For these reasons, it was postulated that the application of robotics to LESS could overcome some of the constraints seen with the conventional laparoscopic approach. Issues such as instrument clashing, inability to achieve effective triangulation for dissection, and difficulties with intracorporeal suturing have limited the widespread adoption of conventional LESS in urology.

Kaouk et al. [8] reported the first experience with robotic LESS (R-LESS) in 2008 (radical prostatectomy, nephrectomy, and pyeloplasty). They noted that intracorporeal suturing and dissection were easier, as compared with standard LESS. Since then there have been numerous reports and refinements in technique from the same group, for a number of different urologic procedures [9–11]. Furthermore, there have been a number of series that have compared R-LESS to either standard laparoscopy, conventional LESS, or standard robotic surgery [9, 12, 13]. While these studies have been small and retrospective in nature, they have shown that R-LESS is not inferior with regard to perioperative outcomes and may offer better cosmesis. Additionally, the surgeons found the EndoWrist technology and three-dimensional high-definition camera beneficial. However, despite the advantages of the robotic platform, R-LESS is not free of challenges, which are similar to conventional LESS. Instrument clashing remains an issue due to the bulky external profile of the current robotic system. Other issues include lack of space for the assistant at the bedside, inability to incorporate the fourth robotic arm for retraction, and difficulties with triangulation.

Although solutions for some of these issues are currently under development [14, 15], R-LESS is still very much in its infancy. Standard robotic surgery and R-LESS share numerous similari-

ties. The setup of the operating room is identical, as well as all the instruments, drapes, sutures, etc. Docking of the robot is also identical, although the arms may be angled differently to minimize instrument clashing. With regard to the procedures, almost all of the steps of standard robotic surgery are carried out in R-LESS. That being said, there are improvisations that are made because of the limited space with R-LESS. For example, because there is no space for the fourth arm, which is often used to retract tissue, various other techniques have been employed (i.e., stay and marionette sutures). Also, other strategies are employed to minimize instrument clashing, such as moving the two arms and camera together in unison. For this reason, this chapter will focus on the equipment and aspects of each procedure that are specific to R-LESS and differ from standard robotic surgery.

Access/Port Placement

An important distinction must be made with regard to access in R-LESS, and that is single port vs. single site. Single-port access utilizes a single skin and fascial incision, through which a multichannel access platform is placed (Fig. 10.4). The endoscope and instruments are all placed through the access platform. Single-site access also utilizes a single-skin incision; however, multiple fascial incisions are made, through which the access platform and low-profile ports are placed (Fig. 10.5). The point of access can be umbilical

Fig. 10.4 Robotic single-port approach. Trocars are introduced through a device using a simple skin and fascial incision (GelPOINT™)

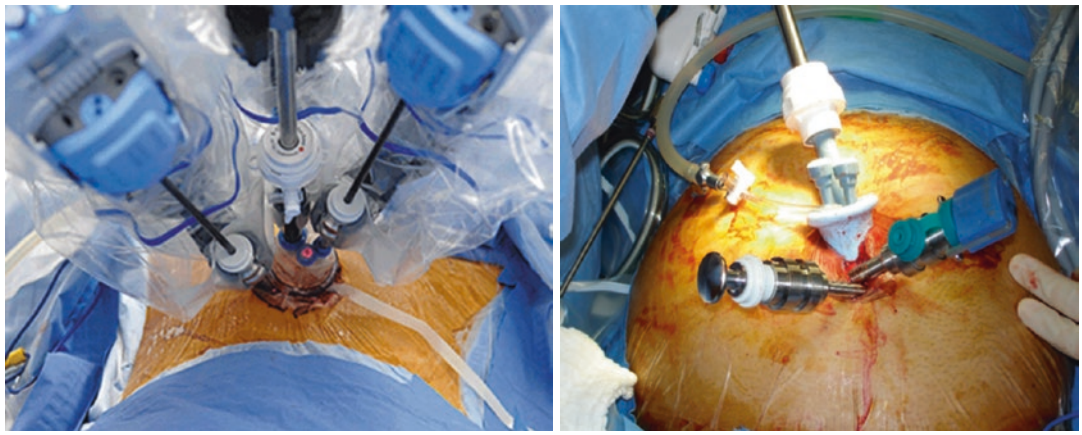

Fig. 10.5 Robotic single-site approach allows to use one skin incision with a different combination of trocars—robotics and conventional—and locations through multiple fascial depending on the type of surgery and surgeon's preferences

or extraumbilical. The umbilical access point has been most commonly utilized [16] as the scar can more easily be hidden and cosmesis maximized.

Single-Port Access

A number of different access devices for single port exist, including a TriPort [8] and a GelPort [9]. Single-port access for upper- and lower-tract R-LESS procedures is similar. A 2–5-cm trans-umbilical incision is made, either directly through the umbilicus or using a semicircular incision concealed within the umbilicus. Dissection then proceeds, using a combination of blunt dissection and electrocautery, to the anterior rectus fascia. A 3–4-cm vertical incision is then made in the linea alba, access to the peritoneal cavity is gained, and the chosen multichannel access device is placed. Stay sutures can be placed in the fascia to aid with port placement and wound closure, if desired. If the GelPort is to be used, the wound protector is placed first. Next, the GelSeal cap is placed, after the port sites have been marked on its surface. Depending on the procedure/pathology, access can be transperitoneal or extraperitoneal, as both approaches have been described. Additionally, a transvesical approach has been utilized, specifically for robotic enucleation of the prostate [17].

Single-Site Access

In a similar fashion to single-port access, an incision is created intraumbilically (3–4.5 cm), and the umbilicus is released from the rectus fascia. A 2-cm incision is then made through the linea alba. The robotic ports are then placed through the same umbilical incision, but through separate fascial stab incisions. Typically, they are tunneled under the skin to the appropriate location. For example, during an R-LESS radical prostatectomy, the first 8-mm robotic port is placed at the most caudal part of the incision and tunneled as far laterally as possible. The subsequent robotic port is then placed on the opposite side of the incision, in a similar fashion. Finally, a multichannel port is inserted through the fascial incision into the peritoneal cavity (or extraperitoneal space).

Multichannel Port Selection

A number of different multichannel ports have been used for R-LESS [18, 19]; however, there have been no direct head-to-head comparisons. In Kaouk's initial R-LESS series, the R-port (Advanced Surgical Concepts, Dublin, Ireland) was used. This port consists of one 12-mm channel, two 5-mm channels, and an insufflation cannula. The port is placed using the Hasson technique through a 2-cm umbilical incision. The authors made no specific comments with regard to the performance of the port, and there were no reported issues with pneumoperitoneum leakage or instrument crowding. White et al. [20] reported their experience with 50 patients, which included 24 renal procedures and 26 pelvic procedures. They used three different commercially available ports, including the SILS Port, the R-port, and the GelPort/GelPOINT. The authors mentioned the three multichannel ports used; they preferred the SILS Port because of its durability, the free exchange of cannulas of varying size, and the ease of passage of staplers, clip appliers, sutures, and entrapment bags through the port. However, they noted that gas leakage was experienced with three multichannel ports, which was usually caused by a fascial incision that was too large. To combat this, they placed a fascial suture or petroleum impregnated gauze along the tract of the port. Stein et al. [9] used the GelPort laparoscopic access system to perform 4 R-LESS upper tract procedures (pyeloplasty $n = 2$, partial nephrectomy $n = 1$, radical nephrectomy $n = 1$). They concluded that the GelPort was beneficial for R-LESS because it allowed for greater spacing and flexibility of port placement and easier access to the surgical field for the bedside assistant. Although the fascial incision used was larger so as to place the port (2–2.5 cm), they found that this facilitated specimen extraction, especially during the radical nephrectomy.

Finally, there have been a number of centers that have had experience using a homemade port, both for conventional LESS and R-LESS. Lee et al. [18] reported the largest series of R-LESS procedures using a homemade port, which consisted of an Alexis wound retractor (Applied Medical, Rancho Santa Margarita, California) and a standard size 7 surgical glove stretched over top. They utilized a 5–6-cm fascial incision to place the wound retractor. Four trocars were placed through the fingers of the glove, including two 8-mm robotic trocars and two 12-mm optical trocars. They performed 68 upper tract procedures, including 51 partial nephrectomies, 12 nephroureterectomies, 2 adrenalectomies, 2 radical nephrectomies, and 1 simple nephrectomy. The authors felt that the homemade port offered greater flexibility of port placement than any of the commercially available multichannel devices, as well as is extremely cost-effective. Limitations included the susceptibility of the glove to tearing with the insertion of the robotic instruments, the larger fascial incision required to place the wound retractor, and ballooning of the glove under higher pneumoperitoneum pressures (>20 mmHg). However, the authors concluded that their homemade port was a safe, effective, low-cost alternative to commercially available multichannel ports.

Docking the Robot

There are only a few subtle differences between docking the robot for standard robotic surgery and R-LESS. The DaVinci Si model has been preferred over the S model because of its enhanced visualization, ability to customize the console settings ergonomically, and smaller external profile, which helps to minimize clashing of the robotic arms [20, 21]. Otherwise, the robot is brought into the surgical field in a standard fashion, which is from behind the patient and over the shoulder for upper-tract procedures and in between the patient's legs for lower-tract procedures.

Additionally, because of the limited working space, the majority of R-LESS procedures employ a two-arm approach. There have been a number of strategies employed in order to minimize clashing of the robotic arms, which is a limitation that is encountered with the current robotic platforms. Joseph et al. [14, 22] developed a "chopstick" technique, whereby the robotic instruments are crossed at the abdominal wall to reduce instrument clashing and improve triangulation. This concept had already been used in conventional LESS; however, the crossing of instruments and resultant "reverse handedness" made the cases very challenging. However, with the DaVinci system, the inputs to the left- and right-hand effectors can be switched electronically, which eliminates the reverse handedness and restores intuitive control of the instruments as they appear on the screen.

Instrumentation

The vast majority of the R-LESS procedures to date have been performed with standard instruments as task-specific tools have remained mostly under development and testing. Two of the larger clinical series report the use of standard 8- and 5-mm instruments for a wide range of R-LESS procedures [18, 20]. White et al. [11] described using an 8-mm instrument in the right hand and a 5-mm pediatric instrument in the left hand for their R-LESS prostatectomy series of 20 patients. The authors felt that this configuration maximized the benefit of each instrument. The 5-mm instruments do not articulate but instead deflect, which greatly increased their range of motion.

Conversely, the authors found that the EndoWrist action of the standard 8-mm instruments greatly facilitated complex tasks, such as suturing. Furthermore, they reported that the 8-mm robotic Hem-o-lok clip applier was beneficial during nerve sparing as clip placement was in the surgeon's hands and clashing with the bedside assistant's instruments was minimized.

Intuitive Surgical Inc. has also addressed the problem of instrument collision and developed a set of R-LESS-specific instruments (Fig. 10.6). The set consists of a multichannel access platform with channels for four ports and an insuf-

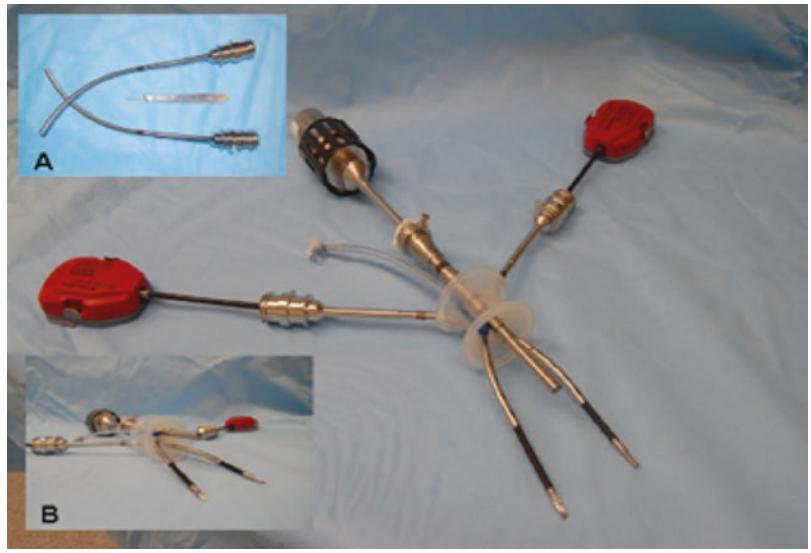

Fig. 10.6 R-LESS Intuitive set. (**a**) curved cannulas. (**b**) Cannulas, instruments, endoscope, and multichannel port assembly

flation valve. The ports themselves consist of two with curved cannulas for the robotic instruments and two with straight cannulas for the endoscope and assistant instruments. The robotic instruments are also curved and are designed to cross at the abdominal wall, effectively separating the arms in space extracorporeally. Furthermore, the design of the system also minimizes internal instrument collision with the camera as they are not arranged in parallel. We described the first urologic applications in the laboratory at our center [15, 23]. Both the porcine model and human cadavers were used to perform a number of upper tract procedures (i.e., pyeloplasty, partial nephrectomy, etc.). Setup and docking times were comparable with the standard robotic system, and there were no significant complications. All procedures were completed successfully without the need for completion. Major limitations included collision with the assistant instruments, which at times limited suction and retraction, and lack of articulation of the robotic instruments, which made suturing difficult when required. The majority of clinical experience with the single-site instruments has been with cholecystectomy [24, 25]; however, Cestari et al. [26] reported their experience in a highly selected group of nine patients with a UPJO. Exclusion criteria included BMI >30 kg/m^2, a large renal pelvis, previous abdominal/renal surgery, and concomitant stone disease. All procedures were performed successfully without the need for conversion or additional ports. Mean OR time was 166 min. A number of different lens configurations have been used with the 12-mm robotic camera during R-LESS procedures. For their R-LESS prostatectomy series, White et al. [11] attempted to use the 0° lens for all procedures but found that the 30° upward lens was beneficial in instances where instrument clashing occurred by positioning the scope out of the path of the instruments. For upper tract procedures, all lens configurations have been used, with no clear advantage favoring one particular choice. It seems that when choosing a lens, one must tailor it to the particular situation and consider port placement, the degree of instrument clashing, and the pathology at hand.

The New Era of Single-Port Robotic Surgery

While the application of robotics to LESS has been somewhat beneficial, there have been several drawbacks, such as instrument clashing and reduced space for the bedside assistant. This is largely due to the fact that the standard multiarms robotic systems have not been specifically designed for their adoption during single-site surgery. The Da Vinci Single-Site was an attempted answer, specific for R-LESS, but the platform lacked the EndoWrist technology, which had obvious limitations.

Multiple series using multiarm robotic systems have been reported showing the feasibility of different urological procedures and approaches; despite that, the abovementioned difficulties remained and prevented the widespread diffusion of the technique. Table 10.1 [8–13, 17, 18, 21, 26–31] summarizes information about these clinical series.

The evolution of robotic platforms, the recent FDA approval, and the introduction of new purpose built single port robotic systems to the market offer an option to fill the gap presented with the older generations and robotics systems.

The SP® Surgical Platform

The SP platform designed for single-port and single-site approach possess features that facilitates the use of this technique for multiple procedures. A single robotic arm is connected to a unique 25 mm multichannel port that holds a 10 × 12 mm articulating camera, three 6 mm robotic instruments with 7° of movement; the double joint configuration of the robotic allows to preserve the triangulation principle once deployed into the workspace (Fig. 10.7). Other characteristics are a 360° anatomical access, a guidance system that shows the surgeon the location of each instru-

Table 10.1 Clinical series of R-LESS using multi-arms robotic systems

Series	Type of procedure(s)	Approach
Kaouk et al. [8]	Radical prostatectomy (n = 1) Dismembered pyeloplasty (n = 1) Radical nephrectomy (n = 1)	Transumbillical/ transperitoneal
Stein et al. [9]	Pyeloplasty (n = 2) Radical nephrectomy (n = 1) Partial nephrectomy (n = 1)	Transumbillical/ transperitoneal
White et al. [11]	Radical prostatectomy (n = 20)	Transumbillical/ transperitoneal
White et al. [10]	Radical nephrectomy (n = 10)	Transumbillical/ transperitoneal
Arkoncel et al. [12]	Partial nephrectomy (n = 35)	Transumbillical/ transperitoneal
Lee et al. [18]	Partial nephrectomy (n = 51) Nephroureterectomy (n = 12) Nephrectomy (n = 3) Adrenalectomy (n = 2)	Periumbilical
Olweny et al. [13]	Pyeloplasty, RLESS (n = 10) vs conventional LESS (n = 10)	Transumbillical/ transperitoneal
Fareed et al. [17]	Simple prostatectomy (n = 9)	Transvesical/extraperitoneal
Cestari et al. [26]	Pyeloplasty (n = 9)	Transumbillical/ transperitoneal
Siedeman et al. [21]	Pyeloplasty (n = 12)	Transumbillical/ transperitoneal
Khanna et al. [27]	Radical nephrectomies (n = 11) Partial nephrectomies (n = 5) Nephroureterectomies (n = 3) Pyeloplasties (n = 7) Simple nephrectomy (n = 1) Renal cyst decortication (n = 1)	Transumbillical/ transperitoneal
Tobis et al. [28]	Pyeloplasty (n = 8)	Transumbillical/ transperitoneal
Park et al. [29]	Adrenalectomy (n = 5)	Retroperitoneal
Kaouk et al. [30]	Partial nephrectomy (n = 4) Simple nephrectomy (n = 2) Radical nephrectomy (n = 2) Radical prostatectomy (n = 11)	Transumbillical/ transperitoneal
Kaouk et al. [31]	Perineal prostatectomy (n = 4)	Perineal

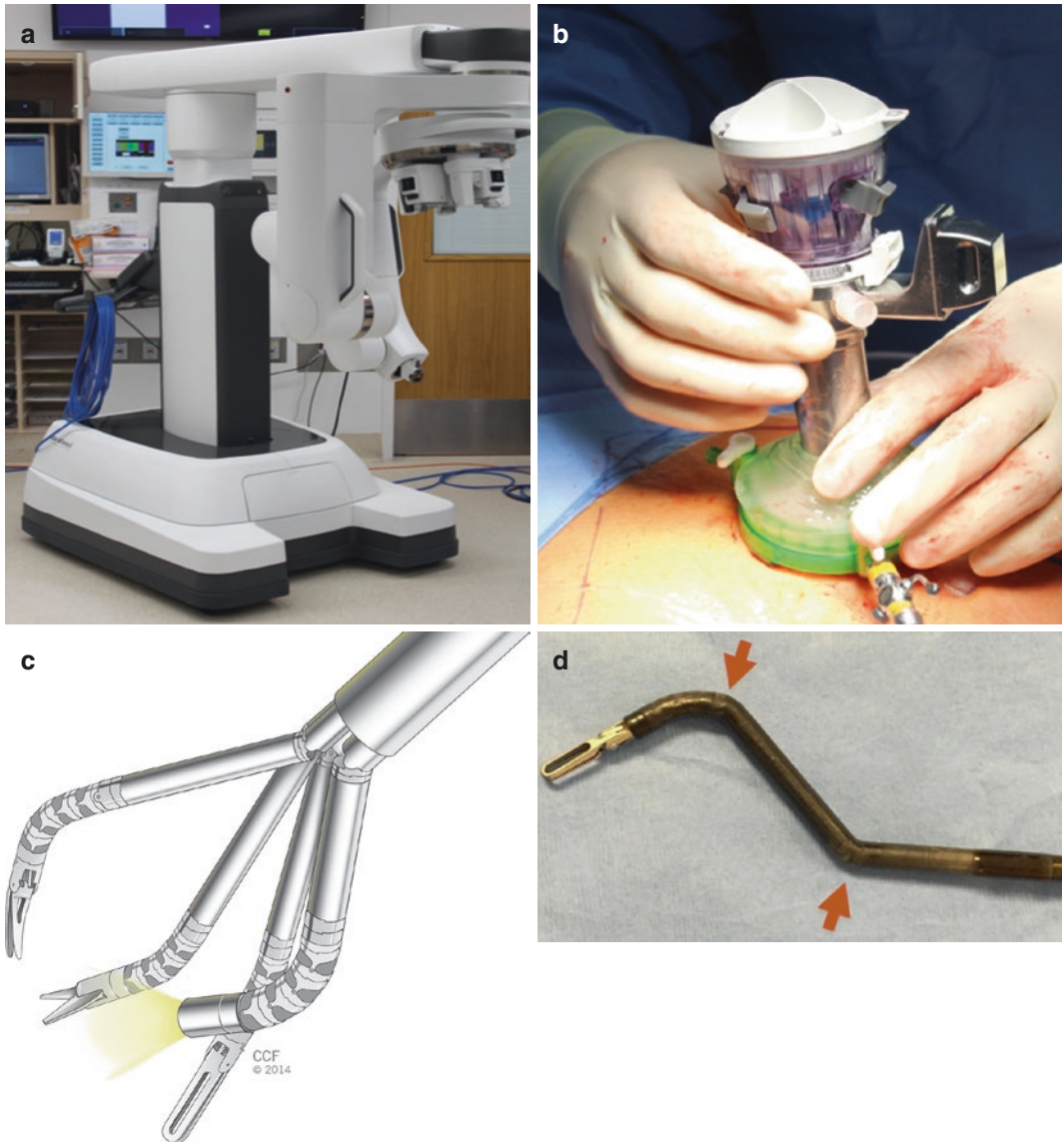

Fig. 10.7 (**a**) Patient cart with single robotic arm. (**b**) da Vinci SP® 25 mm Multichannel port. (**c**) Double-jointed instruments—10 × 12 mm camera, three 6 mm instruments—passing through the multichannel port (© Cleveland Clinic Foundation, used with permission). (**d**) Double-joint (*red arrows*) design of robotic instruments

ment, and an extra clutch allowing for the moving of the instruments and the camera as a unit or individually as needed.

Recent publications showed the feasibility and described techniques with the use of SP platforms. Maurice et al. [32] reported the use of SP1098 surgical system (a predecessor of the new SP) for retroperitoneal approach to partial nephrectomy, and other approaches to pelvic fossa surgeries, such as transvesical, transperitoneal, and transperineal, have also been described in the preclinical setting [33].

The initial clinical experiences using the new SP da Vinci surgical system describing techniques such as ureteral reimplantation, partial nephrectomy, prostatectomy and cystectomy have been successfully reported [34–37] (Fig. 10.8).

The technique for single-port transperitoneal robotic radical prostatectomy has been reported as the first clinical experience ever with the use

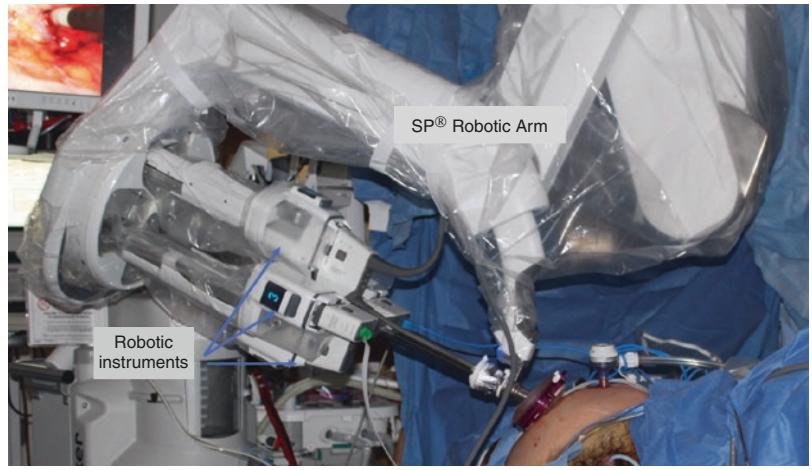

Fig. 10.8 da Vinci SP platform docked during a transperitoneal approach (left robot-assisted partial nephrectomy)

of the SP surgical platform [34]. Kaouk et al. [35] published a step-by-step technique for the management of benign distal ureteral strictures in three consecutive patients with strictures of different etiology. They reported adequate operative time and no complications in all cases, including one bilateral reimplantation. They also described a technique for partial nephrectomy with this device, including three patients; ischemia time averaged 25 min, median operative time was 180 min, and negative surgical margins were achieved in all patients. One patient presented bleeding after surgery and required angioembolization [36]. Limitations reported in initial series are related to restricted access and range of movement for laparoscopic assistance and a new learning curve even for experienced robotic surgeons [37, 38].

Conclusions

R-LESS is a feasible and secure option for multiple approaches and surgical techniques in urology. The intrinsic features of the new SP platform represent a portal for expanding the indications of robotic single port and overcoming the limitations of the former non-dedicated-to-LESS robotic platforms. Further and larger investigations will determine the real utilization of this tool in the urological field. Comparative studies with standard multiarms robotics are needed.

References

1. Raman JD, Bensalah K, Bagrodia A, Stern JM, Cadeddu JA. Laboratory and clinical development of single keyhole umbilical nephrectomy. Urology. 2007;70(6):1039–42.
2. Desai MM, Rao PP, Aron M, Pascal-Haber G, Desai MR, Mishra S, et al. Scarless single port transumbilical nephrectomy and pyeloplasty: first clinical report. BJU Int. 2008;101(1):83–8.
3. Gill IS, Advincula AP, Aron M, Caddedu J, Canes D, Curcillo PG 2nd, et al. Consensus statement of the consortium for laparoendoscopic single site surgery. Surg Endosc. 2010;24(4):762–8.
4. Guillotreau J, Crouzet S, Haber GP. Access techniques, platforms and instruments for LESS. Arch Esp Urol. 2012;65(3):285–93.
5. Cadeddu J, Fernandez R, Desai M, Bergs R, Tracy C, Tang SJ, et al. Novel magnetically guided intra-abdominal camera to facilitate laparoendoscopic single-site surgery: initial human experience. Surg Endosc. 2009;23(8):1894–9.
6. Raman JD, Scott DJ, Cadeddu JA. Role of magnetic anchors during laparoendoscopic single site surgery and NOTES. J Endourol. 2009;23(5):781–6.
7. Canes D, Lehman AC, Farritor SM, et al. The future of NOTES instrumentation: flexible robotics and in vivo minirobots. J Endourol. 2009;23(5):787–92.
8. Kaouk JH, Goel RK, Haber GP, Crouzet S, Stein RJ. Robotic single-port transumbilical surgery in humans: initial report. BJU Int. 2008;103(3):366–9.
9. 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(1):132–6.
10. White MA, Autorino R, Spana G, Laydner H, Hillyer SP, Khanna R, et al. Robotic laparoendoscopic single-site radical nephrectomy: surgical technique and comparative outcomes. Eur Urol. 2011;59(5):815–22.

11. White MA, Haber GP, Autorino R, Khanna R, Forest S, Yang B, et al. Robotic laparoendoscopic single-site radical prostatectomy: technique and early outcomes. Eur Urol. 2010;58(4):544–50.
12. Arkoncel FR, Lee JW, Rha KH, Han WK, Jeoung HB, Oh CK. Two-port robot-assisted vs standard robot assisted laparoscopic partial nephrectomy: a matched pair comparison. Urology. 2011;78(3):581–5.
13. Olweny EO, Park SK, Tan YK, Gurbuz C, Cadeddu JA, Best SL. Perioperative comparison of robotic assisted laparoendoscopic single-site (LESS) pyeloplasty versus conventional LESS pyeloplasty. Eur Urol. 2012;61(2):410–4.
14. Joseph RA, Goh AC, Cuevas SP, Donovan MA, Kauffman MG, Salas NA, et al. Chopstick surgery: a novel technique improves surgeon performance and eliminates arm collision in robotic single-incision laparoscopic surgery. Surg Endosc. 2010;24(6):1331–5.
15. Haber GP, White MA, Autorino R, Escobar PF, Kroh MD, Chalikonda S, et al. Novel robotic da Vinci instruments for laparoendoscopic single-site surgery. Urology. 2010;76(6):1279–82.
16. Kaouk JH, Autorino R, Kim FJ, Han DH, Lee SW, Yinghao S, et al. Laparoendoscopic single-site surgery in urology: worldwide multi-institutional analysis of 1076 cases. Eur Urol. 2011;60(5):998–1005.
17. Fareed K, Zaytoun OM, Autorino R, White WM, Crouzet S, Yakoubi R, et al. Robotic single port suprapubic transvesical enucleation of the prostate (R-STEP): initial experience. BJU Int. 2012;110(5):732–7.
18. Won Lee J, Arkoncel FR, Rha KH, Choi KH, Yu HS, Chae Y, Han WK. Urologic robot-assisted laparoendoscopic single-site surgery using a homemade single-port device: a single-center experience of 68 cases. J Endourol. 2011;25(9):1481–5.
19. Autorino R, Kaouk JH, Stolzenburg JU, Gill IS, Mottrie A, Tewari A, Cadeddu JA. Current status and future directions of robotic single-site surgery: a systematic review. Eur Urol. 2013;63(2):266–80.
20. White MA, Autorino R, Spana G, Hillyer S, Stein RJ, Kaouk JH. Robotic laparoendoscopic single site urological surgery: analysis of 50 consecutive cases. J Urol. 2012;187(5):1696–701.
21. Seideman CA, Tan YK, Faddegon S, Park SK, Best SL, Cadeddu JA, Olweny EO. Robot assisted laparoendoscopic single-site pyeloplasty: technique using the da Vinci Si robotic platform. J Endourol. 2012;26(8):971–4.
22. Joseph RA, Salas NA, Johnson C, Goh A, Cuevas SP, Donovan MA, et al. Video. Chopstick surgery: a novel technique enables use of the da Vinci robot to perform single-incision laparoscopic surgery. Surg Endosc. 2010;24(12):3224.
23. Kaouk JH, Autorino R, Laydner H, Hillyer S, Yakoubi R, Isac W, et al. Robotic single-site kidney surgery: evaluation of second-generation instruments in a cadaver model. Urology. 2012;79(5):975–9.
24. Morel P, Hagen ME, Bucher P, Buchs NC, Pugin F. Robotic single port cholecystectomy using a new platform: initial clinical experience. J Gastrointest Surg. 2011;15(12):2182–6.
25. Konstantinidis KM, Hirides P, Hirides S, Chrysocheris P, Georgiou M. Cholecystectomy using a novel Single-Site® robotic platform: early experience from 45 consecutive cases. Surg Endosc. 2012;26(9):2687–94.
26. Cestari A, Buffi NM, Lista G, Lughezzani G, Larcher A, Lazzeri M, et al. Feasibility and preliminary clinical outcomes of robotic laparoendoscopic single-site (R-LESS) pyeloplasty using a new single-port platform. Eur Urol. 2012;62(1):175–9.
27. Khanna R, Stein RJ, White MA, Isac W, Laydner H, Autorino R, et al. Single institution experience with robot-assisted laparoendoscopic single-site renal procedures. J Endourol. 2012;26(3):230–4.
28. Tobis S, Houman J, Thomer M, Rashid H, Wu G. Robot-assisted transumbilical laparoendoscopic single-site pyeloplasty: technique and perioperative outcomes from a single institution. J Laparoendosc Adv Surg TechA. 2013;23(8):702–6.
29. Park JH, Kim SY, Lee CR, Park S, Jeong JS, Kang SW, et al. Robot-assisted posterior retroperitoneoscopic adrenalectomy using single-port access: technical feasibility and preliminary results. Ann Surg Oncol. 2013;20(8):2741–5.
30. Kaouk JH, Haber GP, Autorino R, Crouzet S, Ouzzane A, Flamand V, Villers A. A novel robotic system for single-port urologic surgery: first clinical investigation. Eur Urol. 2014;66(6):1033–43.
31. Kaouk JH, Akca O, Zargar H, Caputo P, Ramirez D, Andrade H. Descriptive technique and initial results for robotic radical perineal prostatectomy. Urology. 2016;94:129–38.
32. Maurice M, Ramirez D, Kaouk J. Robotic laparoendoscopic single-site retroperitioneal renal surgery: initial investigation of a purpose-built single-port surgical system. Eur Urol. 2017;71(4):643–7.
33. Garisto J, Bertolo R, Kaouk J. Technique for docking and port placement using a purpose-built robotic system (SP1098) in human cadaver. Urology. 2018;119:91–6.
34. Kaouk J, Bertolo R, Eltemamy M, Garisto J. Single-port robot-assisted radical prostatectomy: first clinical experience using the SP surgical system. Urology. 2019;124:309.
35. Kaouk J, Garisto J, Eltemamy M, Bertolo R. Robot-assisted surgery for benign distal ureteral strictures: step-by-step technique using the SP® surgical system. BJU Int. 2019;123(4):733–9.
36. Kaouk J, Garisto J, Eltemamy M, Bertolo R. Pure single-site robot- assisted partial nephrectomy using the SP surgical system: initial clinical experience. Urology. 2019;124:282–5.
37. Kaouk J, Garisto J, Bertolo R. Robotic urologic surgical interventions performed with the single port dedicated platform: first clinical investigation. Eur Urol. 2019;75(4):684–91.
38. Kaouk J, Bertolo R. Single-site robotic platform in clinical practice: first cases in the USA. Minerva Urol Nefrol. 2019;71:294–8. https://doi.org/10.23736/S0393-2249.19.03384-8.

Instrumentation for Stone Disease

11

Bodo E. Knudsen

Introduction

As endourologists, the procedures we perform are tied closely together with the equipment we use. The surgeon's skill and expertise are essential, but without the right tools for the job the procedures will be either much more difficult or not possible at all. Therefore, having a comprehensive understanding of capital equipment including camera and video systems, endoscopes and lithotrites is essential. Furthermore, there has been a vast expansion in the number of disposable products used including different types of guide wires and stones baskets, ureteral access sheaths, and now even single-sue endoscopes. Understanding what devices are available and how they might aid in different situations will help arm endourologists with the knowledge and tools to be able to care best for their patients.

In this chapter, I will review both capital equipment as well as some of the disposable equipment used for percutaneous nephrolithotomy and for ureteroscopic procedures. Given that often multiple manufacturers produce similar products, I will discuss some products in generic terms but in other cases go in more specific examples. This chapter is intended to provide an overview into available equipment but given that this is an ever-evolving field, new products will invariably become available soon after publication.

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Capital Equipment

Video Systems

Video systems are an integral piece of the setup for endourologic procedures both in the operating room and in office settings. The key components include the video display, video processor, light source, camera heads for analogue endoscopes, optional recording equipment for still and video images, and usually a cart or stand to house the devices (Fig. 11.1).

Historically, video systems were analogue and interfaced with fiber-optic or rod-lens endoscopes. The camera head would attach to the scope and then transmit the signal to the video processor. Camera heads could be used with a wide range of endoscopes and were not manufacturer specific (Fig. 11.2). The advantage of this system was that it allowed the user to not be limited to endoscopes from one manufacturer, but rather be able to select endoscopes from a variety of manufacturers to best fits ones needs. With the introduction of digital endoscopes, the video processors and endoscopes became tightly linked. Brand X's endoscope will only connect with Brand X's video processor. Therefore purchasing

S. L. Best, S. Y. Nakada (eds.), *Minimally Invasive Urology*,
https://doi.org/10.1007/978-3-030-23993-0_11

Fig. 11.1 Example of video tower components including light source, processor, and recording devices

Fig. 11.2 Camera head used that is used with fiber-optic endoscopes

decisions, especially when selecting digital instruments, must take this into account.

Numerous manufacturers produce video systems that are used in urology including Olympus (Tokyo, Japan), Karl Storz (Tuttlingen, Germany), Stryker (Kalamazoo, MI), and Richard Wolf (Knittlingen, Germany). All offer systems that are compatible with analogue (fiber-optic, rod-lens) endoscopes used in endourology. The manufacturers typically scale the systems to suit different price points. Differentiators would include the resolution of the camera head and display system, the type of light source (usually Xenon or LED), the features of the video processor, and whether a recording system is included. The cost of system can range from approximately $15,000 up to over $100,00 (US dollars). Currently Olympus, Storz, and Wolf all produce digital endoscopes for urology. It is important to remember that when selecting digital endoscopes that the video processor from the same manufacturer must be factored into the overall purchase cost.

Light Source

Lighting technology, similar to other industries, has evolved from halogen to xenon and now to

light-emitting diode (LED) bulbs. Halogen light sources offer the benefit of lower cost bulbs as compared to xenon and LED, but at the expense of heat generation. The brighter the light, the greater the heat generated. Halogen lights also are not energy efficient, and the bulbs can require frequent replacement. Xenon light sources run cooler than halogen and produce stable light at warm color temperatures allowing for accurate color rendering during procedures. Xenon bulbs last four to five times longer than halogen bulbs and therefore require less frequent replacement. However, Xenon bulbs cannot be dimmed, and an actuator is used to reduce light output when needed. LED light sources are the most recent innovation. LED bulbs have the most consistent light output and longest run time by a wide margin when compared to xenon and halogen light. They are also the most energy efficient and usually run cooler. Although both xenon and LED light sources are currently available, LED will likely completely replace xenon in the future in urologic video systems [1].

Video Processors

The video processor is an essential component of the video system. The process converts the incoming video signal to a format that can be output at the native resolution of the video display. The processor, based on the settings, uses algorithms to attempt to enhance the image that is broadcast on the video display. Most urologists are familiar with the white balance function of the video processor. It is used to correct the color temperature so that the image displayed is not too blue or too yellow. The video processors usually have exposure modes that correct for bright or dark spots in the image. Different exposure modes can be set so that the image is adjusted with peak brightest versus average brightness. Smaller (spot) sampling can be set versus sampling the entire image. This is analogous to settings on a consumer SLR camera. If an image has hot spots, such as the light reflecting off a bright object, then the peak brightness setting tends to work best. However, if the image is more uniform, then I will usually select an averaging setting where the entire image is used to scale the exposure. Often the processor will have basic settings available directly on the front panel, but more advanced settings may be hidden in menu systems.

Some manufacturers have attempted to differentiate themselves by including advanced processing capabilities. One example of this is narrowband imaging (NBI), which is offered on some models of Olympus' video processors. NBI is an optical technology that changes the spectrum of illumination from broadband blue, green, and red to narrowband blue and green [2]. Illumination of the 415 and 540 nm wavelength facilitates the visualization of the submucosal microvasculature and may aid in bladder tumor detection [3, 4]. Karl Storz offers a competing technology with their D-Light C Photodynamic Diagnostic (PPD) system which enables both white light and blue light (wavelength 360–450 nm) fluorescence cystoscopy (Fig. 11.3). Blue light cystoscopy (BLC) using hexaminolevulinate (HAL/Cysview/Hexvix) has been shown to increase detection rates of carcinoma in situ and papillary bladder lesions over white light cystoscopy alone [5]. While these settings are not used during stone procedures, they may add value to the purchase of a video system.

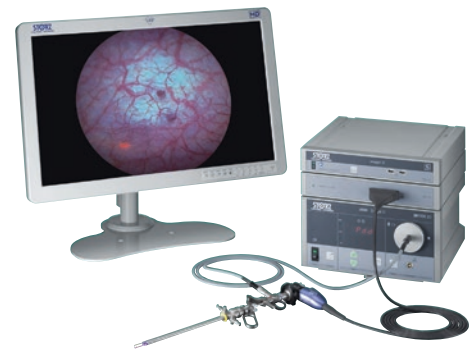

Fig. 11.3 Karl Storz Video System with Photodynamic Diagnostic system (PPD). (Courtesy of Karl Storz, Tuttlingen, Germany)

Endoscopes

Rigid Nephroscopes

Nephroscopes are primarily used during percutaneous nephrolithotomy (PCNL) but can also be adapted to be used for the treatment of bladder stones. Prior generation and many current nephroscopes use rod-lens technology, but some of the modern smaller caliber nephroscopes utilize fiber-optic bundles which allow for some flex of the scope without the resultant "half-moon" image that occurs when rod-lens-based scopes are bent. Nephroscopes are available in a range of diameters, lengths, and lens angles. Olympus, Karl Storz, and Richard Wolf all offer models of different lengths and diameters.

When selecting a nephroscope, the tract size used during a PCNL must be considered. For example, if a sheath with a 30 F inner diameter is used, then the nephroscope should be smaller than this, typically 24–26 F. This permits the nephroscope to pass easily through the sheath but still allows for some outflow of fluid around the scope during the procedure, thus facilitating low intrarenal pressures and maintaining adequate visualization. Manufacturers may offer the option of the offset of the eyepiece to be 45° versus 90°. My preference is a 90-degree offset as I find this makes the nephroscope easier to rotate while keeping the camera head in the correct orientation (Fig. 11.4). The length of the nephroscope may also vary between manufacturers. For example, Karl Storz offers their full size (24–26 Fr outer sheath) nephroscope in both a 19 and 24 cm length. My preference here is always the longer length. The longer length facilitates the use in obese patients or in patients with long percutaneous tracts. Longer nephroscopes can also be useful traversing within the kidney such as when trying to reach the lower pole through an upper pole tract. In addition, the longer nephroscopes can be used to approach bladder stones transurethrally and for tissue morcellation after holmium laser enucleation of the prostate (HoLEP). The Storz system has an adapter that allows the nephroscopes to be used with the outer sheath from the Storz resectoscope set. The allows for atraumatic passage into the bladder (Fig. 11.5).

Fig. 11.4 Nephroscope with 90-degree offset eyepiece

Fig. 11.5 Nephroscope connected to outer sheath of resectoscope set (standard lens with laser bridge also shown)

For smaller 24 Fr nephrostomy tracts, manufacturers offer a variety of slightly smaller and "slender" nephroscopes. Karl Storz manufactures an 18 Fr nephroscope with a 22 Fr outer sheath and is available with both a 45- and 90-degree offset eyepiece (Fig. 11.6). Similarly, Richard

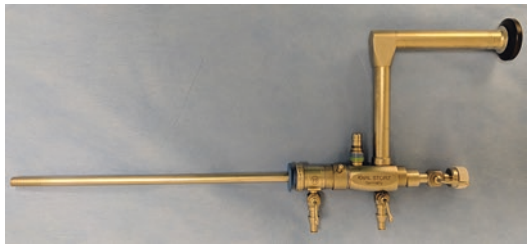

Fig. 11.6 18 Fr "Slender" nephroscope with 22 Fr outer sheath. Used during PCNL with 24 Fr tract

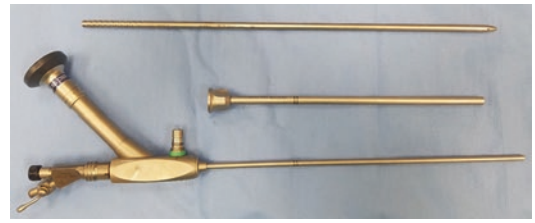

Fig. 11.7 Mini-nephroscope with one-step dilator and reusable sheath (Storz MIPS System)

Wolf offers a universal nephroscope ("Model Dresden") with a small sheath circumference of 20.8–24 Fr and a working channel of 10.5 Fr.

Briefly, a digital nephroscope utilizing complementary metal–oxide–semiconductor (CMOS) technology was available. Dubbed the "Smith" digital nephroscope, it coupled with Gyrus ACMI's Invisio Digital processor. It coupled two LED driver light carriers and a 1 mm digital camera, thereby eliminating the need for an external light source and camera head. This scope offered enhanced ergonomics with a pistol grip handle and is lightweight (470 g) [6]. However, after the acquisition of Gyrus ACMI by Olympus, the digital nephroscope production was ceased. To date, no replacement digital nephroscope has become available.

Since the initial reports of "mini-perc" by Jackman in 1998, PCNL with a reduced cross-sectional diameter tract (<20 Fr) has grown in popularity [7]. With reduced tract size, a requirement for the development of a smaller nephroscope occurred. Currently multiple manufacturers, including Olympus, Karl Storz, and Richard Wolf, produce small caliber nephroscopes that are suitable for mini-PCNL. However, where the products differentiate themselves is in what other equipment is part of the mini-PCNL set. For example, Karl Storz manufacturers the "Storz Modular Minimally Invasive PCNL System" (MIPS). This product includes the mini 12 Fr nephroscope, but also a series of one-step dilators (15, 16.5, 21 Fr) and reusable sheaths (16, 17.5, 22 F) (Fig. 11.7). The tightly integrated reusable system decreases the need for costly single-use disposable products. A limitation of the Storz mini-nephroscope is that the irrigation fluid is run through the 6.7 Fr working channel of the nephroscope and there is not an option to run the fluid through the outer sheath. When using larger instruments in the working channel, irrigation flows are greatly reduced. The Richard Wolf 15/18 Fr mini-PCNL system includes a 12 Fr nephroscope with a 12-degree lens that is coupled with an outer sheath measuring 15 or 18 Fr. In contrast to the Storz MIPS system, the outer sheath of Wolf's system allows for irrigation fluid to be run through it, circumventing the issue with reduced flow with instruments in the working channel of the nephroscope. The Wolf system also offers 12 and 15 Fr dilators. Olympus offers a 15 Fr mini-nephroscope with a 7.5 Fr working channel. It includes a continuous irrigation sheath but does not include dilators.

Ureteroscopes

Semirigid Semirigid ureteroscopes remain an essential component for endourologists to treat stones. They are usually utilized to treat stones in the ureter below the pelvic brim, but also in the mid- and upper ureter in females and occasionally males. Technology for semirigid ureteroscopes has been relatively stable over the past decade. The majority of the semirigid ureteroscopes are fiber-optic and therefore do not have the half-moon effect that a rod-lens-based scope would have when they are flexed. Semirigid ureteroscopes are available in different lengths, ranging from approximately 310 up to 450 mm depending on the make and model. The shorter ureteroscopes are easier to handle and are usually

adequate to reach stones in the distal and mid-ureter in men, and throughout the entire ureter in women. The longer semirigid ureteroscopes can be used to reach the upper ureter in men and renal pelvis in both sexes, provided they can be passed without resistance.

There has been a trend toward miniaturization with semirigid ureteroscopes. Most modern semirigid ureteroscopes have a tip diameter of 7 Fr or less and then usually increase in diameter slightly through the shaft. Designs exist with either one large working channel (≈ 4.5 Fr) or two smaller channels (≈ 2–3 Fr) (Fig. 11.8). The advantage of the single channel is that a larger instrument can be accommodated, but irrigation flow may be compromised since the channel is shared. With two separate working channels, one is typically used for the instrument, while the second channel is dedicated for irrigation.

One other differentiating factor for semirigid ureteroscopes is an offset versus a straight lens configuration. An offset lens allows for a straight working channel that will accommodate a rigid instrument such as a pneumatic lithotripsy probe. However, if holmium:YAG laser lithotripsy is the preferred lithotrite, then the working channel does not need to be straight, and an offset lens is not required since the laser fiber is flexible. In my own practice, I find a semirigid ureteroscope with a straight lens more ergonomic to handle during procedures.

Miniaturization of semirigid ureteroscopes has occurred. Richard Wolf produces an ultra-thin semirigid ureteroscope, dubbed the "needle-scope" that has a 4.5 Fr tip and a shaft that increases to 6.5 Fr. This ureteroscope has a single 3.3 Fr working channel and is available in 315 and 430 mm lengths. The very small distal tip facilitates cannulation of the ureteral orifice and pre-dilation rarely needed. The smaller 3.3 Fr working channel can reduce irrigation flow when a large instrument is passed. For laser lithotripsy, a small caliber fiber with a ≤270 μm core is preferred versus a larger fiber with a 365 μm core. Although initially intended as a semi-ureteroscope for children, it has gained acceptance in treating adults as well. In our hands it has proven to be robust, despite the small size, and is our primary semirigid ureteroscope (Fig. 11.9).

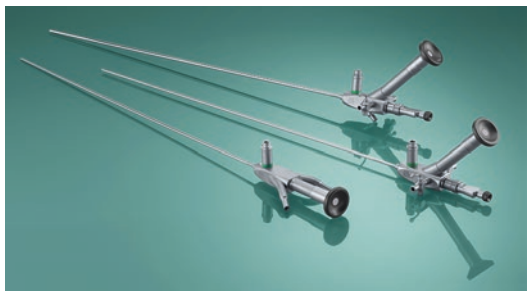

Fig. 11.8 Examples of semirigid ureteroscopes with either one and two working channels and with offset and straight eyepieces. (© Karl Storz SE & Co. KG, Germany, with permission)

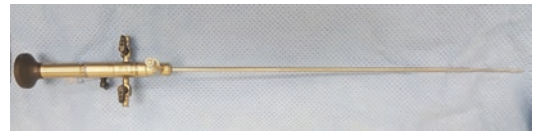

Fig. 11.9 Wolf semirigid "needlescope" ureteroscope with 4.5 Fr tip

Flexible Ureteroscopes The advent of small caliber flexible ureteroscopes coupled with the holmium:YAG laser resulted in a paradigm shift in the management of upper ureteral and renal stones [8, 9]. Shock wave lithotripsy had been the primary treatment option for stones <2.0 cm in the upper tract, but now flexible ureteroscopy with holmium:YAG laser lithotripsy became a viable alternative. After their introduction, flexible ureteroscope technology improved rapidly during the late 1990s and early 2000s resulting in smaller caliber, highly flexible instruments. At present, it is simplest to divide flexible ureteroscopes into several categories: first, fiber optic or digital optics and, second, single use or reusable.

Flexible Fiber-optic Ureteroscopes Fiber-optic ureteroscopes were the first flexible ureteroscopes widely used in the treatment of stones [8]. Initially technology advanced rapidly, but the development of flexible fiber-optic ureteroscopes has slowed recently. However, they remain a

Table 11.1 Flexible digital ureteroscopes currently on the market

	Karl Storz Flex-Xc	Richard Wolf Cobra Vision	Richard Wolf Boa Vision	Olympus URF-V3	Boston Scientific LithoVue
Distal tip	8.5 Fr	5.2 Fr	6.6 Fr	8.5 Fr	7.7 Fr
Sheath diameter	8.5 Fr	9.9 Fr	8.7 Fr	8.4 Fr	9.5 Fr
Recommended UAS	10/12	11/13	10/12	10/12	11/13
Number of working channels	1	2	1	1	1
Working channel	3.6 Fr	3.6 Fr/2.4 Fr	3.6 Fr	3.6 Fr	3.6 Fr
Angulation UP	270°	270°	270°	275°	270°
Angulation DOWN	270°	270°	270°	275°	270°
Working length	700 mm	680 mm	680 mm	670 mm	≈ 680 mm
Viewing angle	90°	90°	90°	80°	90°

UAS ureteral access sheath

valuable device, and all of the major scope manufacturers continue to produce flexible ureteroscopes. The smaller caliber and tip designs of the flexible fiber-optic ureteroscopes make them the best option for difficult-to-reach tight calyces [10]. Although these scopes share many similarities, there are some subtle differences (Table 11.1).

Karl Storz currently produces the Flex-X2S fiber-optic ureteroscope, which is the successor to the prior Flex-X2 and before that the Flex-X. The Flex-X2S has a 7.5 Fr tip size that expands to 8.5 Fr along the shaft. It has 270° of primary deflection both upward and downward with an 88° field of view and 3.6 Fr working channel. The tip of the working channel of the scope is lined by LaserliteTM, a durable material designed to resist damage when the laser is fired inadvertently with the tip of the fiber within the distal working channel. The primary difference between the Flex-X2 and the newer Flex-X2S is that the newer scope has double the number of fiber-optic bundles, increasing from 4000 to 8000. This results in a sharper image with less of the honeycomb effect that can be seen when fewer fiber-optic bundles are employed. Another unique aspect of the Flex-X2S is that it is available in two different shaft lengths. The standard length is 670 mm and would be used for standard adult flexible ureteroscopy. A shorter option at 450 mm is also available and is geared toward pediatric procedures. However, the 450 mm shaft length also works well for antegrade ureteroscopy during a percutaneous procedure.

Olympus recently released its latest generation flexible ureteroscope, the URF-P7. This ureteroscope incorporates many of the features of its predecessor, the URF-P6, but with a design that focused on increased durability and stronger deflection mechanism. It incorporates a 4.9 Fr tip the quickly tapers to a 7.95 Fr shaft. The working channel is 3.6 Fr and the working length is 670 mm. The manufacturer reports 275° of upward and downward deflection. While long-term durability studies are needed to validate the manufacturers claim, this scope incorporates many changes designed to prevent the problems with locking deflection that had been reported in the prior generation of Olympus ureteroscopes [11]. The tapered tip design does facilitate passage directly without the need to place it over a guidewire. This tapered tip design has facilitated office ureteroscope for the surveillance of the upper tract transitional cell carcinoma in select patients [12].

Richard Wolf offers both a single-channel and a unique dual-channel flexible fiber-optic ureteroscope. The single-channel model is named the "Viper" and has a standard 3.6 Fr working channel, 270° of upward and downward deflection, a 680 mm working length, and a tip size of 6 Fr that increases to a shaft diameter of 8.8 Fr. This permits the use in a small diameter 10/12 Fr ureteral access sheath. The dual-channel model, called the "Cobra", has two working channels, each with 3.3 Fr. The tip of fiber-optic Cobra is 6 Fr but increases to 9.9 Fr through the shaft. This increase in overall diameter is the trade-off for

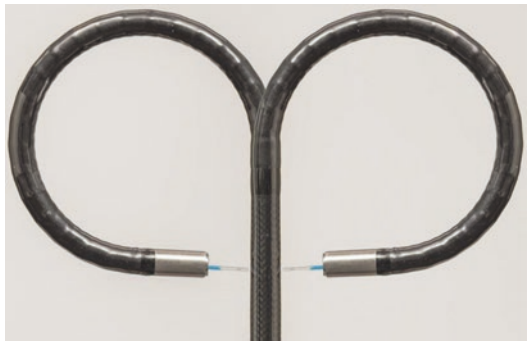

Fig. 11.10 Example of 270° of bidirectional deflection that modern flexible ureteroscopes can obtain. (© Karl Storz SE & Co. KG, Germany, with permission)

having the two working channels. However, the design permits the passage of a stone basket or laser fiber through one channel and thus does not limit irrigation through the second channel. Further creative uses might entail passing a laser fiber through one channel and a stone basket through the second channel. This ureteroscope also maintains the same 270° of bidirectional deflection at the Viper (Fig. 11.10).

Flexible Digital Ureteroscopes With manufacturers incorporating digital image sensors in flexible ureteroscopes, the digital era of flexible ureteroscopes began [13]. Current digital ureteroscopes use one of two different types of imaging chips, either the less commonly used charge-coupled device (CCD) or the more common complementary metal–oxide–semiconductor (CMOS). Both of these devices function by converting photons into electrons [14]. The digital signal is carried through the scope along wires and then converted by the image processor into the displayed image on the monitor. CMOS-based systems require less energy, run at lower temperatures, process images quicker, and are less expensive to produce as compared to CCD based. CCD is however a more mature technology and less affected by signal noise [15]. With continual improvement in technology, the expectation is further improvement in image quality, and reduction in size will occur. This is one of the fastest progressing areas of endourologic equipment.

Digital ureteroscopes offer some advantages over fiber-optic models. The "chip-on-the-tip" design eliminates the need for a separate bulky camera head that is required with fiber-optic scopes in order to display the image on the video monitor. The results in a more ergonomic setup by being lighter and less cumbersome to handle. There are no focusing dials as the digital instruments have a fixed focal length, further simplifying operation. The lighter digital ureteroscopes may result in less hand fatigue, especially during longer procedures. Reducing the number of cords from two (camera and light cord) to one helps to prevent entanglement and clutter. However, as previously discussed, each brand of digital ureteroscope requires a manufacturer-specific video processor, and therefore switching from one manufacturer to another is not simply a process of switching scopes but also requires switching video processors. With fiber-optic ureteroscopes this is simpler, as the camera head can be moved from one scope to another independent of the manufacturer.

Karl Storz manufactures the Flex-Xc, a CMOS-based flexible digital ureteroscope. It has a single 3.6 Fr working channel and a 700 mm shaft length. It is capable of 270° of bidirectional deflection with a 90° field of view. It has a built-in LED bulb for illumination. After its initial introduction, the CMOS chip was upgraded in a revision from 240 × 240 pixels to 460 × 400 pixels. The Flex-Xc has been demonstrated in bench evaluation to be highly maneuverable and out maneuvered other digital ureteroscopes in a bench model [16] (Fig. 11.11).

The latest generation Olympus flexible ureteroscope is the CMOS-based URF-V3. It has a 8.5 distal end outer diameter, a 3.6 Fr working channel, and a length of 670 mm. It provides 275° of bidirectional deflection and has a similar revised deflection mechanism as the URF-P7 designed to be more robust and avoid the prior reported problems with locked deflection [11]. At present, no clinical data regarding performance is available, but it appears to be a promising scope design and of the prior generation URF-V2.

Richard Wolf produces two flexible digital ureteroscopes, the Boa vision and the Cobra vision.

Fig. 11.11 Storz Flex-Xc digital ureteroscope. (© Karl Storz SE & Co. KG, Germany, with permission)

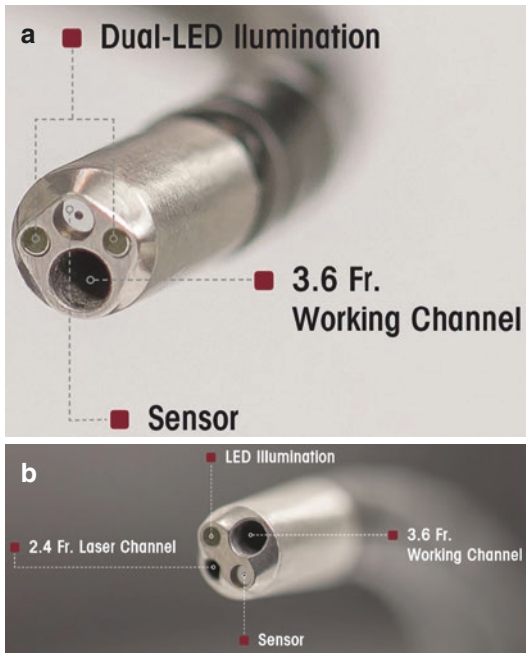

Fig. 11.12 (**a**) Tip of single-channel Wolf Boa vision digital ureteroscope. (**b**) Tip of dual-channel Wolf Cobra vision digital ureteroscope. (© Richard Wolf, Knittlingen, Germany, with permission)

The Boa vision, similar to the fiber-optic Viper, has a single 3.6 Fr working channel. It has a 6.6 Fr stainless steel tip that increases in diameter to an 8.7 Fr shaft. It has a 680 mm working length with 270° of bidirectional deflection. Like the Storz Flex-Xc, it has an integrated LED light (Fig. 11.12a). In contrast, the Cobra vision has two working channels of 3.6 and 2.4 Fr (Fig. 11.12b). The digital Cobra vision has a 5.2 Fr tip that increases to a shaft size of 9.9 Fr. It also has a 680 mm working length, 270° of bidirectional deflection, and an integrated LED light.

Fiber-opticVersusDigitalUreteroscopes There are multiple factors to consider when comparing fiber-optic with flexible digital ureteroscopes including imaging quality, size, maneuverability, durability, and cost. With continual innovation and introduction of new products, it is a moving target to perform direct comparisons between models, but some generalizations can be made. Multiple studies have demonstrated improved image quality when comparing fiber-optic to flexible digital ureteroscopes. In one study, the Karl Storz flexible fiber-optic ureteroscope 11274AA was compared to the Olympus URF-V, a first-generation CCD-based digital ureteroscope. The authors performed 44 consecutive procedures with these two ureteroscopes; the first 22 were with the Karl Storz fiber-optic and the later 22 with the Olympus digital. The digital URF-V scored higher in a subjective measure of maneuverability and visibility. The authors also noted greater clarity, superior magnification, and a lack of a moiré effect. The digital scope was able to visualize the entire collecting system in 90.9% of cases versus 81.8% for the fiber-optic scope [17]. Humphreys reported that with the use of digital ureteroscopes pathology such as Randall's plaques within the renal papilla, which could not have been previously visualized with fiber-optic scopes, could now be seen [13].

Stone-free rates (SFR) were compared between fiber-optic and flexible digital ureteroscopes in several studies. One study compared the Olympus URF-P5 fiber-optic ureteroscope to the digital URF-V and evaluated stone-free outcomes 1 month after flexible ureteroscopy. The SFR was comparable at 88% and 86%, respectively, but the operative times were somewhat longer with the fiber-optic ureteroscope taking an average of 53.8 min versus 44.5 min for the digital ureteroscope [18]. In another study, the Karl Storz Flex-X2 was compared to the Gyrus/ACMI DUR-D and reported similar findings. The stone clearance rates were 88.2% and

85.7%, respectively, but again the fiber-optic instrument took slightly longer to perform the procedure at a mean of 46.5 min versus 38.3 min for the digital device [19]. While it is not entirely clear why the digital ureteroscopes had shorter procedure lengths, possibilities include that the better visualization allows for more accurate targeting of the stone and that the improved ergonomics may allow the surgeon to work in a more time-efficient manner.

Limitations of Flexible Digital Ureteroscopes While flexible digital ureteroscopes appear to have some clear advantages, there are also some drawbacks. The digital image can be disrupted during laser lithotripsy due to the wave produced from the photoacoustic effect of the holmium:YAG laser. This is seen as lines and artifacts passing through the image on the video monitor. To counter this effect manufacturers have begun to place shock-absorbing devices at the tip of the scope where the image sensor is located [20]. While this may have reduced the effect, in my experience it can still be seen even with current generation digital ureteroscopes when the laser fires close to the tip of the scope. Advancing the laser fiber further out from the tip of the scope, and thus increasing the distance between the point where the acoustic shock wave is generated and the image sensor, helps to reduce the effect. A good guideline is to keep the fiber advanced far enough that it occupies one quarter of the screen as reported by Talso [21].

Current generation flexible digital ureteroscopes have larger shaft diameters, and in some cases tip diameters, in comparison to flexible digital ureteroscopes (Table 11.2). This is primarily a limitation of the size of the digital image sensor. The larger size can limit access through a tight ureteropelvic junction (UPJ) or narrow infundibulum. In one report using the Olympus URF-V, the target stone could not be reached in approximately 10% of the procedures, but when the surgeon switched to the smaller fiber-optic URF-P5, the target was reached in all of the procedures [15]. In a bench study using the K-Box (Porges-Coloplast, Humlebæk, Denmark), fiber-optic ureteroscopes had better end-tip deflection by a median of 21° when compared to digital ureteroscopes with the exception of the digital Flex-Xc [16]. This can be a factor when trying to enter a calyx that requires a high degree of angulation. Future advances in miniaturization that allow for a smaller diameter and more compact tip designs will help to overcome these shortcomings. In the interim, it is best to have a fiber-optic backup flexible ureteroscope available if digital ureteroscopes are used as the primary instrument. If the target cannot be reached with the digital ureteroscope, then trying the fiber-optic model is prudent.

Cost Repair One of the challenges of flexible ureteroscopy is the cost. While costs will vary from region to region, with reusable flexible ureteroscopes, there is an initial purchase cost of the capital equipment, but then there is also the ongoing

Table 11.2 Flexible fiber-optic ureteroscopes currently on the market

	Karl Storz Flex-X2	Olympus URF-P6	Richard Wolf Viper	Richard Wolf Cobra
Distal tip	7.5 Fr	4.9 Fr	6 Fr	6 Fr
Sheath diameter	8.5 Fr	7.95 Fr	8.8 Fr	9.9 Fr
Smallest UAS it fits	9.5/11.5	9.5/11.5	9.5/11.5	11/13
Number of working channels	1	1	1	2
Working channel	3.6 Fr	3.6 Fr	3.6 Fr	3.3 Fr × 2
Angulation UP	270°	275°	270°	270°
Angulation DOWN	270°	275°	270°	270°
Fits other camera systems	Yes	Yes	Yes	Yes
Working length	670 mm	670 mm	680 mm	680 mm
Viewing angle	88°	90°	90°	90°

UAS ureteral access sheath

cost of maintenance and repair. In 2000, Afane et al. reported that 6–15 procedures could be performed until repair was required for small caliber (<9 Fr) fiber-optic ureteroscopes [22]. This demonstrated how fragile these instruments are. In another single-center study, the authors employed techniques to try and increase scope longevity of flexible ureteroscopes by utilizing a ureteral access sheath during the procedure, relocating stones in the lower pole to the upper pole, and using more flexible small caliber holmium:YAG laser fibers. With these maneuvers the flexible fiber-optic ureteroscopes averaged 27 uses between repair [23]. However, in a prospective multicenter clinical trial at three tertiary care centers, average failure rates for fiber-optic ureteroscopes remained at approximately ten cases [24]. Flexible digital ureteroscopes were launched with the promise of improved reliability due to the elimination of the fragile fiber-optic bundles. However, in a follow-up prospective trial, flexible digital ureteroscopes did not fare any better than fiber-optic ureteroscopes in terms of number of cases until scope failure [15]. A recent US-based study reported an average cost of $7521 per repair, although the authors did manage an average of 21 procedures between repair [25]. Ultimately, these capital purchase costs, and the ongoing repairs costs, must be budgeting for when planning for a flexible ureteroscopy program utilizing reusable ureteroscopes.

Single-Use Flexible Ureteroscopes The cost and repair of reusable flexible ureteroscopes has led to the development of an alternative product, the single-use flexible digital ureteroscope. The launch of the LithoVue (Boston Scientific, Marlborough, MA) began a new era of having a single-use Flexible digital ureteroscope that is a viable alternative to existing reusable products. The LithoVue has a CMOS-based image sensor with a 7.7 Fr tip that increases to 9.5 Fr along the shaft. It has a standard 3.6 Fr working channel and 270° of bidirectional deflection (Fig. 11.13). The LithoVue requires a separate dedicated image processor that also contains a display monitor, but it can be daisy-chained to existing

Fig. 11.13 Boston Scientific LithoVue single-use ureteroscope

cystoscopy towers. The device is intended for single-use only and is not certified to be reprocessed. The performance characteristics of the LithoVue are similar to reusable flexible ureteroscopes [26, 27]. The advantage of a single-use product is that you should have the same performance available for every case. For example, the ureteroscope should have maximal deflection at the start of each procedure and the optics also consistently stable. The product comes sterile, in a sealed package, similar to other disposables. This eliminates the risk of an improperly sterilized scope and has the potential to minimize intraoperative delays provided that product is stocked and available.

Clinical performance of the single-use LithoVue has been compared to reusable fiber-optic ureteroscopes in a nonrandomized student with comparable treatment groups. The performance of the LithoVue was similar to the reusable fiber-optic ureteroscopes with the exception of operative time, where the LithoVue procedures took on average 10 min less [28]. This finding is similar to the prior studies discussed comparing reusable digital ureteroscopes to reusable fiber-optic scopes.

Another CMOS-based single-use ureteroscope was recently launched called the Uscope UE3022TM (Zhuhai PusenMedical Technology Co., Ltd., Zhuhai, China). It has specifications that are nearly identical to the LithoVue including a CMOS-based imaging system, 9.5 Fr shaft, and a 650 mm working length. The performance characteristics appear to be similar to the LithoVue system during bench analysis [27]. It is likely that additional single-use flexible ureteroscopes will become commercially available in the future.

Cost Comparison: Single Use Versus Reusable Assessing cost effectiveness of single-use versus reusable flexible ureteroscopes is a challenging task. One must consider not only the purchase and repair costs of reusable scopes but also the cost of sterilization and handle the instrument between procedures. Repair contracts can help control costs, but there can be significant variation in these costs from center to center. For single-use ureteroscopes, it is somewhat easier to calculate the associated costs. There is the individual purchase price of each scope, some human resource cost to stock and store the instrument, and cost of disposing it in the trash. Several authors have attempted to assess the cost effectiveness of the LithoVue at each of their centers. Martin et al. evaluated their costs of using a reusable Flex-Xc flexible digital ureteroscope for 160 cases over a 12-month period. They average 12.5 uses between failures and determined the cost per use after repair was $848.10. However, the initial purchase cost of the instrument was not included. Based on this figure, they calculated that after 99 cases in a 12 month period, it would be more cost effective to use a reusable ureteroscope, but for less than 99 cases, the LithoVue would have been more cost effective [29]. Therefore, lower volume centers should consider a single-use option if cost is a priority. For higher volume centers, a reusable flexible ureteroscope appears to be more cost effective.

Another approach used to perform a cost comparison is a micro-costing analysis. Using this approach, Taguchi et al. determined at their institution the cost of using a fiber-optic URF-P6 or a digital LithoVue were comparable at $2799.72 and $2852.89, respectively, per procedure [30]. This study illustrates the complexity of calculating costs, especially when reusable instruments are used. It is important to understand that costs calculated in one center may not directly translate to another center, as the organization structures can directly impact the costs. However, it is clear that a careful value analysis should be performed when assessing the available options.

Intracorporeal Lithotripters

Ureteroscopy

Percutaneous Nephrolithotomy: Standard Tract During percutaneous nephrolithotomy (PCNL) fragmentation and clearance of the stone is performed with a combination of an intracorporeal lithotripter and an extraction device. Typically, pneumatic, ultrasonic, or dual ultrasonic and ballistic devices are utilized for stone fragmentation. More recently, with an increasing interest in smaller tract sizes, the holmium:YAG laser is also being utilized.

Pneumatic Lithotripters Pneumatic lithotripters use ballistic energy to fragment stones. A solid, rigid probe connected to a handpiece is activated by pneumatic pressure that propels the probe at a pressure of about 3 atmospheres. When the stone is struck, the physical force leads to fragmentation. With the increased use of ultrasonic lithotripter, pure pneumatic devices are rarely used for standard 24–30 Fr PCNL's. However, for smaller tract sizes where there are limitations in instrumentation, pneumatic is used more frequently.

The Swiss LithoClast (EMS, Nyon, Switzerland) is a pneumatic lithotripter with available probe sizes from 0.8 to 3.0 mm. This range of sizes allows it to be used with both mini-PCNL instrumentation and with larger nephroscopes. The smallest probes will also work with some larger rigid ureteroscopes. Due to the rigid nature of the probes, they cannot be used with flexible endoscopes. The device rapidly fragments stones and works best when a stone can be pinned against a tissue to keep it from escaping [31]. The device does not generate heat and has been shown to be safe with minimal tissue trauma even with direct contact [32]. The major drawback of the Swiss LithoClast is that after fragmentation the pieces need to be removed. For hard stones, this is simpler as there typically are fewer pieces and they can be rapidly cleared with a two- or three-prong grasper.

Fig. 11.14 Swiss Lithoclast Controller

However, for softer stones, the small pieces will scatter, and removal can be difficulty (Fig. 11.14).

Ultrasonic Lithotripters Ultrasonic lithotripters use ultrasonic waves that are of an acoustic frequency that is out of the range of human audibility. Piezoelectric crystals are contained within the handpiece, and electrical current is applied to them generating the ultrasonic wave. This wave of energy is transmitted along a metallic probe where it is converted to vibrational energy at the tip. The mechanical energy that is created results in fragmentation of the stone and is not related to heat or shock waves. The probe must be in direct contact with the stone for efficient fragmentation to occur [33].

Ultrasonic probes range in size from approximately 2.5 to 6 Fr. The larger probes have a hollow lumen through which suction can be applied. This serves two purposes. First it allows for the evacuation of stone fragments through the device. This can be especially valuable when clearing soft stones, such as struvite. The small particles generated can be efficiently "vacuumed" out, thus preventing scatter throughout the collecting system. The second purpose of the lumen is that as fluid is evacuated through the handpiece, it allows for cooling and thus more efficient operation. The smaller ultrasound probes correspondingly smaller lumens, and thus this limits their efficiency to evacuate fragments. The very smallest sized probes do not have a lumen at all and therefore can only be used for fragmentation and not suction evacuation. With all probe sizes, when larger fragments are generated, they can also simply be removed with a grasper [33].

Ultrasonic lithotripters have been demonstrated to have a wide margin of safety. Histologic studies in rabbits have shown only the development of edema with direct probe contact [34]. Prolonged contact of the probe with the urothelium however can result in thermal damage if the probe overheats. This risk is mitigated by ensuring the suction and fluid flow are occurring.

More recently, several manufacturers of ultrasonic lithotripters including EMS and Olympus have focused on dual modality devices rather than pure ultrasonic lithotripters. However, Richard Wolf has released a modern pure ultrasonic lithotripter, called the UreTron, with promising early clinic results. The UreTron employs a technology that allows for very precise control of the probe vibration that is thought to enhance the efficiency of the device. It is available in probe sizes ranging from 1.5 to 3.5 Fr. Borofsky et al. evaluated the UreTron in 31 percutaneous procedures for stones >2 cm and determined that stone clearance rate was faster than other modern lithotripters including the CyberWand (Olympus Surgical), StoneBreaker (Cook Medical, Bloomington, IN), and LithoClast Select (Boston Scientific, Marlborough, MA). Stone-free rates, clinical complications, and device malfunctions were no different among the devices [35].

Dual Probe Combination Ballistic and Ultrasonic Lithotripters Several manufacturers began to focus on dual-probe dual-modality lithotripters over the last decade. These devices combine the well-established ultrasonic technology with a second probe that allows for a further ballistic impact on the stone. EMS developed the LithoClast Master (marketed in the United States by Boston Scientific as the LithoClast Ultra and later revised to the LithoClast Select), which is a combination pneumatic and ultrasonic lithotripter. The device can be used independently for ultrasound or pneumatic lithotripsy, or the modalities can be used in combination. When used in pure ultrasound mode, it appears similar

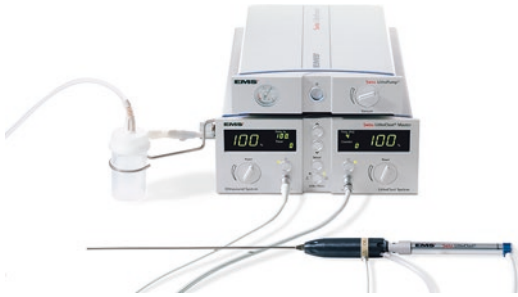

Fig. 11.15 EMS Lithoclast Select Dual Modality Lithotripter. (© EMS, Nyon, Switzerland, with permission)

to other ultrasonic lithotripters with a single probe attached to the handpiece with suction running through it. In combination mode, the pneumatic probe is inserted through the lumen of the ultrasound probe, and an attachment that delivers the compressed air is attached to the handpiece (Fig. 11.15). In combination mode, the ultrasound and pneumatic devices can be activated independently or both at the same time through foot pedal control. The pneumatic frequency can be adjusted from 2 to 12 Hz and run in a single shot or continuous mode. The ultrasound has adjustment setting for duty and power. It operates at a frequency of 24–26 kHz [33]. In dual modality mode, I typically run the pneumatic at a slower frequency (2–4 Hz) in order to allow sufficient time for the ultrasound to make contact with the stone. The concept is that the ultrasound continues to do the primary work but receives an "assist" from the pneumatic device.

A clinical study has shown that the LithoClast Ultra with dual ultrasonic and pneumatic components improved completed stone disintegration and extraction by a factor of two when compared to using a pure ultrasonic device (LUS-2, Olympus). Complication rates and 3-month stone-free rates were not different in the two cohorts [36]. In another clinical study, comparing combination ultrasonic and pneumatic lithotripsy to pure ultrasonic lithotripsy found that the combination mode was faster for hard (calcium oxalate monohydrate, cystine, or calcium phosphate) but not soft stones [37]. It is possible that with the softer stones the suction evacuation of the fragments becomes the time-limiting step. With the dual modality device, the inner lumen of the ultrasound probe is occupied in part by the pneumatic probe thereby decreasing the space for suction evacuation of fragments. One strategy that may improve surgical efficiency is to first fragment the stone in dual modality mode and then remove the pneumatic probe and simply clear the remaining fragments in pure ultrasonic mode. This is a technique I have employed with the LithoClast Select for the treatment of very large and hard stones.

The handpiece of the LithoClast Master was updated midway through its life cycle to a newer design termed the Vario. The new handpiece was designed to address some shortcomings in the initial design including more consistent ultrasonic operation and reduced clogging. In the original handpiece, the suction channel exited out of the handpiece at a 90° angle, and this resulted in frequently clogging. With the updated design, the suction channel exits the handpiece without a bend (i.e., 0°) in pure ultrasound mode and at 45° in dual modality mode. My clinical impression is that this design medication did result in reduced clogging during operation. In the United States, the LithoClast Ultra was renamed the LithoClast Select with this revision (Fig. 11.16).

Fig. 11.16 Vario handpiece for Lithoclast Master. (© EMS, Nyon, Switzerland, with permission)

Fig. 11.17 Partially disassembled CyberWand hand piece showing probe and spring

Dual Ultrasonic Lithotripter The CyberWand (Olympus Surgical) is a dual probe ultrasonic lithotripter. It utilizes a smaller inner probe that operates at a frequency of 21 kHz and is fixed to the handpiece. There is a larger outer probe that is connected via a free mass in the handpiece. The outer probe vibrates at a much slower 1000 Hz and adds a ballistic effect related to the free mass and energy driven by the inner probe. The outer probe has a diameter of 3.75 mm, and the inner probe has a 2.1 mm lumen (Fig. 11.17). Suction is run through the smaller inner probe. Given the smaller inner lumen of 2.1 mm, the CyberWand is less effective at suction clearance of fragments as compared to devices with larger inner lumens [33].

In a prospective, randomized clinical trial evaluating the efficiency of several intracorporeal lithotripters during percutaneous nephrolithotomy, the CyberWand was shown to have equivalent performance to the dual modality LithoClast Select [38]. In my own experience the CyberWand is highly effectively at stone fragmentation, but the small inner lumen limits the clearance of fragments. Therefore, a technique of fragmentation first with the CyberWand and then removal of pieces with a grasper is employed to maximize efficiency.

Single Probe Dual Modality Lithotripters

ShockPulse Stone Eliminator The ShockPulse Stone Eliminator (ShockPulse-SE, Olympus Surgical) was developed as the success to the CyberWand. Instead of the dual probe design of the CyberWand, engineers developed the ShockPulse to have both the ultrasonic component and the ballistic action with a single probe design. By switching to a single probe design, the limitation of the small inner lumen could be addressed. The handpiece houses the piezoelectric crystal, and this produces the 21 kHz acoustic wave that vibrates the probe. The single probe design incorporates the free mass elements at the proximal end which oscillate to produce mechanical waves. The waves transmit to a spring that ultimately causes the probe to vibrate at 300 Hz and create a ballistic impact on the target stone [39].

The ShockPulse also incorporates several other unique features. While it can be operated via a conventional foot pedal, the handpiece also incorporates buttons that allow for activation of the device. Double clicking the button turns the device on and a single click back off. Further, the suction is adjustable via a dial located on the end of the endpiece allowing for fine control by the surgeon during the procedure. In my experience both the button controllers and the suction dial improve the ergonomics of the procedure and are an advancement of prior designs.

The ShockPulse is available in five probe sizes ranging from 2.91 to 3.76 Fr (0.97–3.76 mm). The largest 11.3 Fr probe work well with full-sized 24 Fr nephroscopes to all for maximal stone clearance. The slightly smaller 10.2 Fr probe is best paired with "slender" 22 Fr nephroscopes used through 24 Fr PCNL procedures. The smaller 4.5 and 5.5 Fr probes will work through the Storz MIPS mini-nephroscope, but flow through the scope channel is somewhat impaired. The smallest 2.91 Fr probe lacks an irrigation channel and is intended to be used with semirigid or rigid ureteroscopes (Fig. 11.18).

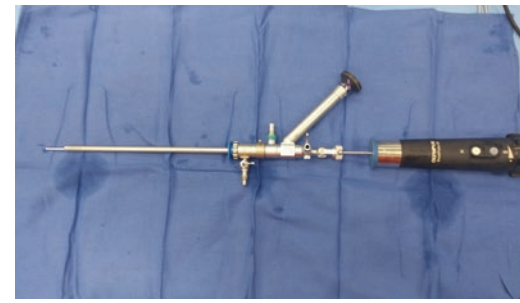

Fig. 11.18 Olympus ShockPulse placed through channel of 22 Fr nephroscope

A bench evaluation of the ShockPulse compared it to the dual modality LithoClast Master and CyberWand, and the pure ultrasonic LUS-2. The ShockPulse demonstrated faster fragmentation and evacuation times as compared to the other three systems [39]. To date no clinical comparative trials have been reported.

Swiss LithoClast Trilogy The LithoClast Trilogy (EMS) is a single probe dual energy lithotripter that produces both ultrasonic and ballistic energy to fragment to the stone. It incorporates a large piston grip style handpiece and offers individually modifiable settings for the ultrasound and mechanical modes as well as suction. A range of probe sizes are available from 3 to11.7 Fr (1.1–3.9 mm). Unlike the ShockPulse, there are no control buttons on the handpiece, but rather a traditional pedal is used to activate the device. A stone-trapping device is used inline with the suction tubing to facilitate capture of stone fragments for later analysis.

In vitro bench testing data comparing the LithoClast Trilogy to the ShockPulse and LithoClast Select demonstrated that the LithoClast Trilogy has the fastest stone clearance times. During stone-drilling testing, the LithoClast Trilogy and ShockPulse appeared equivalent [40].

The LithoClast Trilogy appears to be a promising device for intracorporeal lithotripsy during PCNL. The range of probe sizes will allow it to be used for both mini-PCNL procedures as well as those with full-sized tracts. Further clinical trials will be needed to assess whether the ergonomics of the size and weight of the handpiece, as well as lack of on handle controls, limit its adoption versus the ShockPulse.

Holmium:YAG Laser The holmium:YAG (Ho:YAG) laser is the current gold standard intracorporeal lithotripter for ureteroscopic stone management [41]. It can fragment stones of all compositions via its dominant photothermal effect [42]. The 2140 nm wavelength is highly absorbed in water which contributes to its wide margin of safety. Widespread adoption of the Ho:YAG laser has occurred since the late 1990s, and it is now a standard device in most endourologic operating rooms.

Shortly after Ho:YAG laser was introduced to urology, it became available at a variety of power capabilities. Systems ranged from lower powered laser capable of delivery 10–20 W up to higher powered models up to 80 W. The lower powered systems were adequate for stone fragmentation, but the high-powered models were also used to soft tissue applications including the development of holmium laser enucleation of the prostate (HoLEP) [43]. These early Ho:YAG lasers operated at a short pulse duration of approximately 300 μs (Fig. 11.19). Over time newer systems were developed that both filled in the gaps between the low- and high-powered systems, but also systems that operated at very high-power outputs of up to 120–140 W. Further, the introduction of variable pulse length laser occurred, changing some of the dynamics of stone and soft tissue treatment [44] (Fig. 11.20). All of these factors increase the complexity of the decision-making process when purchasing a Ho:YAG system.

Fig. 11.19 Lumenis VersaPulse 100-W laser capable of 2 J, 50 Hz, but only short pulse duration

Fig. 11.20 Control screen of the Cook Rhapsody H-30 Ho:YAG laser. A low-powered laser capable of short and long pulse duration

Low- Versus High-Powered Ho:YAG Systems The first decision that needs to be made when purchasing a Ho:YAG console is whether to purchase a "low-" or "high-" powered machine. Historically, low-powered systems could be operated on a standard 110-V outlet allowing them to be use in virtually any operating room. These systems employ a single-rod design and are typically limited to a maximum pulse frequency setting of 15–20 Hz. These systems will fragment stones well using pulse energy settings of 0.6–1.0 J at a frequency of 6–10 Hz. The limitation of the lower powered systems come to light when attempting to "dust" stones using low-pulse energy (0.2–0.3 J). The single-rod design limits the pulse frequency, and therefore the dusting process can be slow and tedious. When dusting stones, the pulse frequency is an important factor in how quickly the stone can be treated, essentially it is the gas pedal [45]. For soft tissue applications, such as HoLEP, generally a high-powered console is preferred although there are reports of performing the procedure with a low-powered (50 W) laser [46, 47].

When selecting a Ho:YAG laser, it is important to determine the electrical capabilities of the operating or procedure room that it will be used in. Low-powered systems are compatible with most 110-V outlet. High-powered systems such as the Lumenis Pulse™ 100H usually require 20-A electrical service, which may need to be wired in. Usually this can be done without too much difficult. However, the most powerful systems, such as the 120-W Lumenis MOSES Pulse™ 120H, require 50-A service. In our own experience, this has proven to be problematic unless the operating room has already been wired for such power requirements.

Short Versus Long Pulse Systems Although initially reported in 2005 that longer pulse duration can reduce stone retropulsion during laser lithotripsy, it is only recently that the technology has become more widely available on a range of laser systems [44]. By increasing the pulse duration, less stone retropulsion occurs since the energy from each pulse is delivered over a longer period of time. When using the long pulse mode, the stone remains more stable and thus allows for more effective targeting and less chasing of the stone during the procedure. Longer pulse duration also reduces laser fiber tip degradation (burnback), likely secondary to a reduced photoacoustic effect [48].

At present, I would not recommend purchasing a new Ho:YAG laser without the ability to select short and long pulse duration. This feature is available on both low- and high-powered systems. I have found the ability to reduce retropulsion and laser fiber tip degradation valuable during ureteroscopic procedures. I have also found long pulse duration to be helpful when treating bladder stones, since the large open space in the bladder can result in a lot of stone movement when short pulse duration settings are utilized. With long pulse duration, the stone is much more stable and easier to consistently target resulting in a more efficient procedure.

Pulse Modulation Several newer Ho:YAG laser systems now offer a pulse modulation mode. Although some of the information remains proprietary, the concept is that the laser fibers an initial pulse that vaporizes the fluid between the tip

of the fiber and the target, and then a second pulse very quickly follows and travels through the vapor channel before hit the target. The promise of this technology with stone treatment is a further reduction in stone retropulsion and an increase in fragmentation efficiency. At present this technology is available on several high-end laser consoles.

Lumenis has made the technology available on their top-of-the-line MOSES Pulse™ 120H laser. This 120-W laser offers both short, medium, and long pulse duration mode as well as a MOSES pulse modulation mode that has two settings: MOSES distance and MOSES contact. In MOSES distance mode, the laser fiber tip does not have to be in direct contact with the stone to have an effect. Early in vitro bench testing results show promising results of reduced retropulsion and improve ablation compared to non-MOSES modes [49, 50]. However, further clinical study is needed to determine its true efficacy (Fig. 11.21).

An important consideration regarding the Lumenis MOSES Pulse™ 120H laser is that it is a closed platform, meaning that only laser fibers endorsed by the manufacturer can be used with it due to RFID tagging on the connector. Further, the MOSES mode requires a MOSES-specific laser fiber, currently priced at the very high end of commercially available laser fibers. This brings into question the cost versus benefit of the technology. Stern and Monga performed a recent cost analysis and concluded that "the decrease in lasing time with the MOSES system did not translate into sufficient cost savings to offset the higher cost of the laser fiber and software" [51]. At minimum, these costs must be carefully studied prior to purchase as the closed platform locks the user out of other options for laser fibers.

Fig. 11.21 Lumenis Pulse 120H laser console with MOSES technology

Olympus recently launched a new Ho:YAG platform called EMPOWER™. This platform includes laser of 35, 65, and 100 W and the models are the H35, H65, and H100 respectively. The H65 and H100 models offer a "Stabilization Mode" that is described in a similar manner than the Lumenis MOSES mode in that a vapor bubble is produce that then facilitates delivery of a second laser pulse to the stone. The EMPOWER™ platform is also closed and dedicated fibers must be used with the system. Ideally, future study will evaluate the performance of this mode and how it compares to MOSES.

Open Versus Close Systems Historically, most Ho:YAG systems were open platforms, meaning that laser fibers from different manufacturers could be used on a given laser provided the connector was compatible. In many instances this did not result in problems, but mismatches could occur that could result in damage to both the fiber and the laser console [52]. The benefit of an open system is increased competition and hence lower pricing of fibers. In addition, it helps to promote innovation in the fiber realm, and manufacturers attempt to improve the performance of their fibers. However, laser console manufacturers have taken note, and the industry trend now is to close that platforms down and limit fiber selection to those provided by the manufacturer. This has resulted in a significant increase in laser fiber pricing over the past number of years. While some open platform systems are still available, I anticipate as new laser systems are introduced, all will become closed systems. Therefore, when purchasing decision are being made, one must take into account both the capital equipment cost of the laser and the ongoing cost of the laser fibers.

Ho:YAG Laser Fibers The Ho:YAG laser utilizes low hydroxy silica optic fibers to transmit the laser energy from the console to the target. These are relatively inexpensive fibers to manufacturer and are available in a wide variety of sizes with core diameters ranging from 150 to 1000 μm. There are both single-use and reusable variants available depending on the manufacture. While many fibers have flat tips, a variety of ball-tipped fibers have grown in popularity.

Fiber selection depends both on the choice of laser console, as some are open platforms and can use a range of fibers from different manufacturers, while other platforms are closed and require using a manufacturer-specific fiber. The second consideration is what size of fiber to employ. Fibers with small core sizes of 150–300 μm are used during flexible ureteroscopy, while fibers with larger core sizes of 300–365 μm are better suited to semirigid ureteroscopes which do not require the fibers to bend and the larger irrigation channel is less susceptible to flow impairment by the fiber. This group of fibers also works well for mini-PCNL through the small nephroscopes. For treatment of bladder stones with a larger rigid cystoscope or laser resectoscope, 550–1000 μm core-sized fibers are preferred. These larger fibers are more robust and less likely to bounce around during treatment. The larger core diameter also helps limit fiber tip degradation during the procedure. These 550–1000 μm fibers are also used for HoLEP.

Laser fiber tips have historically been flat. When cleaved, they are cut at a right angle resulting in the flat profile of the tip. When reusable fibers are reprocessed between cases, it is common practice to cut the fiber with a sharp instrument or ceramic scissor and strip the overlying jacket before resterilization. However, with the growing number of single-use fibers, manufacturers have adopted new fiber tip designs. The most common variant now is a ball-tipped fiber (Fig. 11.22). The argument for the ball tip is that the fiber will pass through the working channel of a flexible ureteroscope more easily and will not dig in or gouge the channel. A frequent cause of ureteroscope failure are leaks, and these leaks may stem from small perforations of the working channel liner caused from puncture during the passage of the laser fiber. With a ball tip, the fiber slides through the working channel more easily and is less likely to cause such perforation. Further, a ball-tipped fiber can be advanced more easily with a flexible ureteroscope in a deflected position. This can be of benefit when a difficult-to-reach stone is located and the surgeon does not want to pull the scope back out to pass the fiber. With a ball tip, the fiber can be safely advanced without fear of damaging the channel [53].

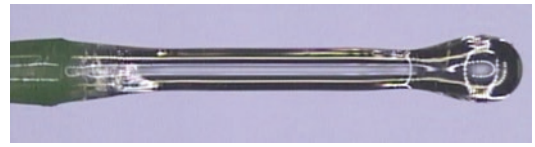

Fig. 11.22 Ball-tipped laser fiber

Fiber performance among manufacturers can vary. Prior studies have demonstrated large differences in the rate of fiber failure, especially in the deflected configuration. Many modern fibers are able to be deflected into the lower pole and function reliably, but some fibers are more prone to failing in this configuration [54]. If users are experiencing fiber failures, especially with lower pole deflection, consideration to changing to a more robust fiber should be made.

Accessory Devices

Stone Baskets

Dormia described the use of a spiral stone basket in 1982 that permitted the extraction of ureteral stones. This allowed for capturing of stone fragments for biochemical analysis, but also increased the potential for the patient to be stone free and reduced the number of fragments that needed to be passed after surgery [55]. Since the early reports of baskets, designs have changed significantly. Early baskets were composed of stainless steel, which were strong but had the drawback of not being able to be safely cut should the basket become entrapped. The introduction of baskets

composed of nitinol (nickel titanium), a soft pliable metal that has shape memory, was an advancement that increased the safety of basket use since the individual wires could be safely cut with the Ho:YAG laser should the basket become entrapped. In addition, nitinol baskets largely preserve deflection of the ureteroscope, unlike stainless steel baskets that can limit deflection by up to 79°. Nitinol baskets also allow for faster retrieval of fragments and are atraumatic to the renal papilla [56].

There are a wide variety of nitinol stone baskets commercially available for ureteroscope. When selecting a basket for ureteroscopy, a size of ≤2.0 Fr is preferred in order to not only limit deflection of a flexible ureteroscope but also to maintain reasonable irrigation flow. Numerous basket designs exist, but tipless nitinol baskets have been shown to be most effective in both the caliceal and ureteral model for retrieving and relocating stones sizes ranging from 4 to 12 mm [57]. In another study the in vitro efficacy of baskets were assessed, and again the tipless nitinol basket was deemed most efficacious for stone retrieval and release [58]. A ≤2.0 Fr tipless nitinol basket is produced by nearly every major manufacturer. While small difference exist in the designs, the overall function of these baskets are similar.

Open-ended nitinol baskets have increased in popularity in recent years. These baskets are designed to facilitate the release of a stone should it be too big to withdraw through a tight infundibulum or the ureter by having an open end. They may also assist in the removal of calculi attached to a papilla by being able to drop the basket directly over the stone and then close it to trap it. Cook produced the original open-ended basket called the NGage and is available in 1.7 and 2.2 Fr sizes. In addition, there are two models of each Fr size that differ in opening diameter (8 and 11 mm). Boston Scientific more recently released the Dakota basket which is a 1.9 Fr open-ended basket available in two opening diameters (8 and 11 mm). A unique feature of the Dakota basket is that it is able to open 39–50% wider than the NGage basket (11 and 8 mm baskets, respectively). A bench study confirmed that the greater opening diameter of the Dakota basket facilitated capture and retrieval of stone pieces ≥7 mm [59] (Fig. 11.23).

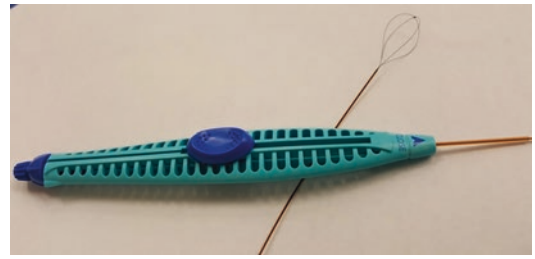

Fig. 11.23 Sacred Heart Medical Halo 1.5 Fr tipless nitinol stone basket

Guidewires

Guide wires are an essential piece of equipment and utilized in the vast majority of endourologic stone procedures including ureteroscopy and PCNL. Guide wires are used to navigate through collecting system, pass instruments safely, and function as a safety measure should a ureteral perforation, tear, or avulsion occur [60, 61]. Numerous studies have assessed the properties and safety margins of guide wires.

Most guide wires used in endourology range between a diameter of 0.035 and 0.038 inches and have a length between 140 and 150 cm. However, several characteristics distinguish them from each other. Wires have an inner core and outer surface coating the impact the properties of it, and these materials can vary between wires. Further, wires have flexible tips, but the material and length of the tip can also vary between wires. Ligouri et al. reported that guidewires with a hydrophilic tip, such as the Radifocus Guide Wire M (Terumo, Belgium) or the Sensor Dual Flex (Boston Scientific), were the least likely to cause a perforation, had the lowest withdrawal force, and were unable to be permanently distorted with bending (memory) [62] (Fig. 11.24).

Similar to stone baskets, guidewires can be composed of different materials. Many modern

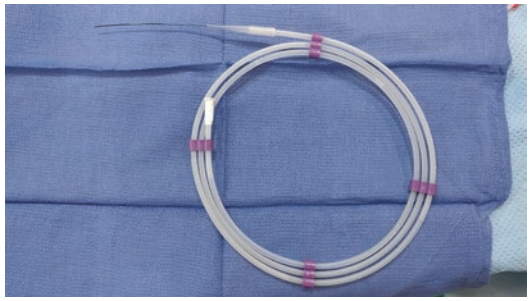

Fig. 11.24 Dual durometer guidewire with hydrophilic tip and nitinol core

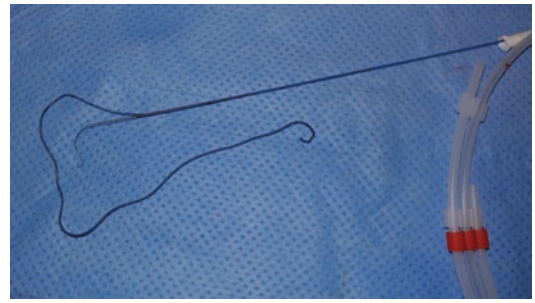

Fig. 11.25 Damaged guidewire with stainless steel core

guidewires have a core constructed from nitinol or a similar alloy. These materials allow the wire to be reasonably stiff but remain kink resistant. Kinking of a guidewire can be problematic during a procedure as it can lead to the inability to pass a catheter or stent over it and thus risk losing access.

Different guidewires may have advantages based on the properties. For example, flexible and lubricious fully hydrophilic wires, with their lower risk of perforation, may be best for initial access during PCNL or ureteroscopy, especially in situations of a tortuous or narrowed ureter, or when navigating an obstruction. However, hydrophilic wires are typically more costly than standard polytetrafluoroethylene (PTFE)-coated wires, and therefore the standard PTFE-coated guidewire could be considered for use during routine, uncomplicated procedures if cost savings is desired. Rigid wires with stainless steel cores, such as the Amplatz Super Stiff (Boston Scientific) or Amplatz Extra-Stiff (Cook Urological), are valuable for straightening a S-curved ureter or for passing balloon, UAS, and placing stents. However, they are susceptible to kinking and carry a greater risk of causing a perforation [62, 63] (Fig. 11.25). Hybrid wires, with a fully hydrophilic tip and a PTFE-coated shaft, offer increased versatility and can be used for both initial access and as a working wire [64]. Examples of hybrid wires include the Sensor (Boston Scientific), UltraTrack (Olympus Surgical), Motion (Cook Urological), Solo Hydro, and Solo Plus (Bard Medical).

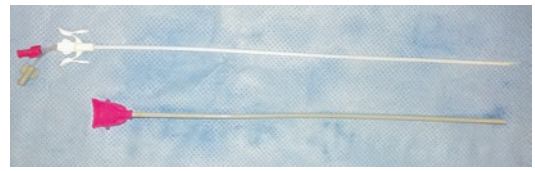

Fig. 11.26 Ureteral access sheath showing inner obturator and outer sheath

Ureteral Access Sheaths

Ureteral access sheaths (UAS) can be utilized during ureteroscopy to allow for multiple passes of the ureteroscope and facilitate basket retrieval of fragments. Other purported benefits include maintaining low intrarenal pressures and improving vision during the procedure by being able to flush out blood and/or debris [65]. It has also been reported that the use of a ureteral access sheath reduces damage to flexible ureteroscopes and decreases operative times [23, 66].

A range of UAS are commercially available. The basic designs of the sheaths are similar, with an inner obturator and then the outer sheath (Fig. 11.26). They are advanced over a guidewire into position, just below the target stone for ureteral calculi, or slightly below the ureteropelvic junction (UPJ) for renal calculi. Most sheaths are available in a range of lengths and diameters. The lengths of sheaths range from approximately 28 to 46 cm. Selecting a sheath that is too long or too short can lead to some challenges. For example, if a sheath it too long, it results in a lengthy portion of the sheath extending out the urethra, and this can make the handling of the ureteroscope

difficult. If, however, the sheath is too short, then the ureter may coapt around the ureteroscope and limit outflow of fluid and thereby negate some of the UAS's benefits. For female patients, I will typically use a 28–36 cm sheath, depending on the patient's height and ureteral length, for renal stones. For male patients, I will use a slightly longer sheath, 36–46 cm, again depending on patient's height and length of ureter. The diameter of the sheath selected depends on the size of the flexible ureteroscope. For example, a 12/14 Fr UAS will accommodate all commercially available flexible ureteroscopes, but a smaller 10/12 Fr sheath will not accommodate some of the larger digital models, or will severely limit outflow of fluid and again negate some of the UAS's purported benefits [67].

Irrigation Systems

During endourologic stone procedures, usually 0.9% saline is run through the endoscope channel into the collecting system to facilitate visualization by washing away blood, contrast, cellular and stone debris, and other material that might distort the field of view. Passive gravity is the simplest system and often adequate with larger instruments such as cystoscopes and full-sized nephroscopes. However, for smaller scopes, such as flexible ureteroscopes, a pressure irrigation system may be needed to keep the field of view clear.

Hendlin et al. compared a passive gravity system (183 cm H_2O) to a series of irrigation systems including the Peditrol foot pump (Peditrol, Durban, South Africa), Cook Medical Ureteroscopy Irrigation System (Bloomington, IN), the Irri-Flo Irrigation Delivery System (Olympus Surgical, formerly ACMI), the Single-Action-Pump (Boston Scientific), and the Universal Piggyback Irrigation System (UPIS) (Kosin Technology, Valparaiso, IN). Both retropulsion of the target stone and the ability to keep the field of view clear were evaluated. It was determined that gravity-controlled flow was the least likely to cause the stone to retropulse but may not be adequate to keep the field of view clear in some scenarios. For pressurized systems, the Cook system and the SAP were the least likely to cause retropulsion of the stone. The SAP device also required the least number of pumps (0.35/s) to keep the field of view clear [68] (Fig. 11.27).

Fig. 11.27 Single-Action Pump (SAP) handheld irrigation system

A follow-up study compared the SAP device to a foot pump irrigation system, the Flo-Assist (NuVista Medical, Cincinnati, OH). The results demonstrated that these devices required a similar number of pumps to keep the field of view clear, but the SAP was less likely to cause retropulsion [69]. One concern with the SAP system is hand fatigue during longer procedure. After 10 min of use, grip strength can diminish [70].

Automated fluid irrigation systems, such as the Thermedx FluidSmart System (Thermedx LLC, Solon, OH) and the Endoflo II (Rocamed, Monaco), allow for continuous irrigation at a set flow rate or pressure (Fig. 11.28). They also offer fluid warming capabilities, something that may be important during longer procedures with high flow rates such as PCNL for staghorn stones. In a study evaluating the Thermedx FluidSmart system, it was noted that the system underestimates the pressure at the tip of the endoscope while overestimating both the flow rates and temperatures delivered from the endoscope [71]. Ideally future refinements in these devices will overcome these limitations, as the automated system will help lessen the burden on a surgical assistant.

Pressurized irrigation systems are vital to maintaining an adequate field of view during endourologic procedures, yet care should be employed during their use as very high pressures can be generated by these devices. As previously

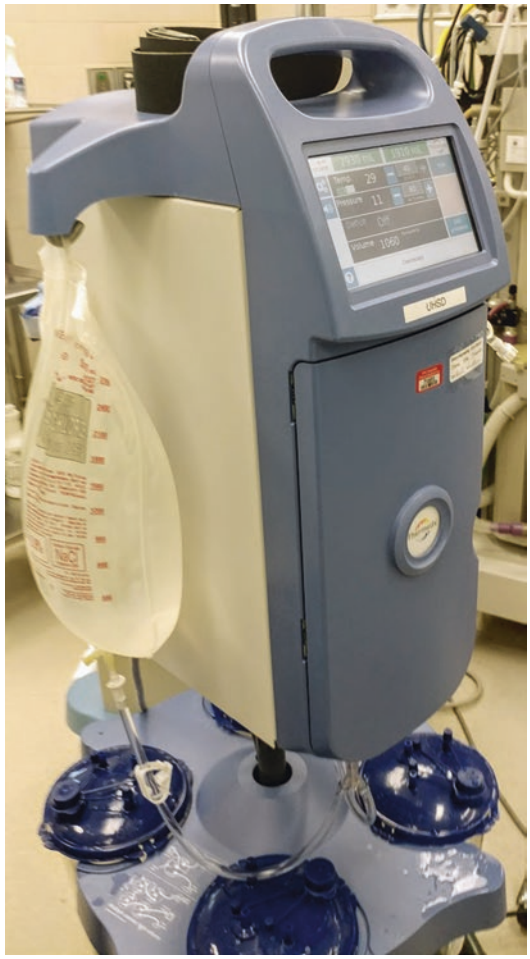

Fig. 11.28 Thermedx FluidSmart automated fluid irrigation system

discussed, the use of a UAS sheath during ureteroscopy can assist in maintaining lower intrarenal pressures. Caution should be employed when working in a closed system as currently there are not commercially available systems to monitor intrarenal pressure [65].

Conclusion

A wide variety of equipment is available for endourologic procedures. Careful thought must go into planning both capital equipment and disposable device purchases. This chapter provides an overview of available equipment and their intended uses. However, this is an ever-evolving field with new products developments occurring regularly. Ongoing education in this area will help the practicing endourologist maintain an up-to-date armamentarium to best service their patients.

References

1. Spradling K, Uribe B, Okhunov Z, Hofmann M, Del Junco M, Hwang C, et al. Evaluation of ignition and burn risk associated with contemporary fiberoptic and distal sensor endoscopic technology. J Endourol. 2015;29(9):1076–82.
2. Gono K. Narrow band imaging: technology basis and research and development history. Clin Endosc. 2015;48(6):476–80.
3. Dalgaard LP, Zare R, Gaya JM, Redorta JP, Roumiguié M, Filleron T, Malavaud B. Prospective evaluation of the performances of narrow-band imaging flexible videoscopy relative to white-light imaging flexible videoscopy, in patients scheduled for transurethral resection of a primary NMIBC. World J Urol. 2018; https://doi.org/10.1007/s00345-018-2537-7. [Epub ahead of print].
4. Kim SB, Yoon SG, Tae J, Kim JY, Shim JS, Kang SG, et al. Detection and recurrence rate of transurethral resection of bladder tumors by narrow-band imaging: prospective, randomized comparison with white light cystoscopy. Investig Clin Urol. 2018;59(2):98–105.
5. Daneshmand S, Bazargani ST, Bivalacqua TJ, Holzbeierlein JM, Willard B, Taylor JM, Blue Light Cystoscopy with Cysview Registry Group, et al. Blue light cystoscopy for the diagnosis of bladder cancer: results from the US prospective multicenter registry. Urol Oncol. 2018;36(8):361.e1–6.
6. Andonian S, Okeke Z, Anidjar M, Smith AD. Digital nephroscopy: the next step. J Endourol. 2008;22(4):601–2.
7. Jackman SV, Docimo SG, Cadeddu JA, Bishoff JT, Kavoussi LR, Jarrett TW. The "mini-perc" technique: a less invasive alternative to percutaneous nephrolithotomy. World J Urol. 1998;16(6):371–4.
8. Grasso M, Bagley D. Small diameter, actively deflectable, flexible ureteropyeloscopy. J Urol. 1998;160(5):1648–53; discussion 1653–54.
9. Sofer M, Denstedt J. Flexible ureteroscopy and lithotripsy with the Holmium:YAG laser. Can J Urol. 2000;7(1):952–6.
10. also M, Proietti S, Emiliani E, Gallioli A, Dragos L, Orosa A, et al. Comparison of flexible ureterorenoscope quality of vision: an in vitro study. J Endourol. 2018;32(6):523–8.
11. Huynh M, Telfer S, Pautler S, Denstedt J, Razvi H. Retained digital flexible ureteroscopes. J Endourol Case Rep. 2017;3(1):24–7.

12. Reisiger K, Hruby G, Clayman RV, Landman J. Office-based surveillance ureteroscopy after endoscopic treatment of transitional cell carcinoma: technique and clinical outcome. Urology. 2007;70(2):263–6.
13. Humphreys MR, Miller NL, Williams JC Jr, Evan AP, Munch LC, Lingeman JE. A new world revealed: early experience with digital ureteroscopy. J Urol. 2008;179(3):970–5.
14. Aslan P, Kuo RL, Hazel K, Babayan RK, Preminger GM. Advances in digital imaging during endoscopic surgery. J Endourol. 1999;13(4):251–5.
15. Shah K, Monga M, Knudsen B. Prospective randomized trial comparing 2 flexible digital ureteroscopes: ACMI/Olympus Invisio DUR-D and Olympus URF-V. Urology. 2015;85(6):1267–71.
16. Dragos LB, Somani BK, Sener ET, Buttice S, Proietti S, Ploumidis A, et al. Which flexible ureteroscopes (digital vs. fiber-optic) can easily reach the difficult lower pole calices and have better end-tip deflection: in vitro study on K-Box. A PETRA evaluation. J Endourol. 2017;31(7):630–7.
17. Multescu R, Geavlete B, Georgescu D, Geavlete P. Conventional fiberoptic flexible ureteroscope versus fourth generation digital flexible ureteroscope: a critical comparison. J Endourol. 2010;24(1):17–21.
18. Somani BK, Al-Qahtani SM, de Medina SD, Traxer O. Outcomes of flexible ureterorenoscopy and laser fragmentation for renal stones: comparison between digital and conventional ureteroscope. Urology. 2013;82(5):1017–9.
19. Binbay M, Yuruk E, Akman T, Ozgor F, Seyrek M, Ozkuvanci U, et al. Is there a difference in outcomes between digital and fiberoptic flexible ureterorenoscopy procedures? J Endourol. 2010;24(12):1929–34.
20. Alexander B, Fishman AI, Grasso M. Ureteroscopy and laser lithotripsy: technologic advancements. World J Urol. 2015;33(2):247–56.
21. Talso M, Emiliani E, Haddad M, Berthe L, Baghdadi M, Montanari E, Traxer O. Laser fiber and flexible ureterorenoscopy: the safety distance concept. J Endourol. 2016;30(12):1269–74.
22. Afane JS, Olweny EO, Bercowsky E, Sundaram CP, Dunn MD, Shalhav AL, et al. Flexible ureteroscopes: a single center evaluation of the durability and function of the new endoscopes smaller than 9Fr. J Urol. 2000;164(4):1164–8.
23. Pietrow PK, Auge BK, Delvecchio FC, Silverstein AD, Weizer AZ, Albala DM, Preminger GM. Techniques to maximize flexible ureteroscope longevity. Urology. 2002;60(5):784–8.
24. Knudsen B, Miyaoka R, Shah K, Holden T, Turk TM, Pedro RN, et al. Durability of the next-generation flexible fiberoptic ureteroscopes: a randomized prospective multi-institutional clinical trial. Urology. 2010;75(3):534–8.
25. Kramolowsky E, McDowell Z, Moore B, Booth B, Wood N. Cost analysis of flexible ureteroscope repairs: evaluation of 655 procedures in a community-based practice. J Endourol. 2016;30(3):254–6.
26. Dale J, Kaplan AG, Radvak D, Shin R, Ackerman A, Chen T, et al. Evaluation of a novel single-use flexible ureteroscope. J Endourol. 2017. https://www.ncbi.nlm.nih.gov/pubmed/27981862?report=docsum
27. Scotland KB, Chan JYH, Chew BH. Single-use flexible ureteroscopes: how do they compare with reusable ureteroscopes? J Endourol. 2019;33(2):71–8.
28. Usawachintachit M, Isaacson DS, Taguchi K, Tzou DT, Hsi RS, Sherer BA, et al. A prospective case-control study comparing LithoVue, a single-use, flexible disposable ureteroscope, with flexible, reusable fiberoptic ureteroscopes. J Endourol. 2017;31(5):468–75.
29. Martin CJ, McAdams SB, Abdul-Muhsin H, Lim VM, Nunez-Nateras R, Tyson MD, Humphreys MR. The economic implications of a reusable flexible digital ureteroscope: a cost-benefit analysis. J Urol. 2017;197(3 Pt 1):730–5.
30. Taguchi K, Usawachintachit M, Tzou DT, Sherer BA, Metzler I, Isaacson D, et al. Micro-costing analysis demonstrates comparable costs for lithovue compared to reusable flexible fiberoptic ureteroscopes. J Endourol. 2018;32(4):267–73.
31. Denstedt JD, Eberwein PM, Singh RR. The Swiss Lithoclast: a new device for intracorporeal lithotripsy. J Urol. 1992;148(3 Pt 2):1088–90.
32. Denstedt JD, Razvi HA, Rowe E, Grignon DJ, Eberwein PM. Investigation of the tissue effects of a new device for intracorporeal lithotripsy--the Swiss Lithoclast. J Urol. 1995;153(2):535–7.
33. Lowe G, Knudsen BE. Ultrasonic, pneumatic and combination intracorporeal lithotripsy for percutaneous nephrolithotomy. J Endourol. 2009;23(10):1663–8.
34. Terhorst B. The effect of electrohydraulic waves and ultrasound on the urothelium. Urologe A. 1975;14(1):41–5. *[Article in German].*
35. Borofsky MS, El Tayeb MM, Paonessa JE, Lingeman JE. Initial experience and comparative efficacy of the UreTron: a new intracorporeal ultrasonic lithotriptor. Urology. 2015;85(6):1279–83.
36. Pietrow PK, Auge BK, Zhong P, Preminger GM. Clinical efficacy of a combination pneumatic and ultrasonic lithotrite. J Urol. 2003;169(4):1247–9.
37. Lehman DS, Hruby GW, Phillips C, Venkatesh R, Best S, Monga M, Landman J. Prospective randomized comparison of a combined ultrasonic and pneumatic lithotrite with a standard ultrasonic lithotrite for percutaneous nephrolithotomy. J Endourol. 2008;22(2):285–9.
38. York NE, Borofsky MS, Chew BH, Dauw CA, Paterson RF, Denstedt JD, et al. Randomized controlled trial comparing three different modalities of lithotrites for intracorporeal lithotripsy in percutaneous nephrolithotomy. J Endourol. 2017;31(11):1145–51.
39. Chew BH, Matteliano AA, de Los Reyes T, Lipkin ME, Paterson RF, Lange D. Benchtop and initial clinical evaluation of the ShockPulse stone eliminator in percutaneous nephrolithotomy. J Endourol. 2017;31(2):191–7.
40. Carlos EC, Wollin DA, Winship BB, Jiang R, Radvak D, Chew BH, et al. In vitro comparison of a novel sin-

gle probe dual-energy lithotripter to current devices. J Endourol. 2018;32(6):534–40.
41. Sofer M, Watterson JD, Wollin TA, Nott L, Razvi H, Denstedt JD. Holmium:YAG laser lithotripsy for upper urinary tract calculi in 598 patients. J Urol. 2002;167(1):31–4.
42. Vassar GJ, Chan KF, Teichman JM, Glickman RD, Weintraub ST, Pfefer TJ, Welch AJ. Holmium:YAG lithotripsy: photothermal mechanism. J Endourol. 1999;13(3):181–90.
43. Fraundorfer MR, Gilling PJ. Holmium:YAG laser enucleation of the prostate combined with mechanical morcellation: preliminary results. Eur Urol. 1998;33(1):69–72.
44. Finley DS, Petersen J, Abdelshehid C, Ahlering M, Chou D, Borin J, et al. Effect of holmium:YAG laser pulse width on lithotripsy retropulsion in vitro. J Endourol. 2005;19(8):1041–4.
45. Doizi S, Keller EX, De Coninck V, Traxer O. Dusting technique for lithotripsy: what does it mean? Nat Rev Urol. 2018;15(11):653–4.
46. Becker B, Gross AJ, Netsch C. Safety and efficacy using a low-powered holmium laser for enucleation of the prostate (HoLEP): 12-month results from a prospective low-power HoLEP series. World J Urol. 2018;36(3):441–7.
47. Kuo RL, Paterson RF, Kim SC, Siqueira TM Jr, Elhilali MM, Lingeman JE. Holmium laser enucleation of the prostate (HoLEP): a technical update. World J Surg Oncol. 2003;1(1):6.
48. Wollin DA, Ackerman A, Yang C, Chen T, Simmons WN, Preminger GM, Lipkin ME. Variable pulse duration from a new holmium:YAG laser: the effect on stone comminution, fiber tip degradation, and retropulsion in a dusting model. Urology. 2017;103:47–51.
49. Elhilali MM, Badaan S, Ibrahim A, Andonian S. Use of the Moses technology to improve holmium laser lithotripsy outcomes: a preclinical study. J Endourol. 2017;31(6):598–604.
50. Winship B, Wollin D, Carlos E, Li J, Peters C, Simmons WN, et al. Dusting efficiency of the Moses holmium laser: an automated in vitro assessment. J Endourol. 2018;32(12):1131–5.
51. Stern KL, Monga M. The Moses holmium system – time is money. Can J Urol. 2018;25(3):9313–6.
52. Marks AJ, Mues AC, Knudsen BE, Teichman JM. Holmium:yttrium-aluminum-garnet lithotripsy proximal fiber failures from laser and fiber mismatch. Urology. 2008;71(6):1049–51.
53. Carlos EC, Li J, Young BJ, Radvak D, Wollin DA, Winship BB, et al. Let's get to the point: comparing insertion characteristics and scope damage of flat-tip and ball-tip holmium laser fibers. J Endourol. 2019;33(1):22–6.
54. Akar EC, Knudsen BE. Evaluation of 16 new holmium:yttrium-aluminum-garnet laser optical fibers for ureteroscopy. Urology. 2015;86(2):230–5.
55. Dormia E. Dormia basket: standard technique, observations, and general concepts. Urology. 1982;20(4):437.
56. Honey RJ. Assessment of a new tipless nitinol stone basket and comparison with an existing flat-wire basket. J Endourol. 1998;12(6):529–31.
57. Chenven ES, Bagley DH. Retrieval and releasing capabilities of stone-basket designs in vitro. J Endourol. 2005;19(2):204–9.
58. Zeltser IS, Bagley DH. Basket design as a factor in retention and release of calculi in vitro. J Endourol. 2007;21(3):337–42.
59. Bechis SK, Abbott JE, Sur RL. In vitro head-to-head comparison of the durability, versatility and efficacy of the NGage and novel Dakota stone retrieval baskets. Transl Androl Urol. 2017;6(6):1144–9.
60. Torricelli FC, Marchini GS, Pedro RN, Monga M. Ureteroscopy for management of stone disease: an up to date on surgical technique and disposable devices. Minerva Urol Nefrol. 2016;68(6):516–26.
61. Türk C, Petřík A, Sarica K, Seitz C, Skolarikos A, Straub M, Knoll T. EAU Guidelines on Interventional Treatment for Urolithiasis. Eur Urol. 2016;69(3):475–82.
62. Liguori G, Antoniolli F, Trombetta C, Biasotto M, Amodeo A, Pomara G, et al. Comparative experimental evaluation of guidewire use in urology. Urology. 2008;72(2):286–9; discussion 289–90.
63. Clayman M, Uribe CA, Eichel L, Gordon Z, McDougall EM, Clayman RV. Comparison of guide wires in urology. Which, when and why? J Urol. 2004;171(6 Pt 1):2146–50.
64. Torricelli FC, De S, Sarkissian C, Monga M. Hydrophilic guidewires: evaluation and comparison of their properties and safety. Urology. 2013;82(5):1182–6.
65. Auge BK, Pietrow PK, Lallas CD, Raj GV, Santa-Cruz RW, Preminger GM. Ureteral access sheath provides protection against elevated renal pressures during routine flexible ureteroscopic stone manipulation. J Endourol. 2004;18(1):33–6.
66. Kourambas J, Byrne RR, Preminger GM. Does a ureteral access sheath facilitate ureteroscopy? J Urol. 2001;165(3):789–93.
67. Al-Qahtani SM, Letendre J, Thomas A, Natalin R, Saussez T, Traxer O. Which ureteral access sheath is compatible with your flexible ureteroscope? J Endourol. 2014;28(3):286–90.
68. Hendlin K, Weiland D, Monga M. Impact of irrigation systems on stone migration. J Endourol. 2008;22(3):453–8.
69. Hendlin K, Sarkissian C, Duffey B, Monga M. Systematic evaluation of a novel foot-pump ureteroscopic irrigation system. J Endourol. 2012;26(2):126–9.
70. Tarplin S, Byrne M, Farrell N, Monga M, Sivalingam S. Endoscopic valves and irrigation devices for flexible ureteroscopy: is there a difference? J Endourol. 2015;29(9):983–92.
71. De S, Torricelli FC, Sarkissian C, Kartha G, Monga M. Evaluating the automated Thermedx Fluid Management System in a ureteroscopy model. J Endourol. 2014;28(5):549–53.

12 Percutaneous Management of Large Renal Calculi (Percutaneous Nephrolithotomy)

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Percutaneous nephrolithotomy (PCNL) is the standard of care for large (>2 cm) renal calculi and has a wide breadth of other indications including the treatment of lower pole stones larger than 10 millimeters, the treatment of stones without available retrograde access, and the percutaneous access may be used in the treatment of upper tract urothelial carcinoma [1]. PCNL requires specialized instrumentation and a unique surgical skill set covering such broad topics as intraoperative imaging, percutaneous access, endoscopic manipulation, and intracorporeal lithotripsy.

Exclusions from PCNL

PCNL is contraindicated in those who cannot undergo general anesthesia, patients who are pregnant, and patients who are anticoagulated and cannot stop anticoagulation in the perioperative period. PCNL has been shown to be safe in patients who continue on a low-dose aspirin [2]. Those with poor respiratory function may not tolerate the prone position or be able to tolerate the small risk of pneumothorax/hydrothorax associated with securing percutaneous access to the kidney. All patients should have a urine culture completed prior to surgery, and PCNL should only be performed after appropriate treatment of urinary tract infections.

Positioning

Positioning is generally surgeon-dependent. Initial access to the upper tract is gained with the patient either in the supine, lateral, or prone split leg position. If necessary, the patient is then moved to a different position, and percutaneous access is obtained. Recent meta-analysis of supine versus prone position for PCNL found that the stone-free rate was superior in the prone position; however, the prone position was associated with a longer operative time and higher blood transfusion rate [3]. Benefits of supine surgery are reported to include improved patient and surgeon comfort, lower intrarenal pressures, better renal drainage, and easily accessible urethral meatus [4]. Advantages of prone access include improved access to multiple calyces, better scope manipulation, improved collecting system distention, and shorter tract lengths [5].

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S. L. Best, S. Y. Nakada (eds.), *Minimally Invasive Urology*,
https://doi.org/10.1007/978-3-030-23993-0_12

Percutaneous Access

The most common strategies to gaining renal access are ultrasound-guided and fluoroscopic-guided. A recent meta-analysis comparing ultrasound-guided access and fluoroscopic-guided access found comparable stone-free rates and a lower complication rate with ultrasound-guided access [6]. One clear advantage of ultrasound-guided access is the ability to visualize other organs such as the pleura and colon and avoid inadvertent puncture [7].

There are several different ways to approach gaining fluoroscopic access, including triangulation, bull's-eye, retrograde percutaneous, and endoscopic-assisted. Retrograde pyelograms, using contrast and/or air, are used with all methods other than endoscopic-assisted access. The triangulation technique uses two fluoroscopic planes to align the access needle with the appropriate calyx while avoiding the overlying ribs. Using the initial pyelogram, the anterioposterior (AP) orientation of the intensifier dictates the medial limit of the needle. Two more locations are selected at right angles (lateral and inferior to the initial position), and the intersection of all three points estimates the required trajectory of the needle. The bull's-eye approach uses the AP position of the C-arm to establish needle tip position overlying the appropriate calyx. The C-arm is then rotated approximately 30° away from the surgeon and advanced toward the endoscope using the fluoroscopy to guide the depth of needle insertion. The retrograde approach utilizes a steerable catheter positioned under fluoroscopic or ureteroscopic guidance. A puncture wire is then advanced (retrograde) through the calyx, renal parenchyma, and retroperitoneum, and out to the skin for through-and-through access.

For all patients anatomic variations should be considered, and the position of the retrorenal colon or spleen or liver, pelvic kidneys, horseshoe kidneys, and crossed fused ectopia should alert the urologist to consider ultrasound- or CT-guided nephrostomy tube placement with the help of interventional radiology, so as to minimize the risk of inadvertent organ or vascular injury.

Tract Size

Standard rigid nephroscopes are 26 Fr and utilize a 30 Fr working sheath for adequate manipulation and drainage. Recently, a significant amount of interest has been placed in mini-percs and micro-percs. Reducing the working tract to 22 Fr or smaller, mini-percs have been widely used in the pediatric and adult population, particularly in geographical locations where access to flexible ureteroscopy and/or SWL may be limited. Porcine studies evaluating renal scarring after 30 Fr and 11 Fr sheath insertion showed no significant differences in surgical morbidity or histopathology [8]. Another porcine study showed higher intrarenal pressures and increased bacterial seeding in the spleen and liver in the setting of an infected collecting system with a 16 Fr tract versus a 30 Fr tract [9]. A recent meta-analysis comparing PCNL (both standard and minimally invasive PCNL) with retrograde intrarenal surgery found that mini-PCNL is less effective at clearing stones than ureteroscopy, while standard PCNL maintains the highest stone-free rate [10].

Endoscopic-Guided Percutaneous Nephrolithotomy[1]

Equipment List

- C-arm and monitor
- Cystoscopy video tower
- Fluoroscopy-compatible OR table
- Steris split leg extensions
- Wall suction
- Adjustable height irrigation stands with pressure bags or automatic pressure device

Cystoscopy

- 20 Fr rigid cystoscope (women)
- 17 Fr flexible cystoscope (men)
- Endoscopy camera

[1]This equipment list contains specific equipment, disposables, along with trade names, used in our practice. Other types of wires, lithotripsy devices, and other disposables are available and may function equivalently.

- Bard SOLO guidewire (0.035", 150 cm, Bard Medical, Covington, GA)
- Cook 6/10 Fr dual-lumen catheter (50 cm, Cook Medical LLC, Bloomington, IN)
- Olympus Amplatz Super Stiff guidewire (0.038", 150 cm, Olympus, Tokyo, Japan)

Flexible Ureteroscopy

- Flexible ureteroscope
- Adjustable biopsy port seal (Gyrus ACMI)
- Single-action pump (Boston Scientific, Marlborough, MA)
- Ureteral access sheath (Boston Scientific Navigator™ HD)
  - 28 cm or 36 cm length (females)
  - 36 cm or 46 cm length (males)
  - 11/13 Fr or 13/15 Fr depending on caliber of ureter
- Nitinol basket (Halo, Sacred Heart Medical, Minnetonka, MN)

Percutaneous Access with Through-and-Through Safety Wire

- Boston Scientific Chiba needle (18 gauge, 20 cm)
- Cook Amplatz Needle Holder
- Olympus Bentson guidewire, 15 cm flex tip (0.035", 150 cm)
- 5 Fr open-ended ureteric catheter
- X-Force balloon dilator (30 Fr, Bard Medical)

Stone Fragmentation

- Rigid nephroscope (25 cm length, Richard Wolf, Vernon Hills, IL)
- Flexible cystonephroscope
- ShockPulse-SE (Olympus)
- 120 W holmium:YAG laser with 200 um laser fibers

Stone Capture Devices

- Perc NCircle (12 Fr, 38 cm, Cook Medical)
- 2-prong reusable graspers
- Cook N-Circle (4.5 Fr) (for flexible cystonephroscope)
- Sacred Heart Halo (1.5 Fr) (for cystonephroscope and antegrade ureteroscopy)

Tubeless Drainage

- Double-J ureteric catheter (7 Fr)
- 2-O Prolene suture
- 18 Fr Foley catheter (coude tip for men)

Procedure

Step 1: Positioning and Setup
(Fig. 12.1)

The patient is brought into the operating room, and general anesthesia is induced by the anesthesia team prior to moving the patient to the surgical table. Once under general anesthesia, with the endotracheal tube secured appropriately, the patient is flipped prone on to the OR table (which is positioned to accommodate a mobile C-arm unit and split leg extensions). The patient is positioned so that the genitalia are freely accessible at the edge of the bed. Arms are brought up to the superman position on arm boards maintaining an axillary angle of <90° with appropriate axillary padding to avoid brachial plexus injury. The head is maintained with neutral positioning of the C-spine, using a foam face pad. Increased ocular pressures are to be avoided, and the endotracheal tube needs to be well seated and secured during any repositioning. Legs are loosely fixed to the split leg extensions using 2 inch broad silk tape and towels to avoid skin abrasions. The legs are then abducted to 30°.

Two chest rolls are placed longitudinally along the anterior axillary line. The diameter of these rolls should allow for a neutral C-spine positioning, and the breasts are to be placed medially. Placing rolls too medially under the abdomen may cause the colon to be forced posteriorly, potentially increasing the risk of bowel injury during renal access. All pressure points are padded, and pneumatic stockings are maintained for anti-embolic prophylaxis.

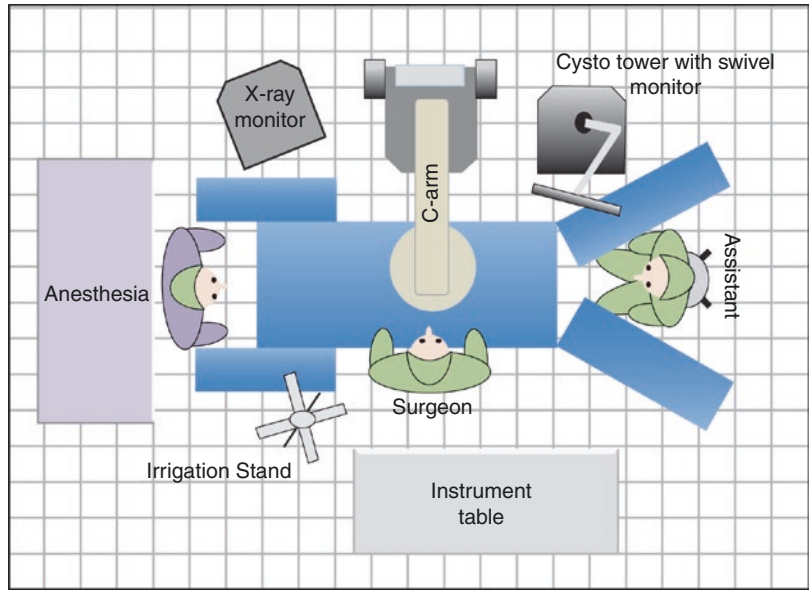

Fig. 12.1 Bird's-eye view of the surgical suit equipment and personnel setup

Once the patient is positioned, the table is placed in a mild Trendelenburg to keep the patient's back parallel to the floor, ensuring AP imaging is not distorted. The genitals, perineum, and flank are prepped widely, and percutaneous nephrolithotomy drapes are placed over the flank, with leg drapes covering the split leg extensions. The flank catch pouch is fixed to suction, and a receptacle is placed on the floor under the genitals to catch irrigation.

On the contralateral side of the patient, the fluoroscopy screen is at shoulder level, with the C-arm aligned with the respective flank. The endoscopic tower is aligned with the patient's thigh and initially directed toward the operator seated to perform the initial cystoscopy. The monitor is adjusted to an ergonomic position to avoid neck strain, in either the sitting or standing position. The camera and light cord are secured to the drape, and typically only one tower provides visualization for the initial cystoscopy, flexible ureteroscopy, and PCNL (see Fig. 12.1). The irrigation stand is placed at the patient's ipsilateral shoulder, and tubing is fixed to the drape and brought down to the cystoscope. Extra suction tubing is maintained on field for use during ultrasonic lithotripsy.

Step 2: Prone Cystoscopy and Ureteroscopy

A cystoscopy is initially required to survey the bladder, trigonal anatomy, and to place guidewires. Rigid cystoscopy (20 Fr cystoscope, 30° lens) can be used in women, while men require a flexible cystoscopy in the prone position. It is important to clear air from the tubing as this will rise to the trigone in the prone position and obscure the ureteral orifices.

If the patient is pre-stented, a stent grasper is used to deliver the distal curl to the meatus, at which point it may be used to place the initial guidewire. If the initial survey shows significant mucosal edema or inflammation or stent incrustation, a guidewire may be placed alongside the stent prior to removal.

The ureteric orifice will be located superior-lateral when the patient is prone. By starting at the bladder neck 12 o'clock position then sweeping laterally, the ureteric ridge can be followed to the 2 and 8 o'clock positions where the ureteral orifice will generally be encountered. With previous bladder neck or prostate surgery, prolapse, and benign prostatic hypertrophy (BPH), the ureteric orifices may not be in the expected positions.

Careful observation for urine jets or the administration of intravenous indigo carmine or methylene blue may help identify the ureteral orifice.

Once the ureteric orifice is identified, a SOLO guidewire is advanced to the level of the kidney using fluoroscopic confirmation. A 10 Fr dual-lumen catheter is then advanced over the guidewire to the proximal ureter to introduce an Amplatz Super Stiff guidewire while providing mild dilation of the ureter. During advancement, one may appreciate a "tight" ureter, which can help in selecting the appropriate ureteric access sheath diameter.

Once both wires are placed, the SOLO wire is maintained as a safety wire and fixed to the drape using a hemostat. The stiff wire becomes the working wire, and it is important to fluoroscopically ensure that the metal wire core extends past the point to which the ureteric access sheath needs to travel.

The size of the sheath selected should be tailored to the patient. Optimal length would place the tip of the sheath in the proximal ureter, without too much excess sheath protruding from the urethral meatus. With proper placement, the maximal amount of ureteral mucosa is protected, and renal drainage of irrigation and stone fragments is achieved. The optimal length of the access sheath can be estimated using the amount of the dual access catheter outside of the patient when the tip is in the proximal ureter during the prior step. Pre-stented ureters can usually accommodate a 13/15 Fr sheath. If the patient was not previously stented, most ureters accommodate 11/13 Fr, though a small number of patients require even smaller sheaths (9.5/11.5 Fr). It is important to be cognizant of the external diameter of your flexible ureteroscope prior to access sheath selection, as not all scopes will fit the smallest diameter access sheaths.

With the working stiff wire in position, the ureteric access sheath is advanced to the proximal ureter. The inner dilator and sheath are assembled, so both are seated properly, and the outer surface is wetted to activate the hydrophilic coating to decrease resistance. Back-loading the sheath over the working wire (with the penis outstretched in men), a change in resistance may be met at the membranous urethra and the ureteric orifice. Fluoroscopy should be used during advancement if resistance is encountered and as the sheath approaches the renal pelvis. If the smallest available sheath will not advance, consider secondary manipulations such as sequential dilation with the inner sheath, balloon dilation, JJ stent insertion, and passive dilation, advancing the ureteroscope over a wire, or an alternative access strategy (fluoroscopy or ultrasound guided).

Once the sheath is placed, the dilator and stiff wire are removed. Flexible ureteroscopy is then performed using intermittent pressure irrigation via a single-action pump. This allows visualization of the relationship of the stone burden to the calyceal anatomy. Stones can be basketed and repositioned prior to gaining percutaneous access, so as to minimize the number of renal access sites and optimize the selection of the access site least likely to be associated with risk of complication or interference from the overlying ribs. Stones can also be lasered to clear a path to an appropriate calyx. On occasions, small stone collections (often appearing as large single stones on imaging) can be removed ureteroscopically, potentially sparing a puncture.

The ureteroscope is manipulated into a posterior calyx to prepare for puncture. Air bubbles can confirm a posterior position. Intermittent fluoroscopy is performed to find a calyx with the straightest trajectory of the scope.

Renal Puncture and Access

Once the appropriate calyx has been selected, the tip of the scope is held steady against the center of the papilla by an assistant. The fluoroscopic image is rotated so that the patient's spine is at the top of the screen, which allows for more intuitive needle movements in relation to the fluoroscopic image. The C-arm is rotated until the tip of the ureteroscope is seen "end-on," confirming that the bull's-eye tract will be in line with the tip of the calyx. With an upper pole puncture, the C-arm is AP for the initial needle manipulation. If the calyx is obscured by an overlying rib, the

C-arm can be rotated superiorly or inferiorly to throw the projection of the calculus above or below the rib, respectively, or a different calyx can be selected.

The tip of a Chiba needle is then positioned (using a needle holder) in line with the tip of the scope (under fluoroscopy, on expiration). The shaft of the needle is then manipulated so its trajectory is in line with the C-arm and scope tip forming a bull's-eye. Once this angle is established, it is maintained, and anesthesia is directed to hold respirations. The needle is advanced through the skin, and the C-arm is rotated toward the radiology technician to get an oblique view to monitor the depth of advancement of the needle as it approaches the tip of the ureteroscope. Once the needle appears to meet the scope on fluoroscopy (Fig. 12.2), anesthesia can resume ventilation, and the assistant inspects the calyx and identifies the tip of the needle endoscopically.

The inner stylet of the needle is removed, and irrigation effluxes from the needle hub. While maintaining the needle tip under direct vision, a Bentson wire is advanced through the Chiba needle, and a Halo basket (Sacred Heart Medical) is advanced through the working channel of the ureteroscope and used to grasp the wire. The wire is then pulled down the ureter and sheath to the urethral meatus for through-and-through access.

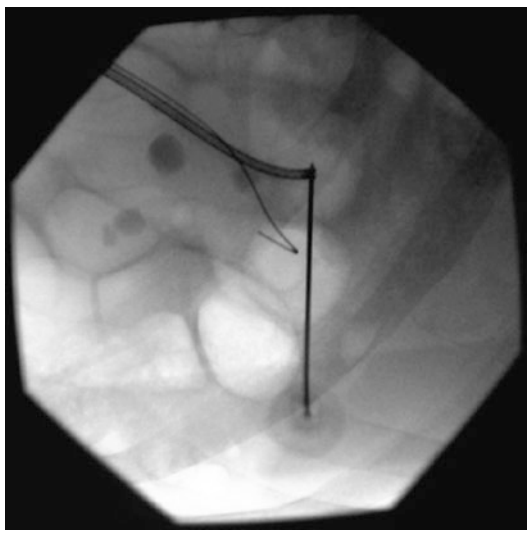

Fig. 12.2 Fluoroscopic view of percutaneous access

Once at the urethral meatus, the wire is held by the assistant under tension, and a 2 mm skin incision is made at the needle site to accommodate antegrade advancement of a 5 Fr open-ended ureteric catheter. This catheter is used to replace the Bentson wire with the super stiff guidewire. The tip of the stiff wire that extends out of the urethral meatus is secured with a hemostat, which is then left to dangle to gravity.

Tract Dilation

With the stiff wire in place, a 10 mm skin incision is made, and the 15 cm balloon dilator is advanced over the wire (with the preloaded 30 Fr working sheath). The ureteroscope is returned to the selected calyx, and the tip of the dilator is observed entering the collecting system. Direct visualization of the dilation ensures that the balloon is not placed too deep (injuring the collecting system) or too shallow (requiring a second dilation). Using the Bard X-Force, dilation to 30ATM is performed.

Once the balloon is adequately inflated, the sheath is advanced in a gentle forward twisting motion while holding the balloon to avoid inadvertent advancement. The sheath is identified ureteroscopically, and the bevel rotated to the optimal position. The ureteroscope is then removed, leaving the access sheath in place to drain the kidney during nephroscopy. The stiff wire is secured with a heavy Kelly clamp. The rigid nephroscope, without its outer sheath, is then inserted after removal of the dilating balloon. A combination of irrigation and suction is used to clear any clots that may have been created with tract dilation (Fig. 12.3).

Lithotripsy and Tubeless Technique

Rigid nephroscopy is then performed, aided by the knowledge gained by ureteroscopy of where the majority of the stone burden will be encountered. Stones <1 cm can be grasped and removed through the sheath, typically with the Perc NCircle disposable grasper.

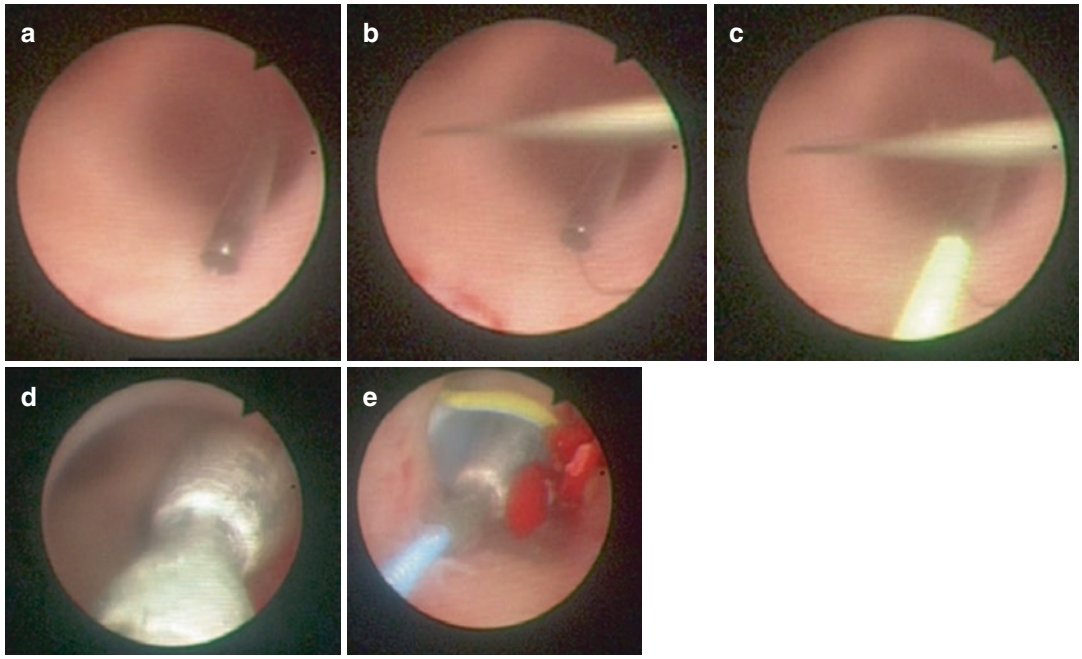

Fig. 12.3 Endoscopic view of percutaneous access: (**a**) needle piercing selected papilla, (**b**) deploying endoscopic basket, (**c**) guidewire placed through needle and grasped by basket, (**d**) visualization of balloon dilator placement and inflation, and (**e**) sheath placement

If fragmentation is required, the Olympus ShockPulse is utilized to pulverize and suction the stone. The hand piece allows the operating surgeon to control the level of the ultrasonic lithotripsy (low vs. high) and the amount of suction. Once all stones accessible with the rigid nephroscope are treated, systematic nephroscopy with the flexible cystonephroscope is performed. Any stones visualized are extracted with the Halo basket or 4.5 Fr NCircle basket. If there are multiple small stones, the NCompass basket may be utilized. Any stones too large to extract with a basket and only accessible with the flexible scope should be fragmented with the holmium laser than extracted.

If a calyx is unreachable by flexible nephroscopy, a guidewire or basket can be advanced into the calyx like a filiform to help guide the tip to the target. The scope can be turned upside down (leaving the camera in the original orientation), as many scopes have a tighter radius for upward deflection. Flexible antegrade or retrograde ureteroscopy can also be performed as the access sheath maintains easy ureteral access. If stones are located in these difficult areas, laser lithotripsy can be performed, or the stone can be moved ureteroscopically to a location more accessible for nephroscopic extraction.

Once the upper tract is deemed clear on visual inspection, fluoroscopy is used on high magnification. With the upper tract cleared, the stiff wire is removed, and antegrade flexible ureteroscopy is performed as the ureteral access sheath is removed under vision to identify any fragments in the ureter that require basket extraction and to assess the ureter for mucosal injuries or perforations.

We perform a “tubeless approach” with a double-J ureteric stent for 5–7 days. If there is significant impaction with a ureteral calculus or a high grade injury from the ureteral access sheath, the stent is left for 10–14 days. The stent is placed in a retrograde fashion over the SOLO wire, and placement is fluoroscopically confirmed. If the stent needs to be manipulated, it can be done so with graspers and the rigid nephroscope. An 18 Fr

Foley (coude for males) is placed. The nephrostomy sheath is removed, and a vertical mattress suture with a 2–0 prolene is placed in the skin to approximate the edges, and a Primapore dressing is placed. The suture is removed at the time of stent removal, and the Foley is generally removed 24–48 hours postoperative.

Complications (Table 12.1)

The most common complications from PCNL are fever and bleeding. A global study using the Clinical Research Office of Endourology (CROES) database identified complications in 20.5% of 5724 patients, though 80% were considered minor [11]. The rate of posteropative fever/infection is reported to be 10.5% and the transfusion rate 5.7% [12]. Risk factors for increasing the severity of complications included American Society of Anesthesia (ASA) scores, use of anticoagulation, positive urine culture, and presence of cardiovascular disease [11].

We prefer upper pole access, when possible, and often this is obtained via a supracostal puncture. We looked at 375 patients who underwent supracostal upper pole access and found a 4% rate of chest complications requiring a postoperative thoracentesis or chest tube insertion [13]. This is similar to the 5.8% rate of hydrothorax reported by the CROES group when specifically evaluating upper pole access [14]. Our transfusion rate for a supracostal puncture was 6.7% overall, but only 5.1% in patients with a normal hemoglobin above 10 mg/dL, which is consistent with the prior data reported above [12, 13].

Table 12.1 Most common complications of PCNL procedure

Complication type	Incidence
Bleeding requiring transfusion	5.7%
Infection	10.5%
Pulmonary complication (upper pole access)	5.8% hydrothorax, 4% intervention (thoracentesis, chest tube)

Conclusion

Many alternatives exist with regard to patient positioning and method of gaining renal access. The prone split leg position facilitates endoscopic-guided access, which places the control in the hands of the urologist, irrespective of level of training in fluoroscopic techniques. The accuracy of access into the tip of the most appropriate calyx improves outcomes and decreases the need for secondary procedures.

References

1. American Urological Association. Endourological Society. Surgical Management of Stones: AUA/Endourology Society Guideline 2016. [Online]. http://www.auanet.org/guidelines/surgical-management-of-stones-(aua/endourological-society-guideline-2016). Accessed 16 Nov 2018.
2. Leavitt DA, Theckumparampil N, Moreira DM, Elsamra SE, Waingankar N, Hoenig DM, et al. Continuing aspirin therapy during percutaneous nephrolithotomy: unsafe or under-uitilized? J Endourol. 2014;28(12):1399–403.
3. Yuan D, Liu Y, Rao H, Cheng T, Sun Z, Wang Y, et al. Supine versus prone position in percutaneous nephrolithotomy for kidney calculi: a meta-analysis. J Endourol. 2016;30(7):754–63.
4. Ibarluzea G, Scoffone CM, Cracco CM, Poggio M, Porpiglia F, Terrone C, et al. Supine Valdivia and modified lithotomy position for simultaneous anterograde and retrograde endourological access. BJU Int. 2007;100(1):233–6.
5. Friedlander JI, Duty BD, Smith AD, Okeke Z. Percutaneous nephrostolithotomy: an assessment of costs for prone and Galdakao-modified supine Valdivia positioning. Urology. 2012;80(4):771–5.
6. Yang YH, Wen YC, Chen KC, et al. Ultrasound-guided versus fluoroscopy-guided percutaneous nephrolithotomy: a systematic review and meta-analysis. World J Urol. 2018; https://doi.org/10.1007/s00345-018-2443-z. [Epub ahead of print].
7. Ng FC, Yam WL, Lim TYB, Teo JK, Ng KK, Lim SK. Ultrasound-guided percutaneous nephrolithotomy: advantages and limitations. Investig Clin Urol. 2017;58(5):346–52.
8. Traxer O, Smith TG 3rd, Pearle MS, Corwin TS, Saboorian H, Cadeddu JA. Renal parenchymal injury after standard and mini percutaneous nephrostolithotomy. J Urol. 2001;165(5):1693–5.
9. Loftus CJ, Hinck B, Makovey I, Sivalingam S, Monga M. Mini versus standard percutaneous nephrolithotomy: the impact of sheath size on intrarenal pelvic

pressure and infectious complications in a porcine model. J Endourol. 2018;32(4):350–3.
10. De S, Autorino R, Kim FJ, Zargar H, Laydner H, Balsamo R, et al. Percutaneous nephrolithotomy versus retrograde intrarenal surgery: a systematic review and meta-analysis. Eur Urol. 2015;67(1):125–37. Erratum in Eur Urol. 2016:69(4):e85.
11. Labate G, Modi P, Timoney A, Cormio L, Zhang X, Louie M, et al. The percutaneous nephrolithotomy global study: classification of complications. J Endourol. 2011;25(8):1275–80.
12. de la Rosette J, Assimos D, Desai M, et al. The Clinical Research Office of Endourological Society percutaneous nephrolithotomy global study: indications, complications, and outcomes in 5803 patients. J Endourol. 2011;25:11–7.
13. Altschuler J, Jain R, Monga M. Supracostal upper pole endoscopic-guided prone tubeless "Maxi-PCNL": a contemporary evaluation of complications. J Endourol. 2018; https://doi.org/10.1089/end.2018.0502. [Epub ahead of print].
14. Tefekli A, Esen T, Olbert PJ, Tolley D, Nadler RB, Sun YH, et al.; CROES PCNL Study Group. Isolated upper pole access in percutaneous nephrolithotomy: a large-scale analysis from the CROES percutaneous nephrolithotomy global study. J Urol. 2013;189(2):568–73.

Ureteroscopy for Treatment of Calculi

13

John Roger Bell and Necole M. Streeper

Introduction

The first ureteroscopic stone removal was reported in 1980 by Perez-Castro-Ellendt and Martinez-Pineiro. Since that time, the advancement in the technology for endoscopic instrumentation has allowed the treatment modalities for ureteral stones to evolve, largely replacing open surgery and blind basketing. Medical expulsive therapy (MET) to facilitate spontaneous stone passage has become commonplace, although its efficacy has recently been called into question [1–3]. However, the AUA Guideline panel on the surgical management of stones recommended to offer MET in patients with distal ureteral stones ≤10 mm [3]. When ureteral calculi fail to progress after a sufficient trial of time, generally 4–5 weeks, then surgical intervention is recommended.

Other indications for surgical intervention that may prompt more urgent treatment include persistent obstruction causing renal dysfunction, solitary kidney, recurrent urinary tract infections, large stone burden, presence of unremitting renal colic, and patient preference. Consideration of the following is essential when making decisions about the treatment of both renal and ureteral calculi: probability of stone-free rate, need for additional procedures, and morbidity related to the treatment modality. This chapter will focus on the indications, technical considerations, and complications of ureteroscopy for both renal and ureteral calculi.

Indications for Ureteroscopic Management of Renal Calculi

The treatment options for renal calculi include ureteroscopy (URS) with intracorporeal lithotripsy, shock wave lithotripsy (SWL), and percutaneous nephrolithotomy (PCNL). Ureteroscopy has traditionally shown high treatment success with >90%, for renal stones less than 2 cm, regardless of location within the kidney [4]. However, studies that have used CT imaging for follow-up show that small fragments may be present in up to 50% of patients [5, 6]. In general, PCNL is the preferred management of stones >2 cm, with the exclusion of pregnant patients and those with irreversible coagulopathy and severe morbid obesity, who can be treated with URS with less associated morbidity. In addition, URS is considered an effective treatment for SWL-failure stones and for renal stones with associated ureteral stone burden [7].

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S. L. Best, S. Y. Nakada (eds.), *Minimally Invasive Urology*,
https://doi.org/10.1007/978-3-030-23993-0_13

Lower pole renal stones present increased technical difficulty when performing URS due to its anatomic location. It can be quite challenging to navigate the ureteroscope into the lower pole due to the angle and amount of flexion required of the ureteroscope. The degree of flexion can be even more limited once the laser fiber is inserted into the scope. One strategy to mitigate these limitations is to displace the stone with a basket to an upper pole calyx prior to beginning lithotripsy [8]. While SWL for calculi in the lower pole may be considered, patients may fail to clear the fragments from the kidney, given the position and angle of the lower pole to the renal pelvis. Pearle et al. conducted a prospective, randomized multicenter trial and did not find a statistically significant difference in stone-free rates between SWL and URS for lower pole renal calculi less than 1 cm [5]. Another study evaluated URS compared to PCNL for stones between 1.5 and 2 cm located in the lower renal pole and found stone-free rates to be comparable, 89.2% and 92.8%, respectively [9]. Sener et al. evaluated the role of ureterosopy for asymptomatic single lower pole renal stones <1 cm, randomizing patients to URS, SWL, and observation in a three-armed randomized controlled trial [10]. The stone-free rate for URS was 92% and 90% for SWL after an average of 1.48 ± 0.65 sessions. During the 2-year follow-up period, the observation group had a 12% rate of developing symptoms or stone growth, concluding that each treatment option is suitable. These data reveal that ureteroscopy is a versatile modality capable of treating stones of various sizes and locations, though interpretation of most studies must take into account the fact that most studies use plain Xray rather than CT to define stone-free rates, which may be inaccurate.

Indications for URS Management of Ureteral Calculi

The accepted treatment methods for ureteral calculi include observation or medical expulsive therapy (MET), shock wave lithotripsy (SWL), ureteroscopy (URS), and percutaneous nephrolithotomy (PCNL) with antegrade ureteroscopy if necessary. Decision making concerning treatment modality takes into consideration stone size, stone location, stone composition, presence or absence of infection, patient comorbidities, and patient preference.

Guidelines state that observation should be offered to patients with ureteral stones ≤10 mm as first-line therapy with the consideration of MET for distal ureteral stones of this size. However, certain circumstances may prompt earlier surgical management, including uncontrolled pain, infection/sepsis, or acute kidney injury [11]. The preferred agents for MET are alpha-blockers such as Tamsulosin [11, 12]. The average amount of time required to pass a stone is dependent on stone size; for example, 95% of stones less than 4 mm pass spontaneously by 40 days. However, the passage rate decreases to less than 50% for stones between 5 and 10 mm [13, 14]. Given that the spontaneous passage of a stone may take 4–6 weeks and may be accompanied with renal colic, the patient needs to be appropriately counseled and may prefer to have earlier surgical intervention, especially for larger stone size and more proximal stone location.

According to the AUA Guidelines for the management of ureteral calculi, both SWL and URS are acceptable first-line treatments [3]. Aboumarzouk et al. performed a meta-analysis of seven randomized controlled trials to compare SWL and URS [15]. The stone-free rate was significantly better for URS than for SWL (92% vs. 77%, RR 0.84, 95% CI 0.73–0.96). The rate of secondary procedure was higher for SWL in comparison to URS (21% vs. 3%, RR 6.18, CI 3.68–10.38). However, URS was associated with higher complications, which were minor, and longer hospital stay [15]. In addition, URS has also been found to be more cost-effective when compared to SWL for the treatment of stones that have failed a trial of passage [16].

Stone Composition and URS

The Hounsfield unit (HU) density may be calculated on CT imaging to suggest potential stone composition [17]. SWL-resistant stones include cystine, brushite, and calcium oxalate

monohydrate. URS should be considered over SWL in patients with these stone compositions due to poor stone-free rate outcomes and risk of additional procedures; therefore, it is important to identify these stones with higher likelihood of fragmentation resistance preoperatively to adequately inform the patient when making treatment decisions. Studies suggest that stone attenuation, measured in HU, is the best predictor of SWL success [18, 19]. Ouzaid et al. found that stones with measured HU density <970 had a 96% stone-free rate compared to those with >970 HU, which had a 38% stone-free rate, and concluded that those patients with increased likelihood of poor outcome with SWL should undergo alternative therapy [19]. In contrast, ureteroscopy is highly effective against all stone compositions and can treat stones in the distal and proximal ureter in addition to the kidney.

Special Considerations

During surgical planning, the following patient characteristics should be given special considerations: pediatric patients, pregnant patients, patients with coagulopathies or bleeding disorders, and patient body habitus (Table 13.1).

Several studies have shown that ureteroscopy is safe and efficacious in the pediatric population, with comparable stone-free rates and complications when compared to the adult population [13, 20–22]. Treatment decision should consider the child's size and genitourinary tract anatomy. If the available ureteroscope will not accommodate the small diameter of the pediatric urethra or ureter, then a less-invasive approach with SWL would be favored.

Table 13.1 Special considerations during treatment decision making

Patient factors	Anatomical features	Stone features
Obesity	Solitary kidney	Overall stone burden/size
Coagulopathy	Horseshoe kidney	Stone composition
Comorbidities	Ectopic kidney	Hounsfield unit (HU) density
Pregnancy	Lower pole stone	SWL resistance
Renal insufficiency	Skin-to-stone distance	Coexisting ureteral stones

Ureteroscopy is safe during pregnancy if patients fail conservative management of an obstructing ureteral stone [23, 24]. The holmium:YAG laser is the intracorporeal lithotripter of choice and has proven to be safe to be utilized on pregnant patients. Ultrasound may be used rather than fluoroscopy during treatment if trained personnel are available. Other approaches to reduce radiation exposure to the fetus include direct visualization without fluoroscopy and low-dose fluoroscopy with the use of an Xray shield under the pelvis to protect the fetus if the radiation source comes from underneath, as with most C-arm machines. When making treatment decisions, it is important to consider that pregnancy is associated with hypercalciuria and accelerated encrustation of stents/nephrostomy tubes; therefore, exchanges may need to be every 4–8 weeks. The most favorable timing for surgical intervention is during the second trimester. The first trimester carries increased risk to the fetus, and the third trimester can be more technically challenging due to the patient's habitus. SWL and PCNL are contraindicated during pregnancy.

Patients with coagulopathy or on anticoagulation medication are poor candidates for both SWL and PCNL due to increased bleeding risk. Watterson et al. showed that ureteroscopy with holmium:YAG laser lithotripsy is safe for this patient population without correcting coagulopathies or cessation of anticoagulation medications preoperatively [25]. Electrohydraulic lithotripsy (EHL) has a higher rate of mucosal damage and is not recommended for use in this population. Similar stone-free rates and intraoperative and postoperative complications have been reported when compared to patients with normal coagulation [25]. In patients who are anticoagulated, we have noticed an increased likelihood of perirenal bleeding postoperatively, likely secondary to guidewire perforation. In these patients, using a wireless access may be a favorable approach.

Body habitus is an important factor when deciding treatment modality, given that both SWL and PCNL have limitations in patients who

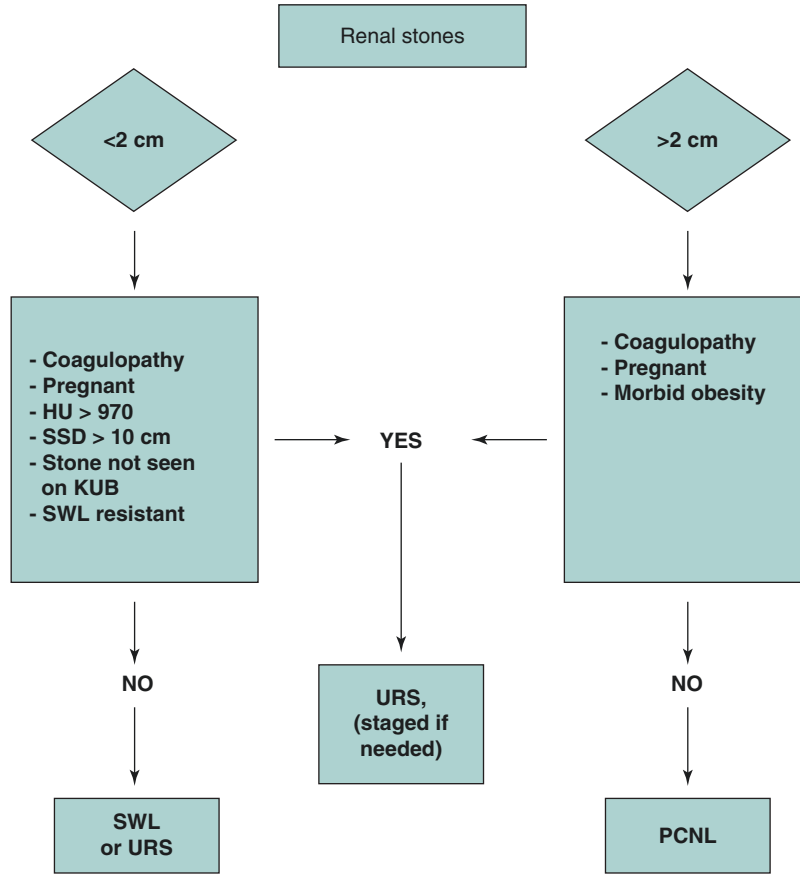

Fig. 13.1 Algorithm for the treatment of renal stones

are obese [26]. It is known that patients with large skin-to-stone distances (SSD) have poorer outcomes with SWL [27, 28] Pareek et al. found that SWL in patients with an SSD greater than 10 cm is likely to fail [27]. For PCNL, limitations include length of access sheath and instrumentation, as well as anesthetic risk in the prone position. URS can be safely performed in obese patients since stone-to-skin distance is not an indicator of success and studies have proven it to be efficacious [29, 30].

URS may be indicated due to patient comorbidities that preclude treatment by SWL or PCNL, even for very large renal stones >2 cm, in patients with coexisting ureteral stones, coagulopathy, morbid obesity, pregnancy, or renal anomalies [31, 32]. Treatment may be done in planned staged procedures to minimize the risk of prolonged anesthesia time. An algorithm for the treatment of renal stones, as shown in Fig. 13.1, can be used to guide decision-making in patients with these clinical features.

Preoperative Considerations

Prior to surgical intervention for calculi, the patient should undergo preoperative anatomic imaging with CT noncontrast scan, ultrasound, KUB, or IVP. This will provide important details concerning the stone, including the location and size, which will aid in deciding on the treatment modality. Our standard remains to obtain CT imaging because in addition to the above information, the Hounsfield unit density and skin-to-stone distance may be calculated in order to predict success with alternative treatment options [17, 27, 28]. A detailed history and physical examination should be completed, and the patient should be medically optimized prior to surgery.

Preoperative laboratory evaluation should include a urine culture, or urine dipstick in uncomplicated cases, 1–2 weeks prior to the surgery date and treated with culture-specific antibiotics, if necessary. Based on the AUA Best Practice Policy Statement, the antimicrobial prophylaxis of choice to be given prior to ureteroscopy is a fluoroquinolone or TMP-SMX with a duration of less than or equal to 24 h [33]. Alternative choices include aminoglycoside (aztreonam) ± ampicillin, first- or second- generation cephalosporin, or amoxicillin/clavulanate [33].

Technique

Table 13.2 lists an example of the instrument list required for ureteroscopic stone management, though the surgeon's preference may favor alternatives. Figure 13.2 illustrates a step-by-step approach to ureterscopy. The patient is placed in the dorsal lithotomy position. A 19–22 F rigid cystoscope is inserted through the urethra into the bladder. The ureteral orifice is cannulated with a guidewire and advanced to the level of the renal pelvis. It may be useful to perform a retrograde pyelogram (RPG) using a 5 F open-ended ureteral catheter to delineate the anatomy of the collecting system prior to the placement of the guidewire.

Table 13.2 An example of a list of instruments required to perform ureteroscopy for the treatment of calculi

Rigid cystoscope (19–22 F) with 30° lens
Open-ended ureteral catheter (5 F)
Guidewire (Boston Scientific Sensor, following should be available: straight and angled Boston Scientific Glidewire and Boston Scientific Amplatz Super Stiff)
Flexible ureteroscope (Olympus P5/P6 fiberoptic ureteroscope, Storz Flex Xc digital ureteroscope)
Semi-rigid ureteroscope (ACMI Micro-6)
Camera and light source
Irrigation setup and endoscopic irrigator (Pathfinder, Boston Scientific Single Action Pumping System)
Adaptor (Applied Medical Sureseal, US Urology UroSeal)
Holmium laser fiber (200 or 270 μm) with setup
Radiopaque contrast (omnipaque)
Basket (1.5 F or 2.2 F N-circle, Cook 2.4 F N-compass)
Double J ureteral stent (6 F, 22–28 cm)
Optional – Cook ureteral access sheath (9.5/11.5 F, 10.7/12.7 F, 12/14 F or 14/16 F, 35–45 cm)
Optional – Cook ascend AQ dilation balloon
Optional – Cook dual lumen catheter or 8/10 F ureteral dilator Optional – Boston Scientific 8/10 F coaxial dilator

For distal or mid-ureteral stones, the semirigid ureteroscope is used to enter the ureter alongside the guidewire up to the level of the stone (Fig. 13.3). The semirigid ureteroscope has a larger working channel and is preferred over flexible ureteroscopes for distal ureteral stones. Depending on the size of the stone, it may be extracted with a basket or fragmented with holmium laser lithotripsy with subsequent extraction or evacuation of the fragments with irrigation. Generally, stones that are less than 4 mm may be successfully removed with a basket or graspers (Fig. 13.4). When removing stones or stone fragments, however, extreme care must be taken to make sure that the stone is withdrawn without resistance because ureteral avulsion is a risk if this is not done properly [34]. In addition, no blind basketing should be done for this reason.

For proximal ureteral or renal calculi, a flexible ureteroscope should be used. The flexible ureteroscope may either be inserted over a guidewire or inserted through a ureteral access sheath based on the surgeon's preference. Free-handed technique alongside a guidewire may also be done in certain circumstances if preferred. If the ureteroscope does not pass the orifice, it may be necessary to sequentially dilate the distal ureter, which is the authors' preference, or a balloon dilator may be used. Ureteral sheaths are available in a variety of diameters—from 9.5/11.5 to 14/16 F with lengths of 20–55 cm. Ureteral access sheaths facilitate repetitive access into the upper tract for basket stone extraction while decreasing operative time, improving stone-free rate, and decreasing intrarenal pressure [35–37]. However, they can be associated with ureteral injuries [38]. Therefore, it is recommended to insert these over a stiff wire, and excessive force should be avoided when inserting the access sheath. If the ureteral sheath does not insert easily, the inner obturator may be passed initially and then placement

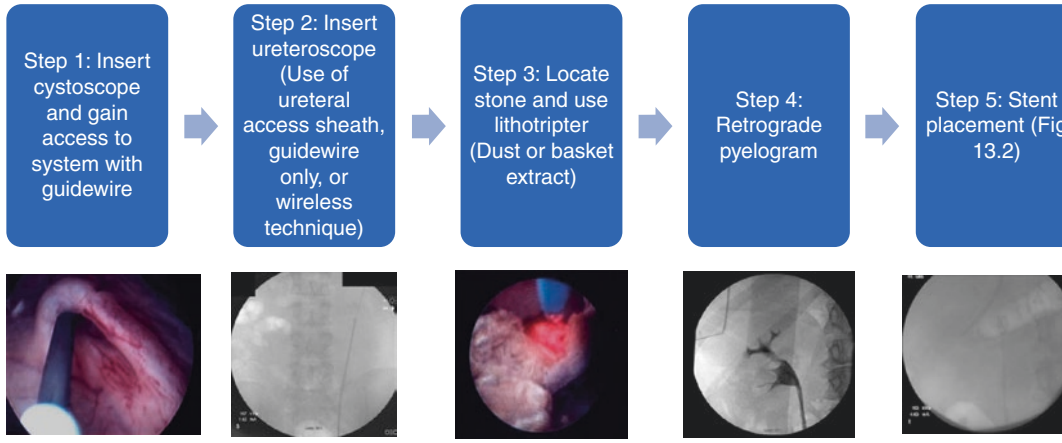

Fig. 13.2 Step-by-step approach to ureteroscopy

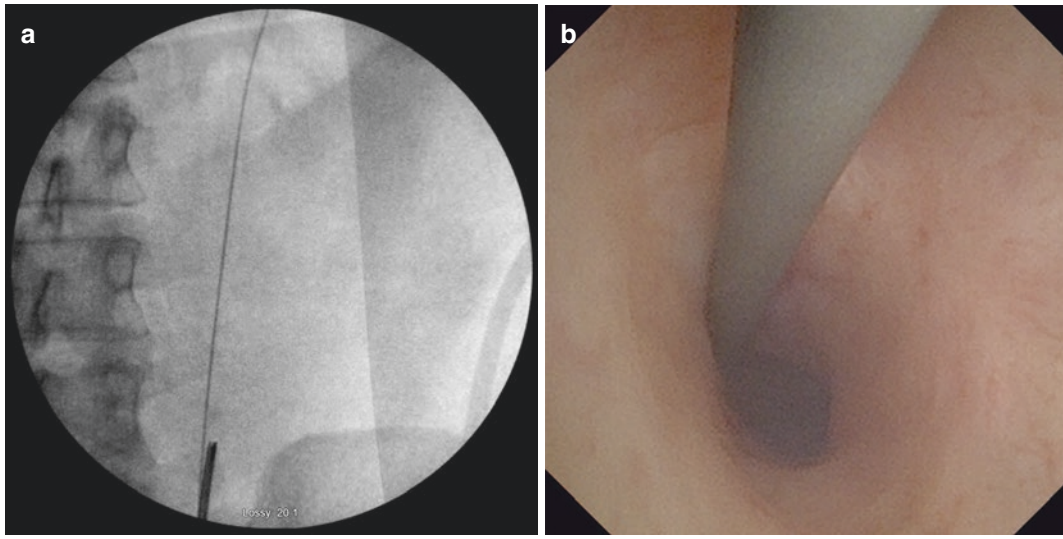

Fig. 13.3 Semi-rigid ureteroscopy. (**a**) Semi-rigid ureteroscope as seen under fluoroscopy with a safety wire alongside the uteroscope. (**b**) Endoscopic view of the ureter with the safety wire

of the entire device should be attempted subsequently. Delvecchio et al. found a similar ureteral stricture rate, 1.4%, in patients who had a ureteral access sheath utilized during their ureteroscopy [39]. However, there is a theoretical risk of ischemic effects with the use of a ureteral sheath, and, therefore, it is best not to use large sheaths for long periods of time.

Ureteroscopy is typically performed with the use of a safety wire, meaning an extra wire that is not used to insert the ureteroscope or ureteral access sheath. This allows for continuous access into the kidney even if the ureteroscope or access sheath is removed. Furthermore, in the event of a ureteral injury or avulsion, it can provide a means to place a ureteral stent. If the use of a safety wire is preferred, then prior to insertion of the ureteroscope, a dual lumen catheter, or an 8/10 F dilator, may be inserted over the guidewire and a safety wire may be placed at that time. However, there are several publications documenting the advantage of not using a safety wire in experienced hands. Omitting the safety wire allows for greater ease when inserting the

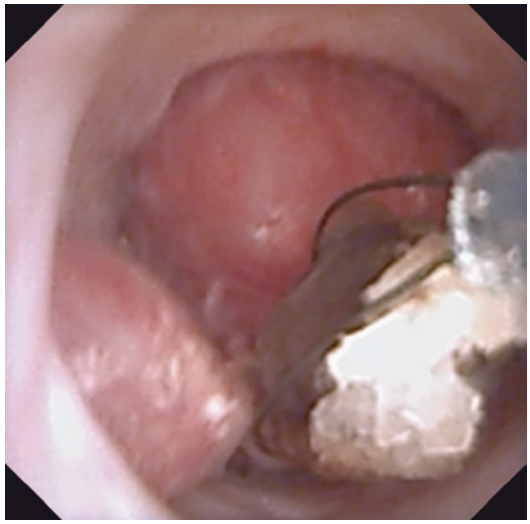

Fig. 13.4 Ureteroscopic basket stone extraction. An endoscopic view showing basket extraction of a calyceal stone fragment

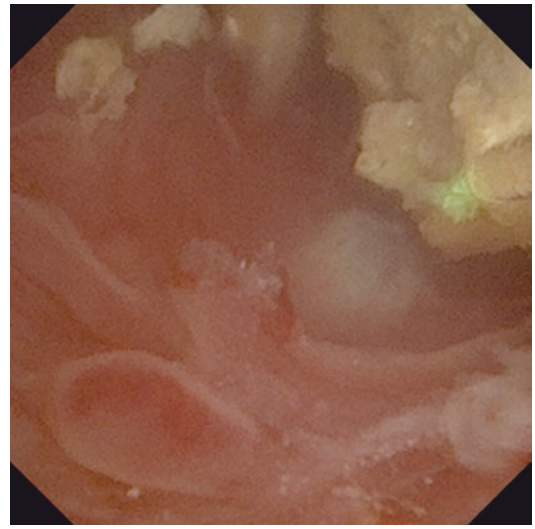

Fig. 13.5 Ureteroscopic laser lithotripsy. The tip of the laser fiber is seen near the 3 o'clock position of the picture. The aiming beam is green and is seen on the surface of the urinary stone that is being treated. The laser can be used to fragment the stone with subsequent extraction of the pieces or to dust the stone into small enough particles that will pass spontaneously out of the urinary tract

Table 13.3 Guidelines for ureteroscopy without a safety wire

Renal procedures primarily	Avoid in patients with UPJ obstruction or duplicated systems
Stone treatment primarily	Avoid in patients with intrinsic ureteral disease or impacted stones
Straightforward ureteral access	No stone distraction
Replace guidewire through ureteroscope prior to removal	

ureteroscope and decreases overall disposable equipment costs [40–43].

Table 13.3 outlines criteria for omitting the safety wire.

Lithotripter Options and Techniques

Historically, several technologies have been used to fragment urinary stones, including ultrasonic lithotripsy, electrohydraulic lithotripsy (EHL), laser lithotripsy, or pneumatic lithotripsy [44, 45] The holmium:YAG laser has been used since the early 1990s and is currently the most commonly used and studied modality as it is effective against all stone compositions, can be delivered through small laser fibers, and causes minimal damage to surrounding tissues [3, 46]. It fragments stones through a photothermal mechanism (Fig. 13.5) [47].

Multiple techniques have been described using the holmium:YAG laser. Wolf et al. described different approaches for stone fragmentation utilizing the holmium laser [48]. One commonly used technique is dusting the stone into small enough fragments that may spontaneously pass. This can be accomplished by using the dancing or chipping technique, as described by Wolf et al., in which the laser fiber is either brushed back and forth across the stone to ablate in layers or directed toward the periphery of the stone until small fragments of the stone are chipped off [48]. An alternative method, the popcorn technique, does not require the laser fiber to be in direct contact with the stone. Instead, the laser fiber is positioned near a collection of stones within a dependent portion of the calyx. The laser is fired continuously, creating rapid stone motion within the calyx and, ablation of the stone results

from the collision of the stone fragments with the laser fiber [48].

In general, when one desires to fragment the stone with the goal of primarily extracting the pieces, a higher-energy setting (0.8–1.2 J) is used with a lower frequency (6–12 Hz) [49, 50]. If the goal is to primarily dust the stone into small enough fragments to pass, then lower energy settings (0.2–0.5 J) are used with higher frequency settings (40–80 Hz) [51, 52]. One significant innovation in laser technology has been the introduction of longer pulse widths and other stabilization methods to decrease stone retropulsion during treatment. The pulse width is the length of time that the laser energy is transferred to the stone. Increasing the pulse width results in decreased stone retropulsion [53–55]. It should be mentioned that laser settings across different lasers are not necessarily comparable, and therefore urologists should adjust the settings based on the observed and desired outcomes [53]. Furthermore, treatment efficiency is increased by increasing the overall wattage of laser settings. Therefore, if lower energy is to be used, higher frequency settings can decrease treatment time [54]. There is also growing data evaluating the heat produced by lasers. Therefore, higher pulse energies should be minimized when possible and irrigation should be used to decrease heat buildup [56, 57].

There has been much debate recently regarding the practice of fragmenting renal stones with subsequent basket extraction versus "dusting" the stone into small enough fragments for spontaneous passage. The EDGE consortium has recently published their data comparing dusting and extraction [58]. This was a multiinstitutional study where urologists performed the technique with which they were most comfortable. Their data showed that basket extraction increased the mean operative time by 38 min compared to the dusting group. There was no difference in the rate of complications, hospital readmissions, or additional procedures between the dusting and basket extraction groups. The authors utilize a combination of dusting and basket extraction, depending on anatomical features and stone characteristics. Stones that have a hard composition may not dust well and may require basket extraction. For larger stone burden in cases where PCNL is contraindicated, the authors prefer to perform a staged approach in which dusting is utilized for the initial procedure, and then on the second look procedure 2–3 weeks later a ureteral access sheath is utilized to basket extract fragments that did not pass. Furthermore, treating large volumes of stones may produce a large amount of debris, which may increase the risk of complications. The choice of technique also varies depending on the experience of the surgeon and available equipment.

The size of the laser fiber should be minimized in order to allow for better irrigation flow through the ureteroscope and deflection of the scope [52, 59]. Fortunately, there does not appear to be a significant difference in ablation volume or energy transmission between laser fibers from 200 and 365 μm [52, 59]. Moreover, there is significant variability between the advertised diameter and the actual diameter of laser fibers [60]. The authors prefer to use a 200–270 μm laser fiber for both semi-rigid and flexible ureteroscopy. This decreases the need to order and stock different sizes based on technique. When treating hard stones or performing prolonged laser lithotripsy surgeries, the tip of the laser fiber can degrade. This is commonly referred to as "burn-back." The use of long pulse widths and lower pulse energy helps to minimize this fiber tip degredation [52]. If the tip of the fiber does begin to fray or break, this can be cleaved to create a fresh tip. Stripping the end of the laser fiber has often been advocated. However, this practice has been shown to decrease the efficiency of laser energy transmission [52]. This is partly because the coating helps to redirect laser energy toward the tip of the fiber and not out of the sides. The laser fiber should be positioned about 3 mm from the tip of the ureteroscope in order to minimize any damage to the ureteroscope. This distance can be estimated endoscopically by advancing the fiber at least 25% from the edge of the screen toward the middle [61].

Ureteral Stents

Most urologists place a ureteral stent at the conclusion of ureteroscopy. Pais et al. performed a meta-analysis demonstrating a twofold increase

in unplanned visits after ureteroscopy when a ureteral stent was omitted in randomized trials. However, when trials were examined that left stent placement up to the surgeon, there was no difference in unplanned visits [62]. These data were corroborated by an analysis of the CROES (Clinical Research Office of the Endourological Society) database [63]. Therefore, the authors recommend routine placement of a ureteral stent for a duration of less than 7 days. However, the stent may be safely omitted after uncomplicated ureteroscopy, particularly when the stone is primarily extracted from the distal ureter without the need for ureteral dilation [64–66]. However, stents should be placed if there is evidence of ureteral trauma, injury, or stricture, if a large residual stone burden was treated, or in the case of patients with a solitary kidney, renal insufficiency, and coagulopathies.

The authors generally use a 5 or 6 F diameter stent. The length of the stent can be estimated based on the patient's height or measured endoscopically using a ureteral catheter or by measuring the length of the ureter on preoperative imaging [67, 68]. Most ureteral stents come with an extraction string attached. This can be left in place or removed prior to inserting the stent. Leaving the string on the stent allows the patient to remove the stent or is for stent removal in the clinic without the need for cystoscopy. However, leaving the string, while more convenient, places the patient at a higher risk for accidental premature removal of the stent. A string should only be left if the stent is needed for 7 days or less. One technique is to leave the string shorter in the male so that it is in the anterior urethra, facilitating cystoscopic removal without having to enter the bladder while also eliminating premature stent removal. The stent is typically left in place between 3 and 7 days following routine ureteroscopy and for longer duration, 2–6 weeks, following ureteral injury or dilation of ureteral stricture.

Placement of the stent may be accomplished with the use of the rigid cystoscope under direct visualization or fluoroscopically. For placement under direct visualization, the stent pusher is inserted through the working channel of the cystoscope. The guidewire is then "backloaded" through the pusher. Then the pusher is removed, leaving the guidewire in the cystoscope. The cystoscope is then advanced into the bladder in order to visualize the ureteral orifice. The stent is advanced through the cystoscope with the pusher until the distal black marker on the ureteral stent is at the ureteral orifice and the proximal end of the stent is in proper position within the renal pelvis. At this point, the guidewire is withdrawn enough to see the proximal end of the stent coil into good position under fluoroscopic visualization. Attention is then turned to the distal end of the stent. The cystoscope is withdrawn to the bladder neck, and the stent is advanced until the distal end is at the bladder neck. The guidewire is completely removed, and the distal end of the stent will subsequently be curled within the bladder. In cases with a narrow renal pelvis, the extraction string may be used to set the proximal curl and then subsequently removed, if desired, before setting the distal curl.

The second approach to the placement of the ureteral stent is under fluoroscopic visualization alone; see Fig. 13.6, which outlines the steps as described below. The ureteral stent is advanced over the guidewire using the pusher. The C-arm should be positioned over the bladder, and the pusher should be advanced until the radiopaque marker is at the mid-pubic symphysis. Maintaining the pusher in the same position, the C-arm is moved to the kidney to ensure that the proximal end of the stent is in good position. The guidewire is withdrawn enough to see the proximal end coil within the renal pelvis. The C-arm is then relocated over the bladder, and fluoroscopy is used to ensure that the marker on the pusher is still in the proper location. Once verified, the guidewire is completely removed, deploying the distal end of the stent to coil within the bladder.

Difficult Ureteral Access

An impacted ureteral stone or ureteral stricture may make placement of the guidewire into the renal collecting system difficult. If this occurs, then the ureteral access catheter should be passed over the guidewire just distal to the level of the obstruction, and a retrograde pyelogram should

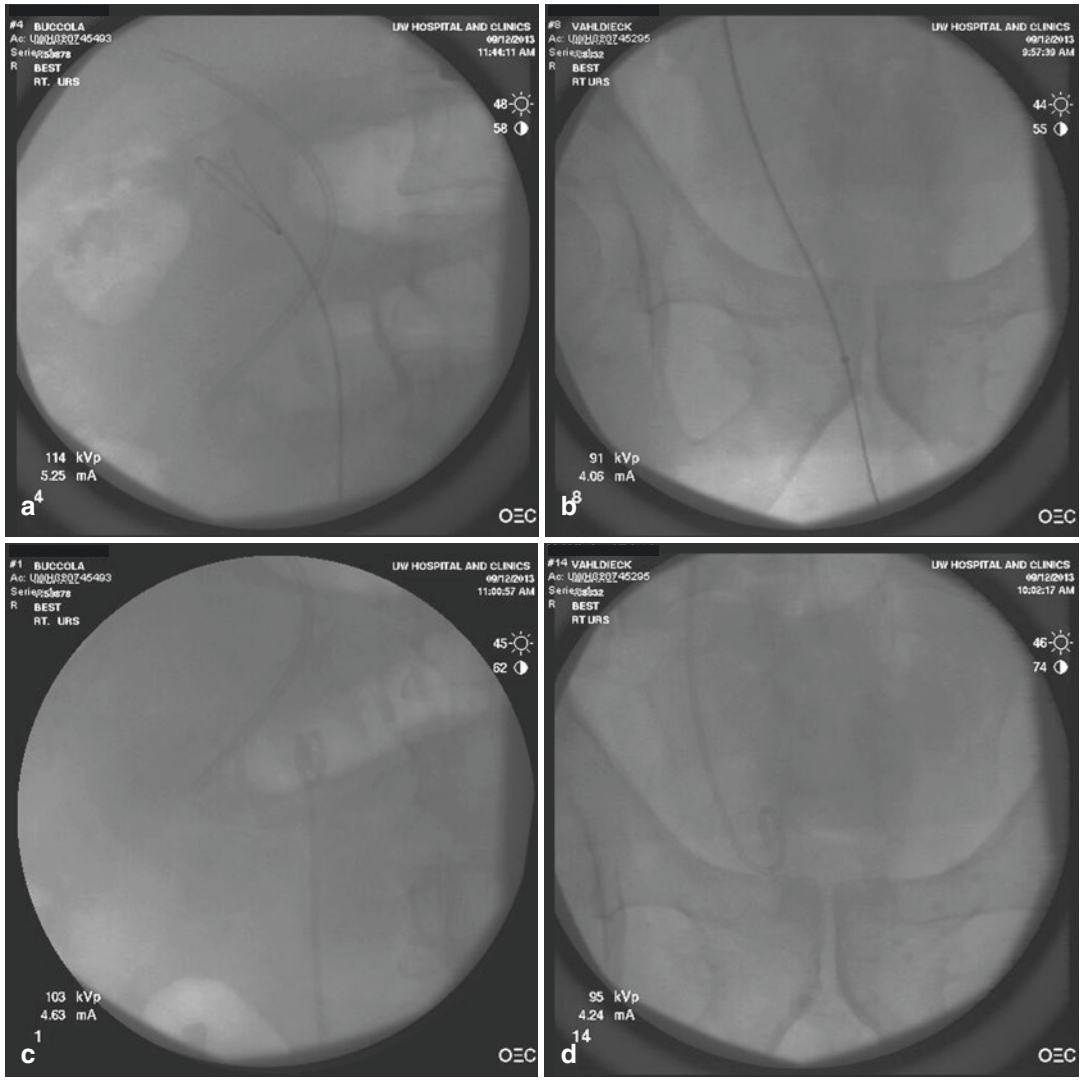

Fig. 13.6 Fluoroscopic placement of a ureteral stent. (**a**) Guidewire is advanced to the level of the renal pelvis and coiled. (**b**) The ureteral stent is advanced over the guidewire using the pusher. The C-arm should be positioned over the pubic symphysis, and the pusher should be advanced until the radiopaque marker is at the mid pubic symphysis (*see arrow*). (**c**) Maintaining the pusher in the same position, the C-arm should be positioned over the kidney, and the guidewire should be withdrawn enough to see the proximal end coil within the renal pelvis. (**d**) The C arm should again be positioned over the pubic symphysis to ensure that the pusher is still in proper location. Once verified, the guidewire is completely removed, deploying the distal end of the stent to coil within the bladder

be performed. Using the imaging gained from the retrograde pyelogram, a hydrophilic guidewire, such as the glidewire, should then be readvanced through the ureteral access catheter to negotiate past the obstructing stone or stricture. It is important to carefully manipulate the guidewire with care so as not to perforate the ureter. Glidewires are often able to bypass an impacted stone and are less likely to cause a false passage or ureteral perforation. There are both straight and angled glidewires available. Once the glidewire is coiled within the renal pelvis, the ureteral access catheter should be passed over the wire and above the area of obstruction. If the urine draining from the

access catheter appears to be infected, then the procedure should be abandoned, a stent should be placed, and treatment should be performed after appropriate antibiotics have eradicated the infection. Otherwise, the glidewire should then be exchanged for a stiffer guidewire to avoid the glidewire from inadvertently being removed. If access is not possible by this point, it may be safer to have a nephrostomy tube placed and refer to a more experienced center.

However, in experienced hands, another option is to place a wire under direct visualization using a ureteroscope. A guidewire should be left in place just below the impacted stone, and the ureteroscope, either semi-rigid if within the distal ureter or flexible if within the mid/proximal ureter, should be passed to the level of the obstruction. Under direct visualization, the degree of stone impaction and/or ureteral stricture may be assessed. The guidewire may then be directed around the obstruction at a favorable appearing location. If stone impaction prevents this, then laser lithotripsy may be carefully performed until a guidewire is able to be passed. It is not recommended to attempt basketing the stone without a safety wire in place. In cases of failed retrograde access, a percutaneous nephrostomy tube should be placed with plans for antegrade ureteroscopy.

For a ureteral stricture, after successful retrograde access, the next step is determined by the location of the stricture that is compromising access to the stone. Due to the fragility of the proximal ureter, it is best to stent and allow for passive dilation rather than active dilation with a ureteral balloon dilator. A second-look URS may be done in 1–2 weeks, typically with an easily accessible ureter. For distal ureteral strictures, a safety wire should be placed prior to balloon dilation. The safety wire may be placed with a dual lumen catheter, 8/10 dilator, or under direct visualization with the ureteroscope.

Ureteral balloon dilators can be used for the dilation of distal ureteral strictures that compromise access to the ureteral stone. The balloon has radiopaque markers at the proximal and distal ends, which is used to position the balloon over the working guidewire using fluoroscopy (Fig. 13.7). They should never be inflated over an obstructing ureteral stone due to the risk of ureteral perforation. Once the balloon is in proper position, it is inflated with half-strength contrast using a pressure gauge syringe. The balloons typically can withstand inflation pressures up to 17–20 atm; however, dilation of the ureter typically can be achieved at lower pressures (4–6 atm). The lowest pressure necessary to dilate the ureter should be used to avoid ureteral perforation, and therefore it is important to inflate the balloon under fluoroscopic guidance. Typically, a "waist" is seen in the balloon at the location of the stricture, and one should continue to inflate slowly until the "waist" disappears. The balloon is then deflated and removed, leaving the guidewire in place. Ureteroscopy may then be performed to treat the stone.

Current Ureteroscopes

Table 13.4 reviews the specifications of the flexible ureteroscopes that are currently available. Flexible ureteroscopes vary in the degree of active deflection, maximal and tip diameter, presence of secondary deflection, and the type of lens. There have been advances over the years in the primary active deflection capabilities of flexible ureteroscopes to 270°, as well as scopes that have a second lever allowing for secondary active deflection up to 310° (Gyrus-ACMI DUR-8 Elite, Stryker Flexvision U500), allowing for increased access into the lower pole and acutely angled calyces [69]. Scopes that have variable upward and downward deflection, such as 180°/270° as seen in Olympus URF-P5 and URF-V, allow for greater options in maneuverability when attempting access into more challenging calyces. The Olympus URF-P6 has a stiffer shaft and may be helpful to use in cases where the URF-P5 buckles prohibiting advancement of the scope. The URF-P6 also has a smaller shaft diameter and may be used through the smallest available ureteral access sheaths, 9.5/11.5 F, when necessary.

The majority of flexible ureteroscopes have a 3.6 F working channel. Instruments should be passed through the working channel with the ureteroscope

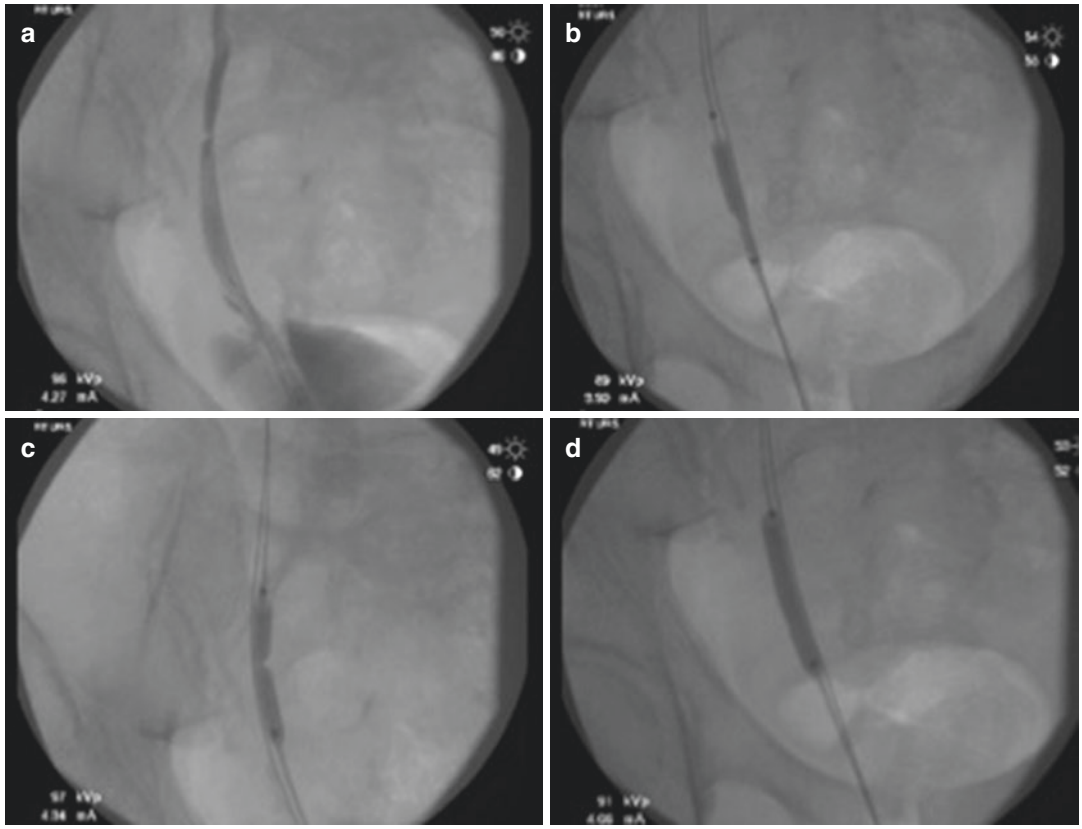

Fig. 13.7 Balloon dilation of a ureteral stricture. (**a**) A retrograde pyelogram (RPG) is performed to evaluate the area of obstruction. The arrow indicates the location of the ureteral stricture. (**b**) The balloon has radiopaque markers at the proximal and distal ends, which is used to position the balloon over the working guidewire using fluoroscopy. Once the balloon is in proper position, it is inflated with half-strength contrast using a pressure gauge syringe. (**c**) It is important to inflate the balloon under fluoroscopic guidance to dilate the stricture with the lowest pressure required. Typically a "waist" is seen in the balloon at the location of the stricture, as indicated by the arrow. (**d**) The balloon is inflated slowly until the "waist" disappears

in a neutral position to avoid damage to the working channel. The insertion of devices into the working channels inhibits the degree of deflection, as well as decreases irrigation flow [70]. Given the size of the working channel, instruments should be less than 3 F in order to maximize irrigation flow. An irrigation system is necessary to maintain proper visualization of the lumen of the ureter and the renal collecting system during ureteroscopy. Either a hand irrigation system, such as a Pathfinder bulb or a single-action pump system syringe, or a pressurized irrigation system can be utilized. Hand irrigation systems allow for greater control over the amount of irrigant used, as well as the prevention of retrograde stone migration [71]. Pressurized irrigation up to 300 mmHg can be used during ureteroscopy; however, it is advisable to utilize a ureteral access sheath in order to maintain lower intrapelvic pressure [37].

Reusable flexible ureteroscopes invariably will incur injury and will need to be repaired. There is variable data regarding the longevity of these instruments, with repair rates reported anywhere 9–34 uses. Furthermore, once the ureteroscope had been repaired, its durability significantly decreased [72, 73]. A new category of single-use flexible ureteroscopes are being increasingly used and studied. The proposed advantages of single-use scopes are that repairs are not required; they do not need to be reprocessed. It also eliminates the possibility of transmitting infection from one

Table 13.4 Specifications of current flexible ureteroscopes

Scope	Tip diameter (F)	Maximal shaft diameter (F)	Working channel diameter (F)	Active deflection in degrees (up/down)	Presence of active secondary deflection	View (°)	Type of lens
Olympus							
URF-P5	5.3 F	8.4 F	3.6 F	Up 180°/down 275°	No	90	Analogue
URF-V	8.3 F	9.9 F	3.6 F	Up 180°/down 275°	No	90	Digital
URF-P6/P6R	4.9 F	7.95 F	3.6 F	Up 275°/down 275°	No	90	Analogue
Gyrus-ACMI							
AUR-7	7.2 F	11 F	3.6 F	Up 120°/down 160°	No	80	Analogue
DUR-8 Elite	6.75 F	8.7 F	3.6 F	Up 170°/down 180°	Yes – down 130°	80	Analogue
DUR-8	6.75 F	8.7 F	3.6 F	Up 170°/down 180°	No	80	Analogue
DUR-8 ULTRA	8.6 F	9.36 F	3.6 F	Up 270°/down 270°	No	80	Analogue
DUR-D	8.7 F	9.3 F	3.6 F	Up 250°/down 250°	No	80	Digital
Storz							
Flex-X2	7.5 F	8.4 F	3.6 F	Up 270°/down 270°	No	110	Analogue
Flex-XC	8.5 F	8.5 F	3.6 F	Up 270°/down 270°	No	90	Digital
Wolf							
Cobra	6 F	9.9 F	3.3 F × 2	Up 270°/down 270°	No	85	Analogue
Viper	6 F	8.8 F	3.6 F	Up 270°/down 270°	No	85	Analogue
Stryker							
FlexVision U500	6.9 F	–	3.6 F	Up 275°/down 275°	Yes	90	Analogue
Boston Scientific							
LithoVue	7.7 F	9.5 F	3.6 F	Up 270°/down 270°	No	–	Digital

patient to another. The single-use ureteroscopes are always available, and the surgeon does not need to wait for an instrument turnover. Yet these advantages need to be balanced against the cost, which is not amortized over several cases and the environmental concerns of increased waste. One proposal has been to utilize single-use ureteroscopes selectively during cases with large stone burden, difficult anatomy, or stones treated within the lower pole [74].

Semi-rigid ureteroscopes are primarily used for distal ureteral stones and have some advantages, including larger working channels and resistance to buckling in the bladder. Olympus Gyrus-ACMI, Wolf, Storz, and Stryker all produce a variety of semi-rigid ureteroscopes that vary in the angle of eyepiece, optics, scope diameter, length, and the number and size of the working channels.

Complications

Acute complications from ureteroscopy include bleeding, infection like sepsis, ureteral stent discomfort, ureteral injury, and need for secondary

treatment. Late complications include renal damage and ureteral stricture [75, 76]. Complications are typically minor and may be minimized through patient selection, careful systematic technique, sterilization of urine in patients with active infection, and the use of appropriate prophylactic antibiotics. In patients who have ureteral stent discomfort, alpha-blockers have been shown to be useful [77, 78]. Inaccurate sizing of the ureteral stent can lead to increased stent discomfort; therefore, it is important to make sure the stent does not cross midline due to excessive length [79].

Ureteral false passage is a complication that can occur with the attempted passage of a guidewire across a strictured ureter or impacted stone. The ureteral wall mucosa is perforated in this type of injury, but the wall itself remains intact. Recognition of the injury is the first step, followed by correct placement of the guidewire with confirmation by RPG. A ureteral stent should then be placed to allow the false passage to heal for 2 weeks. False passage is associated with a postoperative ureteral stricture rate of 0.4–0.9% despite intraoperative recognition [73].

The risk of ureteral perforation or injury is increased in cases of impacted stones or ureteral strictures with difficult ureteral access. It may occur with the advancement of guidewires, ureteral access sheath, ureteroscopes, or aggressive ureteral balloon dilation. Diagnosis is made by contrast extravasation at the level of the injury during RPG or by direct visualization with the ureteroscope. Treatment of a ureteral perforation typically involves termination of the procedure and placement of a ureteral stent. The stent should be left in place for 4–6 weeks prior to the second procedure. Ureteral avulsion is a rare complication that is avoidable with careful technique.

Ureteral strictures are a late complication of ureteroscopy that can lead to loss of renal function. The overall incidence of ureteral stricture after ureteroscopy is 0.5–3.5% [38, 79]. The cause of ureteral strictures is multifactorial, primarily due to trauma during ureteroscopy from mechanical or thermal injury. Impacted stones may cause severe inflammation and vascular compromise that leads to stricture formation. Roberts et al. found that the rate of ureteral stricture disease after URS of impacted calculi was 24%, much higher than the less than 1% noted in the general population of calculi treated with ureteroscopy [78]. Ureteral perforation is another cause of stricture formation secondary to injury to the ureter. Stoller et al. found a ureteral stricture rate of 5.9% in patients with intraoperative ureteral perforation, compared to an overall 3.5% rate [79].

Key Points

- For ureteral stones <10 mm, observation (with or without MET) may be offered to patients as first-line therapy, although certain circumstances may indicate the need for earlier surgical management, including uncontrolled pain, infection/sepsis, acute kidney injury, or patient preference.
- Treatment decision for renal calculi should take into consideration HU density, skin-to-stone distance, presence of coagulopathy, and stone size and location.
- For ureteral calculi, both SWL and URS with laser lithotripsy are considered first-line treatment. However, in the following instances, URS is preferred over SWL: coagulopathy, pregnancy, SSD > 10 cm, distal location, SWL-resistant stone, or HU density > 970.
- Patients should be adequately informed about the treatment modalities utilizing shared decision making; discussing the risks and benefits associated with each modality; taking into consideration the stone size, stone location, its possible composition; and patient comorbidities.
- The choice of dusting vs basket extraction should be based on the surgeon's experience, laser technology available, and type of stone. Dusting may be faster and may avoid the need for a ureteral

access sheath, while extraction offers a higher initial stone-free rate.

- Ureteral stents are typically placed for a short duration (<7 days) after uncomplicated ureteroscopy. In cases of ureteral injury or impacted ureteral stones, a ureteral stent should be left in place for 2–4 weeks.
- Reusable flexible ureteroscopes have a limited lifespan and are costly to repair or replace. Therefore, these instruments should be treated with care. Single-use flexible ureteroscopes may be used and may be advantageous during complex cases.
- Complications of ureteroscopy are typically minor and may be avoided with careful technique and includes bleeding, infection, stent discomfort, ureteral stricture, ureteral injury, and the need for secondary procedure.

References

1. Pickard R, Starr K, MacLennan G, Lam T, Thomas R, Burr J, et al. Medical expulsive therapy in adults with ureteric colic: a multicentre, randomised, placebo-controlled trial. Lancet. 2015;386(9991):341–9.
2. Ye Z, Zeng G, Yang H, Tang K, Zhang X, Li H, et al. Efficacy and safety of tamsulosin in medical expulsive therapy for distal ureteral stones with renal colic: a multicenter, randomized, double-blind, placebo-controlled trial. Eur Urol. 2017; https://doi.org/10.1016/j.eururo.2017.10.033. [Epub ahead of print].
3. Assimos D, Krambeck A, Miller NL, Monga M, Murad MH, Nelson CP, et al. Surgical management of stones: American Urological Association/Endourological Society guideline, PART II. J Urol. 2016;196(4):1161–9.
4. Perlmutter AE, Talug C, Tarry WF, Zaslau S, Mohseni H, Kandzari SJ. Impact of stone location on success rates of endoscopic lithotripsy for nephrolithiasis. Urology. 2008;71(2):214–7.
5. Pearle MS, Lingeman JE, Leveillee R, Kuo R, Preminger GM, Nadler RB, et al. Prospective, randomized trial comparing shock wave lithotripsy and ureteroscopy for lower pole caliceal calculi 1 cm or less. J Urol. 2005;173(6):2005–9.
6. Danilovic A, Cavalanti A, Rocha BA, Traxer O, Torricelli FCM, Marchini GS, et al. Assessment of residual stone fragments after retrograde intrarenal surgery. J Endourol. 2018;32(12):1108–13.
7. Cocuzza M, Colombo JR Jr, Cocuzza AL, Mascarenhas F, Vicentini F, Mazzucchi E, Srougi M. Outcomes of flexible ureteroscopic lithotripsy with holmium laser for upper urinary tract calculi. Int Braz J Urol. 2008;34(2):143–9; discussion 149–50.
8. Auge BK, Dahm P, Wu NZ, Preminger GM. Ureteroscopic management of lower-pole renal calculi: technique of calculus displacement. J Endourol. 2001;15(8):835–8.
9. Bozkurt OF, Resorlu B, Yildiz Y, Can CE, Unsal A. Retrograde intrarenal surgery versus percutaneous nephrolithotomy in the management of lower-pole renal stones with a diameter of 15 to 20 mm. J Endourol. 2011;25(7):1131–5.
10. Sener NC, Bas O, Sener E, Zengin K, Ozturk U, Altunkol A, Evliyaoglu Y. Asymptomatic lower pole small renal stones: shock wave lithotripsy, flexible ureteroscopy, or observation? A prospective randomized trial. Urology. 2015;85(1):33–7.
11. Segura JW, Preminger GM, Assimos DG, Dretler SP, Kahn RI, Lingeman JE, Macaluso JN Jr. Ureteral Stones Clinical Guidelines Panel summary report on the management of ureteral calculi. The American Urological Association. J Urol. 1997;158(5):1915–21.
12. Hollingsworth JM, Rogers MA, Kaufman SR, Bradford TJ, Saint S, Wei JT, Hollenbeck BK. Medical therapy to facilitate urinary stone passage: a meta-analysis. Lancet. 2006;368(9542):1171–9. Review.
13. Preminger GM, Tiselius HG, Assimos DG, Alken P, Buck C, Gallucci M, et al. EAU/AUA nephrolithiasis guideline panel. 2007 guideline for the management of ureteral calculi. J Urol. 2007;178(6):2418–34. Review.
14. Miller OF, Kane CJ. Time to stone passage for observed ureteral calculi: a guide for patient education. J Urol. 1999;162(3 Part 1):688–90; discussion 690–1.
15. Aboumarzouk OM, Kata SG, Keeley FX, McClinton S, Nabi G. Extracorporeal shock wave lithotripsy (ESWL) versus ureteroscopic management for ureteric calculi. Cochrane Database Syst Rev. 2012;(5):CD006029. https://doi.org/10.1002/14651858.CD006029.pub4.
16. Lotan Y, Gettman MT, Roehrborn CG, Cadeddu JA, Pearle MS. Management of ureteral calculi: a cost comparison and decision making analysis. J Urol. 2002;167(4):1621–9. Review.
17. Nakada SY, Hoff DG, Attai S, Heisey D, Blankenbaker D, Pozniak M. Determination of stone composition by noncontrast spiral computed tomography in the clinical setting. Urology. 2000;55(6):816–9.
18. Kacker R, Zhao L, Macejko A, Thaxton CS, Stern J, Liu JJ, Nadler RB. Radiographic parameters on noncontrast computerized tomography predictive of shock wave lithotripsy success. J Urol. 2008;79(5):1866–71.
19. Ouzaid I, Al-qahtani S, Dominique S, Hupertan V, Fernandez P, Hermieu JF, et al. A 970 Hounsfield

units (HU) threshold of kidney stone density on non-contrast computed tomography (NCCT) improves patients' selection for extracorporeal shockwave lithotripsy (ESWL): evidence from a prospective study. BJU Int. 2012;110(11 Ptrt B):E438–42.
20. Tiryaki T, Azili MN, Özmert S. Ureteroscopy for treatment of ureteral stones in children: factors influencing the outcome. Urology. 2013;81(5):1047–51.
21. Raza A, Smith G, Moussa S, Tolley D. Ureteroscopy in the management of pediatric urinary tract calculi. J Endourol. 2005;19(2):151–8.
22. Desai M. Endoscopic management of stones in children. Curr Opin Urol. 2005;15(2):107–12.
23. Semins MJ, Trock BJ, Matlaga BR. The safety of ureteroscopy during pregnancy: a systematic review and meta-analysis. J Urol. 2009;181(1):139–43.
24. Lifshitz DA, Lingeman J. Ureteroscopy as a first-line intervention for ureteral calculi in pregnancy. J Endourol. 2002;16(1):19–22.
25. Watterson JD, Girvan AR, Cook AJ, Beiko DT, Nott L, Auge BK, et al. Safety and efficacy of holmium:YAG laser lithotripsy in patients with bleeding diatheses. J Urol. 2002;168(2):442–5.
26. Calvert RC, Burgess NA. Urolithiasis and obesity: metabolic and technical considerations. Curr Opin Urol. 2005;15(2):113–7.
27. Pareek G, Hedican SP, Lee FT Jr, Nakada SY. Shock wave lithotripsy success determined by skin-to-stone distance on computed tomography. Urology. 2005;66(5):941–4.
28. Patel T, Kozakowski K, Hruby G, Gupta M. Skin to stone distance is an independent predictor of stone-free status following shockwave lithotripsy. J Endourol. 2009;23(9):1383–5.
29. Aboumarzouk OM, Somani B, Monga M. Safety and efficacy of ureteroscopic lithotripsy for stone disease in obese patients: a systematic review of the literature. BJU Int. 2012;110(8 Part B):E374–80.
30. Chew BH, Zavaglia B, Paterson RF, Teichman JM, Lange D, Zappavigna C, et al. A multicenter comparison of the safety and effectiveness of ureteroscopic laser lithotripsy in obese and normal weight patients. J Endourol. 2013;27(6):710–4.
31. Riley JM, Stearman L, Troxel S. Retrograde ureteroscopy for renal stones larger than 2.5 cm. J Endourol. 2009;23(9):1395–8.
32. Breda A, Ogunyemi O, Leppert JT, Lam JS, Schulam PG. Flexible ureteroscopy and laser lithotripsy for single intrarenal stones 2 cm or greater--is this the new frontier? J Urol. 2008;179(3):981–4.
33. Wolf JS Jr, Bennett CJ, Dmochowski RR, Hollenbeck BK, Pearle MS, Schaeffer AJ, Urologic Surgery Antimicrobial Prophylaxis Best Practice Policy Panel. Best practice policy statement on urologic surgery antimicrobial prophylaxis. J Urol. 2008;179(4):1379–90. Erratum in: J Urol. 2008; 180(5):2262–3.
34. de la Rosette JJ, Skrekas T, Segura JW. Handling and prevention of complications in stone basketing. Eur Urol. 2006;50(5):991–8; discussion 998–9.
35. Kourambas J, Byrne RR, Preminger GM. Does a ureteral access sheath facilitate ureteroscopy? J Urol. 2001;165(3):789–93.
36. L'Esperance JO, Ekeruo WO, Scales CD Jr, Marguet CG, Springhart WP, Maloney ME, et al. Effect of ureteral access sheath on stone-free rates in patients undergoing ureteroscopic management of renal calculi. Urology. 2005;66(2):252–5.
37. Rehman J, Monga M, Landman J, Lee DI, Felfela T, Conradie MC, et al. Characterization of intrapelvic pressure during ureteropyeloscopy with ureteral access sheaths. Urology. 2003;61(4):713–8.
38. Traxer O, Thomas A. Prospective evaluation and classification of ureteral wall injuries resulting from insertion of a ureteral access sheath during retrograde intrarenal surgery. J Urol. 2013;189(2):580–4.
39. Delvecchio FC, Auge BK, Brizuela RM, Weizer AZ, Silverstein AD, Lallas CD, et al. Assessment of stricture formation with the ureteral access sheath. Urology. 2003;61(3):518–22; discussion 522.
40. Johnson GB, Portela D, Grasso M. Advanced ureteroscopy: wireless and sheathless. J Endourol. 2006;20(8):552–5.
41. Patel SR, McLaren ID, Nakada SY. The ureteroscope as a safety wire for ureteronephroscopy. J Endourol. 2012;26(4):351–4.
42. Dutta R, Vyas A, Landman J, Clayman RV. Death of the safety guidewire. J Endourol. 2017;31(6):619–20.
43. Dickstein RJ, Kreshover JE, Babayan RK, Wang DS. Is a safety wire necessary during routine flexible ureteroscopy? J Endourol. 2010;24(10):1589–92.
44. Denstedt JD, Clayman RV. Electrohydraulic lithotripsy of renal and ureteral calculi. J Urol. 1990;143(1):13–7.
45. Denstedt JD, Eberwein PM, Singh RR. The Swiss Lithoclast: a new device for intracorporeal lithotripsy. J Urol. 1992;148(3 Pt 2):1088–90.
46. Webb DR, Kockelburgh R, Johnson WF. The Verapulse holmium surgical laser in clinical urology: a pilot study. Minim Invasive Ther. 1993;2(1):23–6.
47. Vassar GJ, Chan KF, Teichman JM, Glickman RD, Weintraub ST, Pfefer TJ, Welch AJ. Holmium:YAG lithotripsy: photothermal mechanism. J Endourol. 1999;13(3):181–90.
48. Hecht SL, Wolf JS. Techniques for holmium laser lithotripsy of intrarenal calculi. Urology. 2013;81(2):442–5.
49. Sea J, Jonat LM, Chew BH, Qiu J, Wang B, Hoopman J, et al. Optimal power settings for holmium:YAG lithotripsy. J Urol. 2012;187(3):914–9.
50. Spore SS, Teichman JM, Corbin NS, Champion PC, Williamson EA, Glickman RD. Holmium:YAG lithotripsy: optimal power settings. J Endourol. 1999;13(8):559–66.
51. Patel AP, Knudsen BE. Optimizing use of the holmium:YAG laser for surgical management of urinary lithiasis. Curr Urol Rep. 2014;15(4):397.
52. Kronenberg P, Traxer O. Update on lasers in urology 2014: current assessment on holmium:yttrium–alumi-

num–garnet (Ho:YAG) laser lithotripter settings and laser fibers. World J Urol. 2015;33(4):463–9.
53. Bell JR, Penniston KL, Nakada SY. In vitro comparison of holmium lasers: evidence for shorter fragmentation time and decreased retropulsion using a modern variable pulse laser. Urology. 2017;107:37–42.
54. Bell JR, Penniston KL, Nakada SY. In vitro comparison of stone fragmentation when using various settings with modern variable pulse holmium lasers. J Endourol. 2017;31(10):1067–72.
55. Wollin DA, Ackerman A, Yang C, Chen T, Simmons WN, Preminger GM, Lipkin ME. Variable pulse duration from a new holmium:YAG laser: the effect on stone comminution, fiber tip degradation, and retropulsion in a dusting model. Urology. 2017;103:47–51.
56. Maxwell AD, MacConaghy B, Harper JD, Aldoukhi AH, Hall TL, Roberts WW. Simulation of laser lithotripsy-induced heating in the urinary tract. J Endourol. 2019;33(2):113–9.
57. Aldoukhi AH, Ghani KR, Hall TL, Roberts WW. Thermal response to high-power holmium laser lithotripsy. J Endourol. 2017;31(12):1308–12.
58. Humphreys MR, Shah OD, Monga M, Chang YH, Krambeck AE, Sur RL, et al. Dusting versus basketing during ureteroscopy–which technique is more efficacious? A prospective multicenter trial from the EDGE Research Consortium. J Urol. 2018;199(5):1272–6.
59. Lusch A, Heidari E, Okhunov Z, Osann K, Landman J. Evaluation of contemporary holmium laser fibers for performance characteristics. J Endourol. 2016;30(5):567–73.
60. Kronenberg P, Traxer O. The truth about laser fiber diameters. Urology. 2014;84(6):1301–7.
61. Talso M, Emiliani E, Haddad M, Berthe L, Baghdadi M, Montanari E, Traxer O. Laser fiber and flexible ureterorenoscopy: the safety distance concept. J Endourol. 2016;30(12):1269–74.
62. Pais VM Jr, Smith RE, Stedina EA, Rissman CM. Does omission of ureteral stents increase risk of unplanned return visit? A systematic review and meta-analysis. J Urol. 2016;196(5):1458–66.
63. Muslumanoglu AY, Fuglsig S, Frattini A, Labate G, Nadler RB, Martov A, et al. Risks and benefits of postoperative double-J stent placement after ureteroscopy: results from the clinical research office of endourological society ureteroscopy global study. J Endourol. 2017;31(5):446–51.
64. Hollenbeck BK, Schuster TG, Faerber GJ, Wolf JS Jr. Routine placement of ureteral stents is unnecessary after ureteroscopy for urinary calculi. Urology. 2001;57(4):639–43.
65. Chen YT, Chen J, Wong WY, Yang SS, Hsieh CH, Wang CC. Is ureteral stenting necessary after uncomplicated ureteroscopic lithotripsy? A prospective, randomized controlled trial. J Urol. 2002;167(5):1977–80.
66. Pengfei S, Yutao L, Jie Y, Wuran W, Yi D, Hao Z, Jia W. The results of ureteral stenting after ureteroscopic lithotripsy for ureteral calculi: a systematic review and meta-analysis. J Urol. 2011;186(5):1904–9.
67. Jeon SS, Choi YS, Hong JH. Determination of ideal stent length for endourologic surgery. J Endourol. 2007;21(8):906–10.
68. Barrett K, Foell K, Lantz A, Ordon M, Lee JY, Pace KT, Honey RJ. Best stent length predicted by simple CT measurement rather than patient height. J Endourol. 2016;30(9):1029–32.
69. Holden T, Pedro RN, Hendlin K, Durfee W, Monga M. Evidence-based instrumentation for flexible ureteroscopy: a review. J Endourol. 2008;22(7):1423–6.
70. Pasqui F, Dubosq F, Tchala K, Tligui M, Gattegno B, Thibault P, Traxer O. Impact on active scope deflection and irrigation flow of all endoscopic working tools during flexible ureteroscopy. Eur Urol. 2004;45(1):58–64.
71. Hendlin K, Weiland D, Monga M. Impact of irrigation systems on stone migration. J Endourol. 2008;22(3):453–8.
72. Carey RI, Gomez CS, Maurici G, Lynne CM, Leveillee RJ, Bird VG. Frequency of ureteroscope damage seen at a tertiary care center. J Urol. 2006;176(2):607–10; discussion 610.
73. Carey RI, Martin CJ, Knego JR. Prospective evaluation of refurbished flexible ureteroscope durability seen in a large public tertiary care center with multiple surgeons. Urology. 2014;84(1):42–5.
74. Molina W, Warncke J, Donalisio da Silva R, Gustafson D, Nogueira L, Kim F. PD53-03 cost analysis of utilization of disposable flexible ureteroscopes in high risk for breakage cases (abstract). J Urol. 2018;199(4 Suppl):e1047.
75. Schuster TG, Hollenbeck BK, Faerber GJ, Wolf JS Jr. Complications of ureteroscopy: analysis of predictive factors. J Urol. 2001;166(2):538–40.
76. Johnson DB, Pearle MS. Complications of ureteroscopy. Urol Clin North Am. 2004;31(1):157–71. Review.
77. Lamb AD, Vowler SL, Johnston R, Dunn N, Wiseman OJ. Meta-analysis showing the beneficial effect of α-blockers on ureteric stent discomfort. BJU Int. 2011;108(11):1894–902.
78. Yakoubi R, Lemdani M, Monga M, Villers A, Koenig P. Is there a role for α-blockers in ureteral stent related symptoms? A systematic review and meta-analysis. J Urol. 2011;186(3):928–34.
79. Rane A, Saleemi A, Cahill D, Sriprasad S, Shrotri N, Tiptaft R. Have stent-related symptoms anything to do with placement technique? J Endourol. 2001;15(7):741–5.

Endoscopic Incisions

14

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Introduction

Urinary tract obstruction that occurs with ureteropelvic junction obstruction (UPJO) or ureteral and urethral strictures is a complex disease with a multitude of etiologies. Technological advances over the past several years have enabled significant evolution in the management of this disease. With the greater adoption of minimally invasive approaches, endoscopic incisional techniques have become a valuable management option for patients with urinary tract obstruction. Despite lower success rates compared with open and laparoscopic or robotic reconstructive techniques, endoscopic management offers a procedure with minimal morbidity, short convalescence, and low risk of complications. Current literature has demonstrated that with careful patient selection, endoscopic incisional techniques can provide excellent outcomes with satisfactory success rates and minimal postoperative recovery. In this chapter, the indications, techniques, equipment, outcomes and complications related to endopyelotomy, endoureterotomy, and visual urethrotomy will be reviewed for the management of UPJO and ureteral and urethral strictures.

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Ureteropelvic Junction Obstruction

UPJO occurs when the flow of urine from the renal pelvis to the ureter is impaired secondary to blockage. Multiple causes of UPJO have been identified, including both congenital and acquired, as well as intrinsic and extrinsic causes, such as aperistaltic ureteral segments, crossing vessels, and iatrogenic strictures. Congenital UPJO occurs in approximately 1:1000 to 1:2000 newborns, while the overall incidence of UPJO in adults is estimated to be 1:1500 [1, 2]. The presentation of UPJO depends on patient age and can include a flank mass, symptoms of acute renal colic precipitated by fluid diuresis, urinary infections, urolithiasis, and incidental discovery on abdominal imaging. Indications for the correction of UPJO are the presence of symptoms, impaired or declining renal function, and development of renal calculi or infections. If untreated, UPJO can result in renal atrophy secondary to interstitial fibrosis from prolonged obstruction.

Open pyeloplasty using a variety of reconstructive techniques was long considered the gold-standard treatment for patients with UPJO requiring surgical correction. However, the

S. L. Best, S. Y. Nakada (eds.), *Minimally Invasive Urology*,
https://doi.org/10.1007/978-3-030-23993-0_14

introduction and advancement of laparoscopic and robotic instruments and surgical techniques over the past several years have shifted the landscape of pyeloplasty to favor minimally invasive approaches. Many large series have demonstrated comparable success rates of laparoscopic or robotic pyeloplasty to open techniques, with a significant reduction in morbidity [3, 4]. As a result, minimally invasive pyeloplasty has now become a first-line surgical option for many patients with UPJO.

In further attempts to reduce the morbidity and invasiveness of reconstructive pyeloplasty, many endourological techniques have been developed for the treatment of UPJO. These include balloon dilation, electroincision utilizing a cutting balloon (Acucise), percutaneous antegrade and retrograde endopyelotomy, and endopyeloplasty. The reported success rates for endopyelotomy are generally lower than for open or minimally invasive pyeloplasty and range from 67% to 85% [5] (Table 14.1). This has called into question the utility of endopyelotomy, especially in the era of robotic and laparoscopic surgery, which has significantly reduced surgical morbidity associated with pyeloplasty.

However, endopyelotomy continues to have an important place in the armamentarium of techniques for the treatment of UPJO. The reported success rates for endopyelotomy techniques range significantly and likely represent a lack of uniformity in the definition of procedure success and patient selection. Multiple factors have been demonstrated to decrease the success rate of endopyelotomy, such as the presence of a crossing vessel, severe hydronephrosis, a high inserting ureter, long stricture length (>2 cm), and poor ipsilateral renal function (<25%) [14, 16]. Without these factors, the success rate of endopyelotomy has been shown to increase to 94% [17]. In addition, endopyelotomy has the advantage of a shorter operative time, reduced hospital length of stay and postoperative recovery, improved cosmetic result, and lower cost [12]. Also, failed endopyelotomy does not compromise the ability or outcomes of subsequent surgical management [18]. The average complication rate for endopyelotomy is 12.5% and has been reported to range from 5% to 35% in different series; the rates of different complications associated with endopyelotomy are outlined in Table 14.2 [12]. Given this, endopyelotomy is a reasonable first-line treatment option

Table 14.1 Selected contemporary results of endopyelotomy

Author	Number of patients	Success rate (%)		Mean follow-up in months (range)
		Primary UPJO	Secondary UPJO	
Minervini et al. [6]	49 antegrade	70		24 (3–62)
	19 retrograde	56		46 (6–106)
DiMarco et al. [7]	182	65		36
		55		60
		41		120
Doo et al. [8]	77	67.5		37 (3–98)
Vaarala et al. [9]	18 antegrade	92		152
	29 retrograde	86		77
Knudsen et al. [10]	61	65		55 (16–138)
	19		74	
Ponsky and streem [11]	35	73		75 (39–133)
	5		80	
Butani and Eshghi [12]	135	96		60 (3–72)
	20		85	
El-Nahas et al. [13]	50		86	72 (14–166)
Park et al. [14]	20		57–70	47 (6–138)
Corbett and Mullassery [15]	128 pediatric	71		23 (8.5–50)
	92 pediatric		75	31 (8.5–61)

Table 14.2 Reported complication rates of endopyelotomy, endoureterotomy, and visual urethrotomy

Procedure	Complication	Rate (%)
Endopyelotomy/ endoureterotomy [12]	Urinary tract infection	3.8
	Stent-related symptoms	2.5
	Bleeding	0.9
	Hematuria	0.9
	Stent migration	0.8
	Sepsis	0.4
	Urinoma	0.2
	Access failure	0.2
	Collecting system perforation	0.2
Visual urethrotomy [19]	Erectile dysfunction	5
	Urinary incontinence	4
	Extravasation	3
	Urinary tract infection	2
	Hematuria	2
	Epididymitis	0.5
	Urinary retention	0.4
	Scrotal abscess	0.3

for primary UPJO in the appropriately selected patient [16]. Furthermore, endopyelotomy plays an important role in the management of secondary UPJO or treatment following failed pyeloplasty, where success rates increase to 70–87% with long-term follow-up [5, 14].

Balloon dilation was initially a promising treatment option with a short learning curve and minimal risk of bleeding; however, several reports failed to show durable results with a success rate of only 42% [20]. The use of an electrocautery balloon incision device (Acucise), which allows for combination fluoroscopic-guided dilation and incision, demonstrated reasonable short-term outcomes [21]. However, longer-term follow-up showed inferior results with a success rate of only 32% [21]. In addition, a potential for major hemorrhagic complications secondary to the incision of a crossing vessel has been reported [22].

A modified technique termed endopyeloplasty, which combines percutaneous antegrade endopyelotomy incision with intracorporeal suturing utilizing a Heineke-Mikulicz reconstruction, has also been described [23]. While promising short-term results have been reported, longer-term follow-up is required to determine the role of this technique in the treatment of UPJO [24].

In comparison, endopyelotomy both through a retrograde or percutaneous antegrade approach has much higher reported success rates of 56–96% and 41–92% respectively [6–8, 12]. These acceptable success rates, combined with the minimal morbidity of endopyelotomy, make it a reasonable first-line option for the treatment of primary UPJO in adults [12]. The reported outcomes of several contemporary series with long-term follow-up are listed in Table 14.1 [6–15]. At present time, the most commonly indicated role for endopyelotomy is in the management of a secondary UPJO scenario, where previous open/laparoscopic/robotic pyeloplasty was unsuccessful [25, 26].

While the use of endopyelotomy has been shown to be successful in the pediatric population, its utilization is limited by the requirement for fluoroscopy, smaller caliber ureters in younger patients, and the need for a second anesthetic in order to remove the stent following the procedure [27]. In addition, several reports have demonstrated a decreased effectiveness of endopyelotomy for the treatment of secondary UPJO in children, possibly due to narrower ureters [28]. The following sections will review the surgical steps involved in endopyelotomy via both retrograde and percutaneous antegrade approaches.

Technique: Percutaneous Antegrade Endopyelotomy

Patients undergoing endopyelotomy should have preoperative imaging performed in order to delineate the length of the narrowed segment, degree of hydronephrosis, presence of a crossing vessel, insertion of the ureter, and presence and location of concomitant stones, ideally with a computed tomography (CT) urogram. Additional considerations when performing a percutaneous antegrade approach include the

location of ipsilateral adjacent structures such as the pleura, colon, and spleen or liver. Diuretic renography is helpful to quantify both the degree of obstruction and the differential renal function. Preoperative prophylactic antibiotics are recommended for all patients undergoing both percutaneous renal surgery and retrograde ureteral surgery [29].

Following the induction of general anesthesia, the patient is placed in a prone position. Care is taken to ensure that all pressure points are adequately padded and joints are appropriately supported. Flexible cystoscopy is undertaken in the prone position, and a Teflon-coated guidewire is advanced into the kidney and then replaced with a 5 French (Fr) ureteric catheter. If there is difficulty in navigating the wire beyond the ureteropelvic junction (UPJ), the use of a hydrophilic guidewire (straight or angled) can be helpful. Combining the hydrophilic wire with an angled 5 Fr angiographic catheter (Kumpe catheter) can be utilized to provide additional control in directing the guidewire if there is significant tortuosity of the ureter.

A retrograde pyelogram is then performed to further characterize the narrowing of the UPJ and assist with percutaneous renal access. An upper or middle pole posterior calyx is preferable for renal access as it allows for a straighter path to the UPJ and minimizes torqueing on the renal parenchyma, which can increase bleeding. An 18-guage access needle is used to puncture the collecting system through a renal papilla, and a hydrophilic guidewire is then advanced into the renal pelvis and through the UPJ. The use of a Kumpe catheter can be especially valuable in navigating the guidewire down the ureter. However, due to the narrow UPJ and dilated renal pelvis, it is often not possible to initially advance the wire beyond the UPJ. In this instance, the hydrophilic wire can be exchanged for an extra-stiff guidewire, which is then amply curled within the voluminous renal pelvis, and allows for dilation of the tract.

Tract dilation can be performed with either serial dilators or a balloon catheter, as with standard percutaneous nephrolithotomy. If concomitant calculi are present that require fragmentation and removal, a 30 Fr working sheath should be utilized in order to allow the passage of a rigid nephroscope. If this is not required, a 24 Fr tract is recommended as it allows for the use of a 21 Fr cold knife endopyelotome and reduces trauma to the renal parenchyma. If renal calculi are present, they should be completely removed prior to endopyelotomy in order to avoid the extrusion of stone fragments into the retroperitoneal space.

If a guidewire was not previously placed across the UPJ, once the percutaneous tract has been dilated, nephroscopy can then be used to facilitate the passage of the guidewire down the ureter under direct vision. If this is unsuccessful, a long exchange wire (270 cm) can be advanced through the 5 Fr ureteral catheter in a retrograde fashion and grasped with the rigid nephroscope using the duckbill forceps. The exchange wire is then brought out through the flank, thereby creating through-and-through access. Every effort should be made to pass the guidewire through the UPJ and into the bladder, as through-and-through access is critical to performing a safe endopyelotomy. If a safety guidewire cannot be placed across the UPJ, the procedure should be aborted and an alternative approach selected.

Once a guidewire across the stricture has been secured, the area of a narrowing is dilated with a ureteral balloon-dilating catheter (6 mm-diameter, 10 cm-length) under fluoroscopy. This allows for a clear demarcation of the area of narrowing and increases the working space for the endopyelotome. Endopyelotomy was originally described by Smith et al. utilizing an endopyelotome with a "cold knife" technique [30] (Fig. 14.1). Various blades are available; however, our preference is the hooked blade (Fig. 14.2). Other modalities of incision have been reported, including electrosurgical incision and laser-energy sources; however, outcomes are similar regardless of the cutting modality utilized [8].

Regardless of the tool and energy source used for endopyelotomy, the incision should be made in the true lateral orientation in order to minimize the risk of lacerating a crossing vessel. In addition, prior to the incision, preoperative imaging should be reviewed to identify the location of any potential vessels, and the UPJ area should be

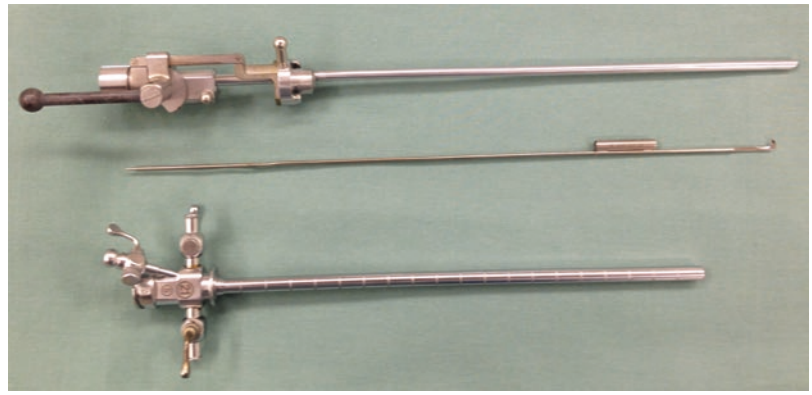

Fig. 14.1 Endopyelotome with cold knife

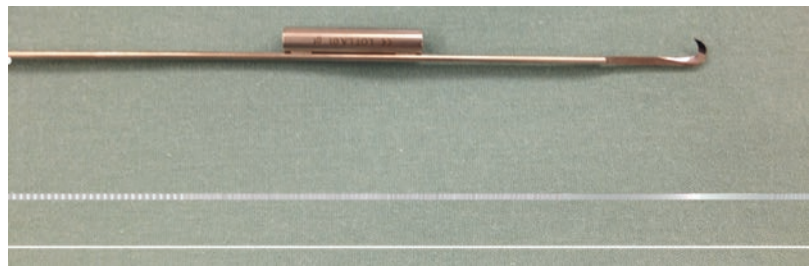

Fig. 14.2 Hooked blade for endopyelotome

closely visualized for any pulsations suggestive of an overlying artery. The incision should encompass the entire length of the narrowed segment and extend at least 1 cm both proximally and distally. Adequate depth is achieved when perinephric fat is visualized. Following the endopyelotomy incision, balloon dilation should be repeated to confirm that all fibrotic bands have been transected.

Following the endopyelotomy, a ureteric stent is inserted in an antegrade fashion; this is based on the technique of intubated ureterotomy described by Davis [31]. There is currently no consensus regarding the optimal stent size and period of stent placement. Some advocate the use of smaller 6–8 Fr stent, while others utilize a larger diameter stent [32]. Our practice is to insert a 14/7 Fr endopyelotomy stent in an antegrade fashion. When Davis initially described the technique of intubated ureterotomy in 1943, a period of stenting for 6 weeks was recommended [31]. However, multiple contemporary series have demonstrated no difference in short-term outcomes with shorter periods of stenting ranging from 2 to 4 weeks [33, 34].

In addition to the ureteric stent, drainage with a nephrostomy tube and Foley catheter is also recommended. We typically utilize a 16 Fr Councill-tip catheter for a nephrostomy tube, which is removed within 48–72 h if the urine is clear and the patient is afebrile. The Foley catheter can be removed once the nephrostomy tube has been discontinued and the flank site is dry. Premature removal of the Foley catheter can cause urine reflux, which may result in persistent flank drainage or urine extravasation.

Once the ureteric stent has been removed, the patient should be followed clinically with regular anatomic imaging, such as a CT urogram or an intravenous pyelogram (IVP), as well as a diuretic renogram. We typically perform an IVP or CT urogram 6 weeks following stent removal, followed by a Lasix renogram 6 weeks later. Repeat imaging should then be performed annually, or sooner if the patient develops recurrent symptoms. There is no consensus on the optimal duration of a follow-up after endopyelotomy. The majority of failures from endopyelotomy occur within the first 2 years; however, recurrences have been demonstrated as late as 10 years

after surgery [6, 7]. It is our practice to follow patients with routine imaging for a duration of 5 years.

Technique: Retrograde Endopyelotomy

Retrograde endopyelotomy allows treatment of UPJO without the need for percutaneous access. This provides many advantages such as reduced blood loss, shorter hospital stay, and faster recovery time compared with antegrade endopyelotomy [35]. However, there are some important disadvantages to consider; specifically, a smaller endoscope is utilized, which results in a narrower field of vision, smaller working space, and reduced irrigation flow compared to the antegrade approach. In addition, the presence of renal calculi is a contraindication for retrograde endopyelotomy as there is a risk of extravasation of stone fragments into the retroperitoneal space. In this case of concomitant renal calculi, an antegrade approach is required.

Preoperative preparation is similar to antegrade endopyelotomy with regard to the requirement for preoperative imaging and prophylactic antibiotics. Retrograde endopyelotomy is performed with the patient under general anesthesia and placed in the dorsal lithotomy position. A retrograde pyelogram is performed in order to delineate the anatomy of the UPJ, specifically the length and degree of narrowing. An extra-stiff guidewire is then advanced and coiled in the renal pelvis. If the UPJ is very tight or there is significant ureteral tortuosity, additional techniques utilizing a hydrophilic guidewire with or without a Kumpe catheter can be employed as described above. The placement of a safety guidewire across the UPJ is essential for a safe endopyelotomy, and if a guidewire cannot be placed the procedure should be aborted and an alternative treatment approach should be considered.

Once a guidewire is secured across the UPJ, balloon dilation is then performed across the area of narrowing, utilizing a ureteral balloon-dilating catheter (6 mm diameter, 10 cm length) under fluoroscopy. The balloon should be dilated until a "waist" is no longer present. This will help to delineate the area of narrowing and provide increased working space for the endopyelotomy.

Retrograde endopyelotomy is most commonly performed utilizing a flexible ureteroscope. The length of the male urethra requires the use of a flexible ureteroscope in order to be able to access the UPJ properly. In females, the UPJ can often be reached with a semi-rigid ureteroscope; however, the potential for ureteral trauma with this approach is higher. Consequently, we recommend the use of a flexible ureteroscope in both circumstances. To advance the flexible ureteroscope, a second wire is inserted to the level of the UPJ utilizing either a dual lumen catheter or an 8/10 Fr coaxial dilator. The ureteroscope is then passed over the second wire, in a coaxial fashion under fluoroscopy, up to the level of the UPJ.

Prior to making the endopyelotomy incision, the UPJ area should be closely visualized for any pulsations, which may indicate an overlying crossing vessel. Similar to the antegrade approach, the incision should be made in the true lateral direction and extend 1 cm both proximal and distal to the area of narrowing. The incision should reach a depth where periureteral fat is visualized. Multiple mechanisms for making the incision have been described, including the Bugbee electrode and the Holmium:YAG laser; however, the laser is most commonly utilized [6]. A 270 nm laser fiber is small enough to permit adequate irrigation flow and a deflection of the flexible scope, which allows for adequate precision of the endopyelotomy incision. Typical laser settings are 0.5–1.5 J/pulse with a rate of 5–15 Hz. Following laser incision, balloon dilation of the UPJ should be repeated to ensure a complete incision of the narrowed segment.

Following the completion of the endopyelotomy, a stent is inserted in a retrograde fashion. As discussed above, there is no consensus regarding the ideal size and duration of the stent following endopyelotomy. It is our practice to place a 14/7 Fr endopyelotomy stent at the end of the procedure. We typically utilize a stent one size longer than the patient's height in order to prevent downward migration of the proximal coil of the stent

into the freshly incised UPJ [10]. A Foley catheter is placed for 48 h, and the stent is removed after 6 weeks. Once again, follow-up anatomical and functional imaging is required, and is performed as described above.

Ureteral Strictures

The etiology of ureteral strictures include trauma, stone impaction, radiation, malignancy, and infection, with the most common cause being iatrogenic injury from gynecological, vascular, general surgical, or endoscopic procedures [36]. The overall rate of ureteral stricture formation following ureteroscopy is estimated to be 1% but has shown to increase to 5–24% with a long duration of stone impaction [36].

A plethora of reconstructive and endoscopic procedures can be considered for the management of ureteral strictures. Technique selection depends on a number of important factors, including the length, location, and etiology of the stricture, as well as the degree of periureteral tissue involvement, ipsilateral and global renal function, and the patient's overall health status. A variety of surgical reconstructive procedures, including ureteroureterostomy, ureteroneocystostomy, Boari flap, transureteroureterostomy, ileal ureteral interposition, and renal autotransplant, can be performed through open, laparoscopic, or robotic approaches. While these techniques typically offer more definitive management with higher reported success rates, they are associated with increased operative morbidity and longer recovery times.

Alternatively, a number of endoscopic management options have evolved, including ureteral stent placement, balloon dilation, and endoureterotomy. While success rates for these procedures are inferior to surgical reconstruction, they remain an important option for the treatment of ureteric strictures in the appropriately selected patient. An understanding of the etiology of the stricture, as well as its anatomical characteristics, can aid in selecting the most appropriate treatment choice. Preoperative imaging should include a contrast study such as an IVP, CT urogram, and retrograde or antegrade pyelogram in order to characterize the stricture location, length, and caliber of the lumen. Strictures with a completely obliterated ureteral lumen will fail endoscopic approaches and should be treated with a surgical reconstruction. Diuretic renography should also be performed in order to determine both ipsilateral and global renal function, as well as the degree of obstruction. If ipsilateral renal function is considerably compromised, nephrectomy may be the most appropriate treatment modality.

Endoscopic management of ureteric strictures is best suited for patients with benign or non-ischemic etiologies, short stricture length (<2 cm), good ipsilateral renal function (>20%), and nonradiated fields and patients who have not previously failed the management of their stricture [37]. In addition, endoscopic techniques offer the advantage of shorter operative time, decreased morbidity, reduced hospital stay and recovery times, lower cost, and improved cosmetic results [17].

Ureteral stent placement is an effective short-term intervention that relieves the effects of obstruction and protects the kidney from damage while definitive therapy is being considered. In very select patients who are not candidates for reconstructive procedures, such as those with significant medical comorbidities or a short life expectancy, a chronic indwelling stent may be a reasonable management option. In this circumstance, the ureteral stent must be exchanged every 3–4 months in order to prevent encrustation.

Balloon dilation alone is rarely an effective treatment for ureteral strictures with only modest reported success rates of between 40% and 75% [38]. However, in selected circumstances when there is a short segment stricture with minimal periureteral fibrosis and no ischemia, ureteral strictures can be managed with balloon dilation alone [39]. Balloon dilation has also been shown to be less effective for strictures located in the mid-ureter [39]. Previous studies have failed to demonstrate an optimal balloon diameter and pressure, with most studies reporting similar outcomes [40]. Given that balloon dilation alone is rarely effective

Table 14.3 Selected contemporary results of endoureterotomy

Author	Number of patients	Success rate (%)			Mean follow-up in months (range)
		Orthotopic	Transplant	Ureteroenteric	
Razdan et al. [41]	50	74			75 (6–108)
Lane et al. [42]	19	68			36 (5–84)
Hibi et al. [43]	18	80			60 (46–74)
Gnessin et al. [44]	35	79			27 (10–72)
Kristo et al. [45]	3		100		24 (6–33)
Gdor et al. [46]	6		67		58 (13–89)
He et al. [47]	8		62		16 (4–45)
Mano et al. [48]	12		83		44 (2–68)
Laven et al. [49]	16			57	20 (9–41)
Watterson et al. [50]	23			71	23 (3–68)
Poulakis et al. [51]	40			60.5	38 (12–85)
Milhoua et al. [52]	15			33	23 (6–86)
Hu et al. [53]	32			69	22 (6–36)

as a monotherapy, it is more commonly used in conjunction with endoureterotomy.

Similar to endopyelotomy, endoureterotomy can be performed using either an antegrade or retrograde approach. Strictures involving the distal and mid-ureter are typically approached in a retrograde fashion with a semi-rigid ureteroscope, while proximal ureteric strictures can be treated through a percutaneous antegrade approach or retrograde technique utilizing a flexible ureteroscope. Reported success rates are comparable for each approach and range from 66% to 83%; the reported outcomes of several contemporary series with long-term follow-up are listed in Table 14.3 [41–53]. The average complication rate following endoureterotomy is reported to be 5.7%, and specific complications are outlined in Table 14.2 [12]. The following section details the surgical steps involved in endoureterotomy.

Technique: Endoureterotomy

Preoperative evaluation and preparation is similar to that previously described for endopyelotomy. General anesthesia is typically utilized; however, spinal anesthesia can be considered for mid or distal ureteric strictures being treated with a retrograde approach. To perform retrograde endoureterotomy, the patient is put in a dorsal lithotomy position, whereas the patient is placed prone if an antegrade approach is utilized, similar to percutaneous nephrolithotomy.

Regardless of the approach being used, the first step is to perform a high-quality contrast study in order to visualize the narrowed ureteral segment. A guidewire is then placed across the strictured segment. This can often be challenging depending on the degree of narrowing and tortuosity of the ureter. If required, a hydrophilic guidewire with or without the addition of a Kumpe catheter can be used to help negotiate the guidewire beyond the stricture. If it is not possible to pass a wire beyond the stricture, the endoureterotomy should be aborted and consideration should be given to alternative treatment modalities. This is due to the significant risk of losing the true lumen of the ureter, which can result in vascular or bowel injury. A "cut to the light" method has been described for the endoscopic treatment of an obliterated ureter, where a new lumen is created using fluoroscopic and visual guidance from above and below the stricture [19]. However, the long-term results of this approach have not proven to be durable, and these strictures are better managed with a surgical reconstructive procedure [19].

Once the safety guidewire has been placed, balloon dilation of the stricture should be per-

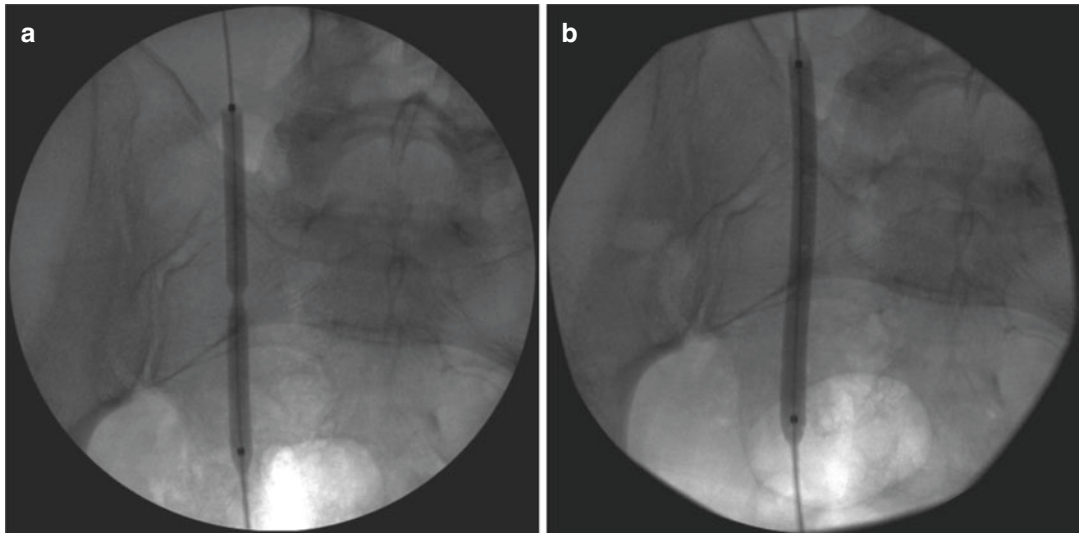

Fig. 14.3 (**a**) "Waisting" seen during balloon dilation of ureteral stricture. (**b**) Resolution of "waisting" with adequate dilation of ureteral stricture

formed, utilizing a ureteral balloon-dilating catheter (6-7 mm diameter, 10 cm length), to remove any "wasting" if possible (Fig. 14.3). Ureteroscopy is then performed to visualize the stricture. If using a semi-rigid ureteroscope, the single safety guidewire is adequate. If a flexible ureteroscope is being utilized, a second guidewire is advanced to the level of the stricture in order to allow for a coaxial advancement of the ureteroscope under fluoroscopy. The area of the stricture should be carefully visualized for any vascular pulsations, especially for ureteral strictures near the iliac vessels. Endoureterotomy incisions can be performed with a cold knife, electrosurgery, and laser energy sources [41, 44]. Published reports have shown no clear advantage of one modality over another; however, the Holmium:YAG laser is most commonly utilized due to its ability to precisely incise tissue with both semi-rigid and flexible ureteroscopes without compromising irrigation flow or endoscope deflection [41, 44].

The location of the incision should be carefully considered in order to avoid injury to periureteral vascular structures. For proximal strictures, the endoureterotomy incision should be orientated laterally or posterolaterally, similar to an endopyelotomy incision [54]. This will avoid the medial blood supply of the ureter or a potential crossing vessel. For mid-ureteral strictures, it is imperative to avoid the iliac vessels and ureteral blood supply; consequently, the incision should be made in an anterior direction [54]. Inadvertent laceration of an iliac vessel can result in massive hemorrhage and may be life threatening [55]. For distal ureteral strictures, an anteromedial orientation incision is recommended; however, one must be cautious of a potential overlying bowel, which may be in close proximity [54]. A careful review of preoperative imaging can help plan the safest incision site.

Similar to the technique for endopyelotomy, the incision for endoureterotomy should extend 1 cm both proximal and distal to the area of stricture and be made full thickness until periureteric fat is identified. Following the incision, balloon dilation should be repeated to ensure that all fibrotic bands have been adequately incised and there is no persistent narrowing. Following this, a stent should be placed. As with endopyelotomy, the optimal size and duration of stenting has not been determined. Our practice is to typically leave a stent for 6 weeks. Following stent removal, follow-up anatomical and functional imaging is required. We recommend a contrast study such as an IVP or CT urogram 6 weeks following stent

removal and a diuretic renogram 3–6 months later in order to rule out persistent obstruction and document renal function. Depending on the etiology of the stricture, recurrence is a potential concern, requiring periodic radiologic and functional surveillance.

Special Situations

Transplant Ureterovesical Anastomotic Strictures

Ureterovesical anastomotic strictures occur in 1–5% of kidney transplant recipients and are often ischemic in nature [48]. Surgical revision or reimplantation can be technically challenging in this already complex patient population. Consequently, endoscopic management of anastomotic strictures offers an attractive option. Similar to ureteral strictures, balloon dilation alone has demonstrated disappointing results with success rates of only 33–53% [46]. However, endoureterotomy has yielded promising results for the management of ureterovesical anastomotic structures with success rates of 67–100% [45–48]. Successful endoureterotomy was more common with short, nonischemic strictures (<1 cm), which had not previously failed endoscopic management [56]. Selected series reporting the use of endoureterotomy for ureterovesical anastomotic strictures are outlined in Table 14.3 [45–48].

The technique for endoureterotomy of a transplant ureterovesical anastomotic stricture is similar to the previously described technique. It can be approached in either an antegrade or retrograde fashion; however, an antegrade approach with a flexible endoscope is most commonly utilized due to the potential difficulty in retrograde access, depending on the location of ureterovesical anastomosis within the bladder (Fig. 14.4). The placement of a guidewire across the stricture is essential prior to undertaking any endoscopic incision. The endoureterotomy incision should be made with the Holmium:YAG laser and directed anteromedially. An internal ureteral or internal/external stent should be kept postoperatively for 6 weeks. Again, there is no strong data available regarding the optimal size and duration of stenting following endoureterotomy.

Ureteroenteric Anastomotic Strictures

Ureteroenteric anastomotic strictures following cystectomy and urinary diversion occur in approximately 3–10% of patients [57]. Stricture rates have been observed to be similar between continent and incontinent diversions, as well as between robotic and open procedures [57]. However, the type of anastomosis has been shown to greatly affect long-term patency, with nonrefluxing anastomoses having a much high rate of stricture formation [58]. In addition, the left ureter is more commonly affected due to the higher risk of ischemia with the greater amount of ureteral mobilization required [58].

As with other types of ureteric strictures, imaging studies are an important part of the preoperative evaluation of ureteroenteric anastomotic strictures. A CT urogram is valuable not only for identifying the length and location of the stricture but also for identifying adjacent structures, especially overlying bowel. In addition, a loopogram may also help to further clarify the anatomy of the diversion (Fig. 14.5). Most commonly, patients with a ureteroenteric anastomotic stricture will have a nephrostomy tube placed in order to relieve the obstruction; this provides an excellent opportunity to perform an antegrade nephrostogram in order to further delineate the anatomy of the stricture. In patients with a history of urothelial carcinoma, it is important to consider recurrent malignancy as a potential cause of the obstruction, and this should be excluded through a review of the cystectomy pathology, preoperative imaging, and urine cytology.

Similar to other types of ureteral strictures, balloon dilation and electroincision utilizing a cutting balloon have been shown to have inferior results compared with endoureterotomy [52]. Overall, the success rates of endoureterotomy for ureteroenteric strictures are reported between 50% and 80% [49, 51]. The rates of recurrence following endoureterotomy are much higher for longer strictures

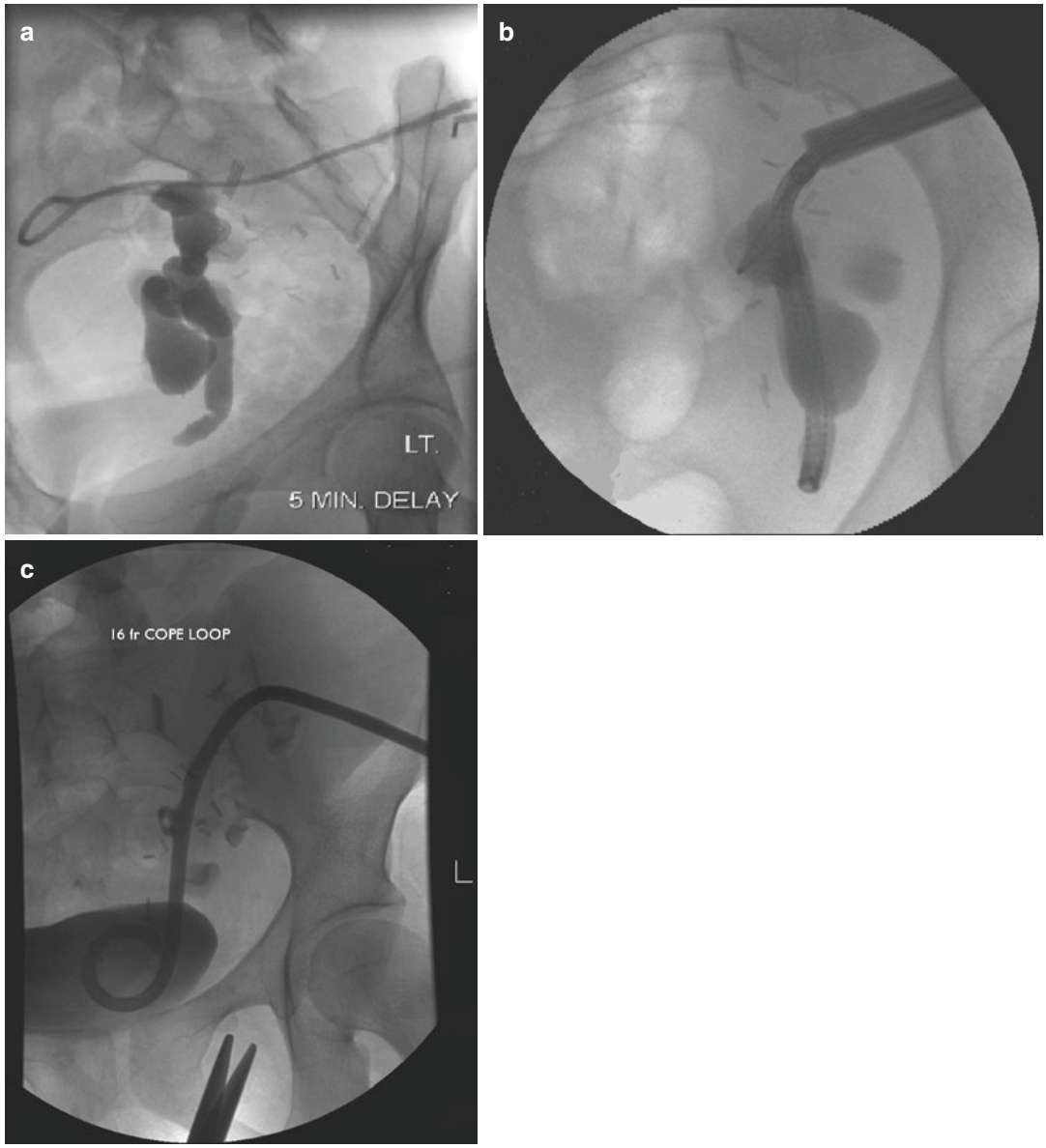

Fig. 14.4 (**a**) Nephrostogram demonstrating ureteral stricture in a transplant ureter. (**b**) Flexible endoscope used to visualize and incise the stricture. (**c**) Cope loop stent placed across the stricture after incision

(>1 cm) and increase with longer follow-up time [51]. A number of selected series reporting the use of endoureterotomy for ureteroenteric strictures are detailed in Table 14.3 [49–53].

Both retrograde and antegrade approaches to endoureterotomy for ureteroenteric strictures have been described; however, the antegrade technique is more commonly utilized. Once again, guidewire advancement across the narrowed ureteral segment is paramount to a safe endoureterotomy, and failure to achieve this critical step should lead to the abandonment of the procedure and consideration of an open surgical repair. For most patients, a flexible cystoscope can be passed antegrade and reach the anastomotic site; this allows for an improved field of view and irrigation flow. A similar technique as described above should be employed with initial balloon dilation, followed by a Holmium:YAG laser endoureterotomy incision and then a

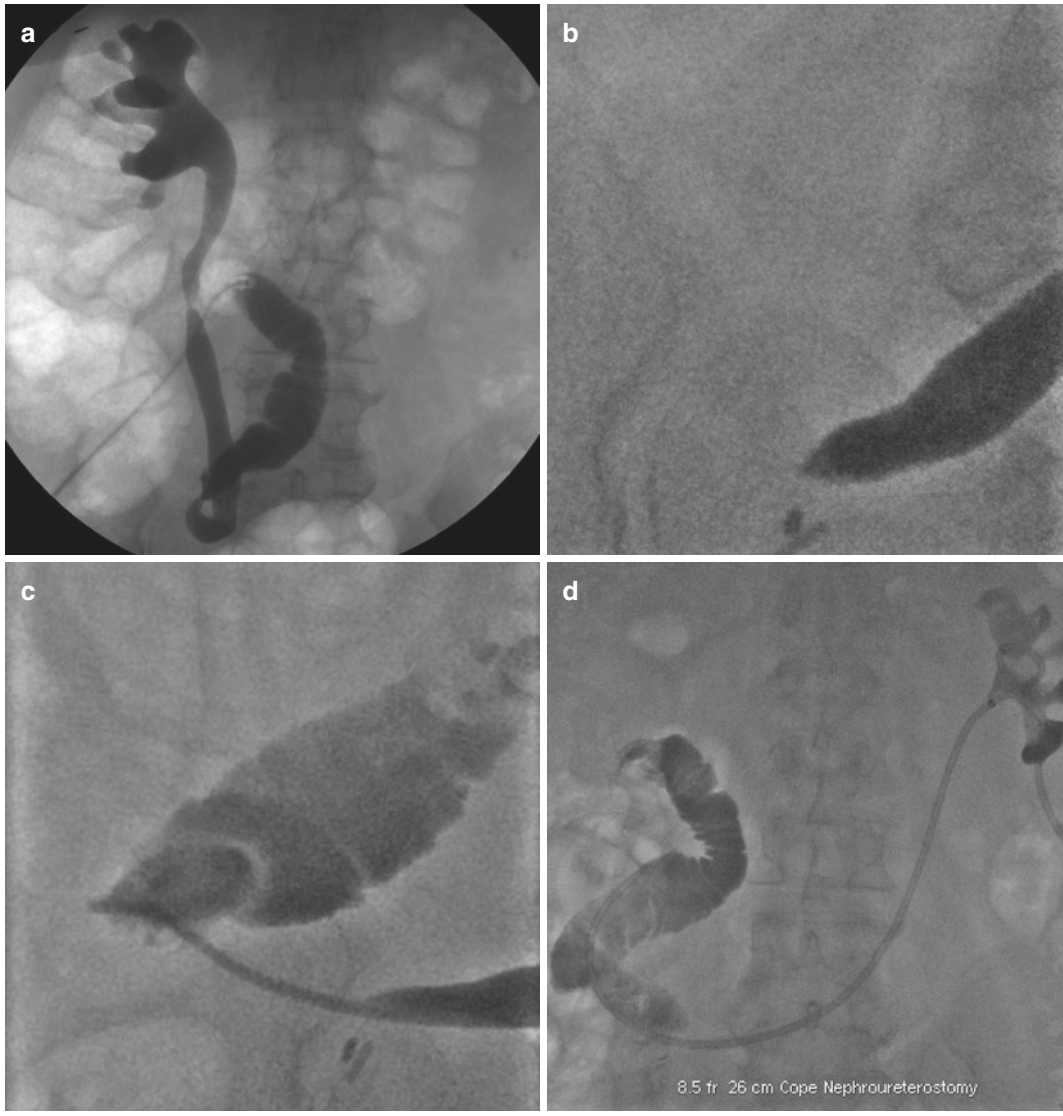

Fig. 14.5 (**a**) Loopogram showing nonvisualization of left uretero-enteric anastomosis. (**b**) High-grade left uretero-enteric stricture shown on antegrade nephrostogram. (**c**) Antegrade nephrostogram showing long narrow strictured segment, with Kumpe catheter traversing the stricture. (**d**) Internal-external stent postballoon dilation of stricture

repeated balloon dilation. Once again, a ureteric stent and nephrostomy tube should be left at the completion of the procedure.

Urethral Strictures

The incidence of urethral stricture disease varies from 10 to 627/100,000 based on geographic location and patient age [59]. The most common etiologies for urethral strictures include blunt perineal trauma, pelvic fractures, infection, inflammatory processes, and iatrogenic causes from urethral instrumentation [59].

Prior to any planned intervention, the key characteristics of the urethral stricture, including the location, length, depth, and presence of spongiofibrosis, should be delineated in order to appropriately guide management decisions. Physical examination allows for a determination of the

depth of the stricture and the presence of spongiofibrosis with palpation. The location and length of the stricture can be determined with cystourethroscopy, retrograde urethrogram, or endoluminal or transcutaneous ultrasound [60]. Cystourethroscopy can also be performed in an antegrade fashion if the patient has a suprapubic catheter or with a pediatric cystoscope to allow for further evaluation.

Many endoscopic and open surgical approaches to the treatment of urethral strictures have been described. Urethral dilation represents the oldest and most widely practiced treatment modality. Although urethral dilation is easy to perform, with minimal morbidity, dilation alone is rarely adequate to provide a long-term resolution of the stricture unless it is very short in length without any significant spongiofibrosis [61].

In comparison, visual internal urethrotomy is also a relatively simple technical procedure with minimal postoperative morbidity but is associated with significantly higher success rates. Similar to all of the incisional techniques described in this chapter, proper patient selection is essential for successful outcomes of visual internal urethrotomy. Most successful outcomes are observed in patients with short strictures (<1.5–2 cm) involving the bulbous urethra without deep or dense spongiofibrosis [61]. Visual internal urethrotomy for the treatment of strictures with these characteristics has demonstrated 3-month resolution rates of up to 70%, with 50–60% of patients remaining stricture-free at 4 years [62]. Treatment of longer or denser strictures shows reduced success rates of only 20–35% [61]. Results from a number of contemporary series examining the outcomes of visual urethrotomy are detailed in Table 14.4 [56, 61–71]. There is an average complication

Table 14.4 Selected contemporary results of visual urethrotomy

Author	Number of patients	Procedure	Success rate (%)	Mean follow-up in months (range)
Aldbers et al. [63]	357	Cold knife with CIC	73	55 (9–192)
	580	Cold knife (unknown adjuvant)	55	38 (3–42)
Steenkamp et al. [61]	104	Cold knife	60	12 (1–49)
	106	Filiform	20	
Heyns et al. [62]	168	Cold knife	50	42 (2–63)
Hafez et al. [64]	31	Cold knife (pediatric)	35.5	79 (24–240)
Hosseini et al. [65]	34	Cold knife + CIC	66	12
	30	Cold knife + steroid gel CIC	70	12
Lauritzen et al. [66]	162	Urethrotomy	69	23 (0.2–70)
	55	Urethrotomy + CIC	81	29 (1–66)
Gucuk et al. [67]	15	Cold knife + steroid gel CIC	80	16 (6–18)
	15	Cold knife + CIC	53	
	15	Cold knife + Foley (3 days)	40	
Mazdak et al. [68]	22	Cold knife	50	13 (1–25)
	23	Cold knife + submucosal steroid	78	
Tavakkoli et al. [69]	36	Cold knife + placebo injection	50	8 (6–24)
	34	Cold knife + steroid injection	78	
Jordan et al. [70]	29	Urethrotomy + Foley	17	12
	63	Urethrotomy + Memokath	79	
Cai et al. [56]	27	Bipolar	81.5	14 (12–21)
	26	Cold knife	53.8	
Holzhauer et al. [71]	127	Cold knife	42	16.4 (13.6–19.3
	65	Ho:YAG laser	31	17.5 (13.9–21)

CIC clean intermittent catheterization; Memokath (Engineers & Doctors A/S, Hornbaek, Denmark)

rate of 6.5% for visual urethrotomy, and specific rates of complications are outlined in Table 14.2 [19].

The decision on the initial treatment modality for a urethral stricture should be based on the characteristics of the stricture, treatment goals, and patient preferences. If initial visual urethrotomy fails to adequately treat the stricture, reassessment of all possible treatment options should be made as repeated visual urethrotomy may result in repeated surgical trauma, which can lead to a worsening of the initial stricture [61]. The following section outlines the surgical technique of visual urethrotomy.

Technique: Internal Urethrotomy

For internal urethrotomy, preoperative prophylactic antibiotics are recommended. The patient should be placed in the dorsal lithotomy position following the induction of spinal or general anesthetic. The first step is to perform urethroscopy in order to confirm stricture location and the degree of luminal narrowing. A rigid adult or pediatric cystoscope can be utilized depending on the severity of the stricture narrowing. It is our preference to pass a Teflon-coated guidewire across the stricture and into the bladder during initial urethroscopy. This allows for coaxial dilation, which facilitates easier advancement of the visual urethrotome and allows for easy placement of a Councill catheter at the completion of the procedure.

Visual internal urethrotomy can be performed using a variety of modalities, such as a cold knife, electrosurgical, or Holmium:YAG laser incision. All techniques have been demonstrated to be comparable in terms of short-term success rates and complications [71]. Our preference is to perform a cold knife incision utilizing the "half-moon" blade (Fig. 14.6). Regardless of the cutting modality used, a single incision at the 12 o'clock location should be performed through the avascular scar and into healthy bleeding tissue. The stricture should be incised slightly beyond its full length and depth in order to allow for healing by secondary intention; however, care should be taken to avoid very deep incisions into the corpora, which can result in excessive bleeding and erectile dysfunction.

Fig. 14.6 "Half-moon" blade used for cold knife visual internal urethrotomy

A urethral catheter should be left in place postoperatively. However, significant controversy exists in the literature regarding the optimal size and duration of catheterization. Some reports have demonstrated improved results with longer catheterization intervals, whereas other series report no difference between 6 weeks and 7 days of catheterization [64]. Furthermore, others have demonstrated that catheterization longer than 3 days was associated with increased stricture recurrence [63]. Alternatively, many reports have shown improvement in success rates with self-

catheterization postoperatively and further improvement with steroid lubrication of the catheter [65, 68, 69]. The results of these studies are outlined in Table 14.4.

No standardized follow-up regimen has been established post visual internal urethrotomy. However, given the potentially high failure rate, it is prudent to periodically reassess patients for worsening symptoms and signs of stricture recurrence. The use of routine serial voiding symptom scores (AUA symptom index), uroflowmetry, and postvoid residual may allow for earlier detection of stricture recurrence before urinary retention or bladder decompensation occurs.

Conclusions

Endoscopic incisions are an important technique in the armamentarium for the management of UPJO, ureteral and urethral strictures. Improvements in both endoscopic equipment and techniques have allowed for significant advances in the endoscopic approach. These techniques provide a minimally invasive alternative to more technically complex procedures and are often associated with shorter operative times, reduced hospital stay and postoperative recovery, and lower costs. Satisfactory success rates have been demonstrated in appropriately selected patients, allowing endoscopic techniques to become a first-line option in certain circumstances. Further research will allow for a continued development of these techniques and an improved understanding regarding ideal patient selection.

Endopyelotomy and Endoureterotomy Equipment List

- *Percutaneous access*: Needle trocar 18GA × 15 cm disposable, Glidewire 0.035 in. × 150 cm angled tip (Glidewire; Terumo, Somerset NJ), angiographic Beacon tip (Kumpe) catheter 5 Fr × 0.038 in. × 40 cm (65 cm optional), Amplatz extra-stiff 0.035 in. × 150 cm straight-tip Teflon-coated guidewire, balloon dilator set with 30 Fr access sheath, or coaxial dilators 12–30 Fr
- *Retrograde access*: Flexible cystoscope, Bentson 0.035 in. × 145 cm Teflon-coated straight guidewires, Pollack ureteral 5 Fr 70 cm open-ended flexi-tip ureteral catheter, 12 cc Luer Lock syringe, contrast Conray 200 (Mallinckrodt, St. Louis, MO) (or Isovue 200; Bracco, Milan, Italy)
- *Working instruments*: For antegrade procedure at UPJ, rigid nephroscope, duckbill forceps, Ascend ureteral catheter 6 mm × 10 cm dilation balloon 65 cm length, 21 Fr endopyelotome, hook blade
- For antegrade ureteral or proximal retrograde procedure: flexible ureteroscope, Holmium:YAG laser and fibers (150–270 nm)
- For retrograde procedure in distal ureter: semi-rigid ureteroscope 6.9 Fr with 150–400 nm Holmium:YAG laser fibers
- Others: 8/10 Fr coaxial dilator and working sheath, Councill-tip 2-way 16 Fr Foley catheter

Visual Internal Urethrotomy Equipment List

- Working instruments: Rigid cystoscope 21 F (if tight stricture, consider 7.5 F pediatric cystoscope), urethrotome with half-moon blade, Bentson 0.035 in. x 145 cm Teflon-coated straight guidewire, Cook/Amplatz urethral dilators 12–30 F
- Other: Councill-tip 2-way 16–18 Fr Foley catheter

References

1. Solari V, Piotrowska AP, Puri P. Altered expression of interstitial cells of Cajal in congenital ureteropelvic junction obstruction. J Urol. 2003;170(6 Pt 1):2420–2.
2. Sepulveda L, Rodrigues F. Giant hydronephrosis—a late diagnosis of ureteropelvic junction obstruction. World J Nephrol Urol. 2013;2(1):33–5.
3. Szydelko T, Kasprzak J, Apoznanski W, Tupikowski K, Pupka A, Janczak D, et al. Clavien classification of complications after 150 laparoscopic pyeloplasties. Urology. 2011;77(6):1359–64.

4. Schwentner C, Pelzer A, Neururer R, Springer B, Horninger W, Bartsch G, et al. Robotic Anderson–Hynes pyeloplasty: 5-year experience of one centre. BJU Int. 2007;100(4):880–5.
5. Park J, Kim WS, Hong B, Park T, Park HK. Long-term outcome of secondary endopyelotomy after failed primary intervention for ureteropelvic junction obstruction. Int J Urol. 2008;15(6):490–4.
6. Minervini A, Davenport K, Keeley FX Jr, Timoney AG. Antegrade versus retrograde endopyelotomy for pelvi-ureteric junction (PUJ) obstruction. Eur Urol. 2006;49(3):536–42.
7. Dimarco DS, Gettman MT, McGee SM, Chow GK, Leroy AJ, Slezak J. Long-term success of antegrade endopyelotomy compared with pyeloplasty at a single institution. J Endourol. 2006;20(10):707–12.
8. Doo CK, Hong B, Park T, Park HK. Long-term outcome of endopyelotomy for the treatment of ureteropelvic junction obstruction: how long should patients be followed up? J Endourol. 2007;21(2):158–61.
9. Vaarala MH, Marttila T, Paananen I, Hellström P. Retrospective analysis of long-term outcomes of 64 patients treated by endopyelotomy in two low-volume hospitals: good and durable results. J Endourol. 2008;22(8):1659–64.
10. Knudsen BE, Cook AJ, Watterson JD, Beiko DT, Nott L, Razvi H, et al. Percutaneous antegrade endopyelotomy: long-term results from one institution. Urology. 2004;63(2):230–4.
11. Ponsky LE, Streem SB. Retrograde endopyelotomy: a comparative study of hot-wire balloon and ureteroscopic laser. J Endourol. 2006;20(10):823–6.
12. Elmussareh TO, Somani BK, Biyani CS. Laser endopyelotomy in the management of pelviureteric junction obstruction in adults: a systematic review of the literature. Urology. 2017;107:11–22.
13. El-Nahas AR, Shoma AM, Eraky I, El-Kenawy MR, El-Kappany HA. Percutaneous endopyelotomy for secondary ureteropelvic junction obstruction: prognostic factors affecting late recurrence. Scand J Urol Nephrol. 2006;40(5):385–90.
14. Van Cangh PJ, Wilmart JF, Opsomer RJ, Abi-Aad A, Wese FX, Lorge F. Long-term results and late recurrence after endoureteropyelotomy: a critical analysis of prognostic factors. J Urol. 1994;151(4):934–7.
15. Corbett HJ, Mullassery D. Outcomes of endopyelotomy for pelviureteric junction obstruction in the paediatric population: a systematic review. J Pediatr Urol. 2015;11(6):328–36.
16. Butani RP, Eshghi M. Cold-knife retrograde endopyelotomy: a long-term follow-up. J Endourol. 2008;22(4):657–60.
17. Jacobs BL, Seelam R, Lai JC, Hanlet JM, Wolf JS, Hollenbeck BK, et al. Cost analysis of treatments for ureteropelvic junction obstruction. J Endourol. 2017;31(2):204–9.
18. Motola JA, Fried R, Badlani GH, Smith AD. Failed endopyelotomy: implications for future surgery on the ureteropelvic junction. J Urol. 1993;150(3):821–3.
19. Conlin MJ, Gomella LG, Bagley DH. Endoscopic ureteroureterostomy for obliterated ureteral segments. J Urol. 1996;156(4):1394–9.
20. Webber RJ, Pandian SS, McClinton S, Hussey J. Retrograde balloon dilatation for pelviureteric junction obstruction: long-term follow-up. J Endourol. 1997;11(4):239–42.
21. Weikert S, Christoph F, Müller M, Schostak M, Miller K, Schrader M. Acucise endopyelotomy: a technique with limited efficacy for primary uretero- pelvic junction obstruction in adults. Int J Urol. 2005;12(10):864–8.
22. Kim FJ, Herrell SD, Jahoda AE, Albala DM. Complications of acucise endopyelotomy. J Endourol. 1998;12(5):433–6.
23. Desai MM, Gill IS, Carvalhal EF, Kaouk JH, Banks K, Raju R. Percutaneous endopyeloplasty: a novel technique. J Endourol. 2002;16(7):431–43.
24. Desai MM, Desai MR, Gill IS. Endopyeloplasty versus endopyelotomy versus laparoscopic pyeloplasty for primary ureteropelvic junction obstruction. Urology. 2004;64(1):16–21.
25. Samarasekera D, Chew BH. Endopyelotomy still has an important role in the management of ureteropelvic junction obstruction. Can Urol Assoc J. 2011;5(2):134–6.
26. Varkaraskis IM, Bhayani SB, Allaf ME, Inagaki T, Ong AM, Kavoussi LR, et al. Management of secondary ureteropelvic junction obstruction after failed primary laparoscopic pyeloplasty. J Urol. 2004;172(1):180–2.
27. Tállai B, Salah MA, Flaskó T, Tóth C, Varga A. Endopyelotomy in childhood: our experience with 37 patients. J Endourol. 2004;18(10):952–8.
28. Veenboer PW, Chrzan R, Dik P, Klijn AJ, de Jong TP. Secondary endoscopic pyelotomy in children with failed pyeloplasty. Urology. 2011;77(6):1450–4.
29. American Urological Association. Wolf Jr JS, Bennett CJ, Dmochowski RR, Hollenbeck BK, Pearle MS, Schaeffer AJ. Urologic surgery antimicrobial prophylaxis. Best Practice Statement. © 2007 American Urological Association Education and Research, Inc. Updated Sep 2008. Revised 20 Sep 2012. https://www.auanet.org/guidelines/antimicrobial-prophylaxis. Accessed 29 Oct 2018.
30. Karlin GS, Badlani GH, Smith AD. Endopyelotomy versus open pyeloplasty: comparison in 88 patients. J Urol. 1988;140(3):476–8.
31. Davis DM, Strong GH, Drake WM. Intubated ureterotomy; experimental work and clinical results. J Urol. 1948;59(5):851–62.
32. Moon YT, Kerbl K, Pearle MS, Gardner SM, McDougall EM, Humphrey P. Evaluation of optimal stent size after endourologic incision of ureteral strictures. J Endourol. 1995;9(1):15–22.
33. Mandhani A, Kapoor R, Zaman W, Kumar A, Bhandari M, Gambhir S. Is a 2-week duration sufficient for stenting in endopyelotomy? J Urol. 2003;169(3):886–9.

34. Kumar R, Kapoor R, Mandhani A, Kumar A, Ahlawat R. Optimum duration of splinting after endopyelotomy. J Endourol. 1999;13(2):89–92.
35. Shalhav AL, Giusti G, Elbahnasy AM, Hoenig DM, McDougall EM, Smith DS. Adult endopyelotomy: impact of etiology and antegrade versus retrograde approach on outcome. J Urol. 1998;160(3 Pt 1):685–9.
36. Roberts WW, Cadeddu JA, Micali S, Kavoussi LR, Moore RG. Ureteral stricture formation after removal of impacted calculi. J Urol. 1998;159(3):723–6.
37. Nakada SY, Johnson M. Ureteropelvic junction obstruction. Retrograde endopyelotomy. Urol Clin North Am. 2000;27(4):677–84.
38. Banner MP, Pollack HM, Ring EJ, Wein AJ. Catheter dilatation of benign ureteral strictures. Radiology. 1983;147(2):427–33.
39. Hafez KS, Wolf JS Jr. Update on minimally invasive management of ureteral strictures. J Endourol. 2003;17(7):453–64.
40. Corcoran AT, Smaldone MC, Ricchiuti DD, Averch TD. Management of benign ureteral strictures in the endoscopic era. J Endourol. 2009;23(11):1909–12.
41. Razdan S, Silberstein IK, Bagley DH. Ureteroscopic endoureterotomy. BJU Int. 2005;95(2):94–101.
42. Lane BR, Desai MM, Hegarty NJ, Streem SB. Long-term efficacy of holmium laser endoureterotomy for benign ureteral strictures. Urology. 2006;67(5):894–7.
43. Hibi H, Ohori T, Taki T, Yamada Y, Honda N. Long-term results of endoureterotomy using a holmium laser. Int J Urol. 2007;14(9):872–4.
44. Gnessin E, Yossepowitch O, Holland R, Livne PM, Lifshitz DA. Holmium laser endoureterotomy for benign ureteral stricture: a single center experience. J Urol. 2009;182(6):2775–9.
45. Kristo B, Phelan MW, Gritsch HA, Schulam PG. Treatment of renal transplant ureterovesical anastomotic strictures using antegrade balloon dilation with or without Holmium:YAG laser endoureterotomy. Urology. 2003;62(5):831–4.
46. Gdor Y, Gabr AH, Faerber GJ, Wolf JS Jr. Holmium:Yttrium-Aluminum-Garnet laser endoureterotomy for the treatment of transplant kidney ureteral strictures. Transplantation. 2008;85(9):1318–21.
47. He Z, Li X, Chen L, Zeng G, Yuan J, Chen W, et al. Endoscopic incision for obstruction of vesicoureteric anastomosis in transplanted kidneys. BJU Int. 2008;102(1):102–6.
48. Mano R, Golan S, Holland R, Livne PM, Lifshitz DA. Retrograde endoureterotomy for persistent ureterovesical anastomotic strictures in renal transplant kidneys after failed antegrade balloon dilation. Urology. 2012;80(2):255–9.
49. Laven BA, O'Connor RC, Steinberg GD, Gerber GS. Long-term results of antegrade endoureterotomy using the holmium laser in patients with ureterointestinal strictures. Urology. 2001;58(6):924–9.
50. Watterson JD, Sofer M, Wollin TA, Nott L, Denstedt JD. Holmium:YAG laser endoureterotomy for ureterointestinal strictures. J Urol. 2002;167(4):1692–5.
51. Poulakis V, Witzsch U, De Vries R, Becht E. Cold-knife endoureterotomy for nonmalignant ureterointestinal anastomotic strictures. Urology. 2003;61(3):512–7.
52. Milhoua PM, Miller NL, Cookson MS, Chang SS, Smith JA, Herrell SD. Primary endoscopic management versus open revision of ureteroenteric anastomotic strictures after urinary diversion—single institution contemporary series. J Endourol. 2009;23(3):551–5.
53. Hu W, Su B, Xiao B, Zhang X, Chen S, Tang Y, et al. Simultaneous antegrade and retrograde endoscopic treatment of non-malignant ureterointestinal anastomotic strictures following urinary diversion. BMC Urol. 2017;17(1):61.
54. Singal RK, Denstedt JD, Razvi HA, Chun SS. Holmium:YAG laser endoureterotomy for treatment of ureteral stricture. Urology. 1997;50(6):875–80.
55. Preminger GM, Clayman RV, Nakada SY, Babayan RK, Albala DM, Fuchs GJ, et al. A multicenter clinical trial investigating the use of a fluoroscopically controlled cutting balloon catheter for the management of ureteral and ureteropelvic junction obstruction. J Urol. 1997;157(5):1625–9.
56. Cai W, Chen Z, Wen L, Jiang X, Liu X. Bipolar plasma vaporization using plasma-cutting and plasma-loop electrodes versus cold-knife transurethral incision for the treatment of posterior urethral stricture: a prospective, randomized study. Clinics (Sao Paulo). 2016;71(1):1–4.
57. Hautmann RE, de Petriconi RC, Volkmer BG. 25 years of experience with 1,000 neobladders: long-term complications. J Urol. 2011;185(6):2207–12.
58. Pantuck AJ, Han KR, Perrotti M, Weiss RE, Cummings KB. Ureteroenteric anastomosis in continent urinary diversion: long-term results and complications of direct versus nonrefluxing techniques. J Urol. 2000;163(2):450–5.
59. Tonkin JB, Jordan GH. Management of distal anterior urethral strictures. Nat Rev Urol. 2009;6(10):533–8.
60. Morey AF, McAninch JW. Ultrasound evaluation of the male urethra for assessment of urethral stricture. J Clin Ultrasound. 1996;24(8):473–9.
61. Steenkamp JW, Heyns CF, de Kock ML. Internal urethrotomy versus dilation as treatment for male urethral strictures: a prospective, randomized comparison. J Urol. 1997;157(1):98–101.
62. Heyns CF, Steenkamp JW, De Kock ML, Whitaker P. Treatment of male urethral strictures: is repeated dilation or internal urethrotomy useful? J Urol. 1998;160(2):356–8.
63. Albers P, Fichtner J, Bruhl P, Muller SC. Long-term results of internal urethrotomy. J Urol. 1996;156(5):1611–4.
64. Hafez AT, El-Assmy A, Dawaba MS, Sarhan O, Bazeed M. Long-term outcome of visual internal urethrotomy for the management of pediatric urethral strictures. J Urol. 2005;173(2):595–7.

65. Hosseini J, Kaviani A, Golshan AR. Clean intermittent catheterization with triamcinolone ointment following internal urethrotomy. Urol J. 2008;5(4):265–8.
66. Lauritzen M, Greis G, Sandberg A, Wedren H, Ojdeby G, Henningsohn L. Intermittent self- dilatation after internal urethrotomy for primary urethral strictures: a case-control study. Scand J Urol Nephrol. 2009;43(3):220–5.
67. Gucuk A, Tuygun C, Burgu B, Oztürk U, Dede O, Imamoğlu A. The short-term efficacy of dilatation therapy combined with steroid after internal urethrotomy in the management of urethral stenoses. J Endourol. 2010;24(6):1017–21.
68. Mazdak H, Izadpanahi MH, Ghalamkari A, Kabiri M, Khorrami MH, Nouri-Mahdavi K, et al. Internal urethrotomy and intraurethral submucosal injection of triamcinolone in short bulbar urethral strictures. Int Urol Nephrol. 2010;42(3):565–8.
69. Tavakkoli Tabassi K, Yarmohamadi A, Mohammadi S. Triamcinolone injection following internal urethrotomy for treatment of urethral stricture. Urol J. 2011;8:132–6.
70. Jordan GH, Wessells H, Secrest C, Squadrito JF Jr, McAninch JW, Levine L, et al. Effect of a temporary thermo-expandable stent on urethral patency after dilation or internal urethrotomy for recurrent bulbar urethral stricture: results from a 1-year randomized trial. J Urol. 2013;190(1):130–6.
71. Holzhauer C, Roelofs AWTM, Kums AC, Weijerman PC, van Balken MR. Is the laser mightier than the sword? A comparative study for the urethrotomy. World J Urol. 2018;36(4):663–6.

Holmium Laser Enucleation of the Prostate (HoLEP)

15

Tim Large and Amy E. Krambeck

Introduction

Transurethral resection of the prostate (TURP) continues to be the most common surgical treatment for benign prostatic hyperplasia (BPH) offered in the United States [1]. However, there are multiple alternative therapies available, including prostatic urethral lift (PUL), water vapor thermal therapy, laser ablation, laser enucleation, and laparoscopic/robotic prostatectomy [2]. Each modality aims to improve lower urinary tract symptoms (LUTS) while reducing procedural morbidity and side effects—notably, prolonged hospital stays and catheter dwell times, incontinence, and retrograde ejaculation. In the case of large gland BPH (glands > 80 g), traditional treatment required open simple prostatectomy (OP). OP, which is associated with significant immediate postoperative patient morbidity, has largely been supplanted by laser enucleation and laparoscopic/robotic simple prostatectomy [3]. Holmium laser enucleation of the prostate (HoLEP) is perhaps the most rigorously studied surgical technique classified as a laser enucleation prostatectomy [4]. HoLEP has profound and durable improvement in patient voiding function and LUTS independent of gland size in both short- and long-term follow-up; some consider it to be the gold standard for BPH surgery [5–7].

Patients currently undergoing treatment for LUTS/BPH are progressively older with more comorbidities; thus, there is an increased need for minimally invasive BPH procedures. In an attempt to reduce the morbidity associated with standard TURP and or OP, several laser therapies have been developed and perfected, including HoLEP, thulmium laser enucleation of the prostate (ThuLEP), and photoselective vaporization of the prostate (PVP; GreenLight™, Boston Scientific, Marlborough MA). These lasers have been used to coagulate, vaporize, and cut prostatic tissue overgrowth using a variety of techniques. They have also been further developed to allow for actual prostatic lobe enucleation with subsequent tissue removal, with the holmium laser being the first utilized and most widely accepted for enucleation.

Since its description more than 20 years ago by Gilling et al., HoLEP has been established as a comprehensive surgical therapy for LUTS/BPH, one that simplifies the management of even the most complex BPH patients [8]. By using the holmium laser to incise the prostate gland, the laser resectoscope to manually enucleate the adenoma, and the morcellator to evacuate the resected tissue from the bladder, the OP technique is recreated during the HoLEP procedure without any abdominal or bladder incision. A multitude of publications have supported the

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S. L. Best, S. Y. Nakada (eds.), *Minimally Invasive Urology*,
https://doi.org/10.1007/978-3-030-23993-0_15

safety and efficacy of HoLEP for small and large gland BPH [3, 6, 7, 9–21], even in the presence of bleeding diatheses and anticoagulation [17]. HoLEP has been found to be as effective as TURP [11–15, 20] and OP [3, 11, 18] for the treatment of obstructive BPH, with the benefit of being less morbid. Long-term studies of patients undergoing HoLEP demonstrate sustained relief from BPH symptoms from 4 to 10 years postoperative, with very low retreatment rates, ranging from 0% to 4% [7, 18, 19, 22, 23].

The efficacy of HoLEP lies in its excellent tissue debulking capabilities. Large case series have shown that HoLEP produces a prostate volume and prostate-specific antigen reduction of 60–90% [6, 10, 16, 17, 19]. Another benefit of HoLEP is its potential to be performed as an outpatient procedure with catheter removal within 24 h of surgery. When compared to contemporary ablative procedures, HoLEP has the advantage of actual tissue removal for pathologic specimen examination, greater prostate volume reduction, and durable long-term results while maintaining low morbidity [24].

Since HoLEP is a laser-based procedure, it is performed using normal saline irrigation, thus eliminating the risk of dilutional hyponatremia, also known as transurethral resection (TUR) syndrome. Furthermore, since the laser not only incises but also coagulates, it can perform pinpoint control of bleeding vessels as they enter the capsule of the prostate. The precise control of bleeding vessels at the time of transection has essentially eliminated the need for blood transfusion after HoLEP in patients without bleeding diatheses. Evidence demonstrates the feasibility of radical prostatectomy after HoLEP; the concomitant treatment of bladder, ureteral, and renal stones at the time of HoLEP; and the limited impact of HoLEP on erectile function [25]. Investigators have reported that once the initial investment for the laser is factored out, HoLEP is more cost-effective compared with TURP and OP due to a shorter length of hospitalization and a decreased need for ancillary interventions (i.e., blood transfusion, and continuous bladder irrigation) [20].

One criticism of the HoLEP procedure is the steep learning curve. Several publications have addressed the learning curve and suggest that a didactic, video, and navigated "hand-grab" training approach provides the quickest path to the surgical mastery of HoLEP [26]. Here we provide an updated guide to HoLEP, including a description of the essential equipment, the procedure (step by step), and a summary of the postoperative recovery and anticipated complications.

Current Equipment Used for HoLEP

Equipment List

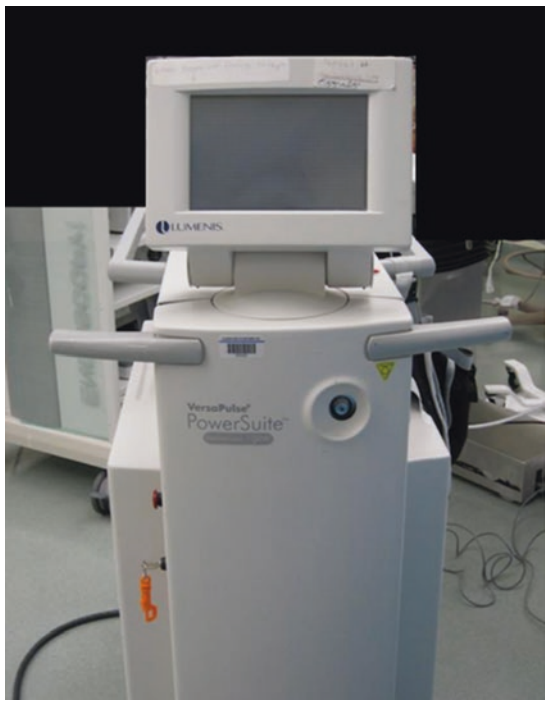
1. 120-W dual pedal holmium laser unit
2. 550 μm Moses (Lumenis, Santa Clara, CA) or 1000 μm SlimLine end fire laser fiber (Lumenis)
3. 30-degree cystoscope lens
4. Video tower and a freely swinging camera head
5. Normal saline irrigation
6. Continuous flow resectoscope (26–28 F) with modified inner sheath and a laser stabilizer
7. 7 F stabilizing catheter
8. Van Buren urethral sounds
9. Ellik evacuator
10. Offset rigid nephroscope with bridge adapter
11. 5 mm tissue morcellator
12. Alligator grasper
13. 22 F 3-way catheter with mandarin guide
14. Otis urethrotome

The holmium laser is a pulsed solid-state laser with a wavelength of 2140 nm. Unlike other available laser systems, the holmium laser is a contact laser with a depth of penetration in prostatic tissue of only 0.4 mm. The laser energy is highly absorbed by water (absorption peak of water: 1.940 nm), which makes up 60–70% of the prostate [25]. This water absorption produces an energy density that heats the prostatic tissue to greater than 100 °C [27]. The thermal energy generated by the holmium laser allows for precise tissue incision with minimal charring and plane

obscuring. With newer laser units such as the Lumenis 120H™, pulse width modulation is possible, which, when set to a narrow pulse width, further improves the precision and dissection capabilities of the laser. Additionally, there is an acoustic pulse from the laser that can fracture loose tissue connections between true prostate and prostate adenoma, helping to expedite enucleation by shelling out obstructing tissues. Lastly, when the laser is set to a wide pulse width and positioned on a bleeding vessel, it can broadly distribute the heat causing coagulation of vessels to a depth of 2–3 mm without cutting the surgical capsule [27].The favorable hemostatic properties of the holmium laser were recognized in the updated American Urological Association (AUA) surgical guidelines for LUTS/BPH. HoLEP was recommended as a preferred surgical option in patients requiring anticoagulant (AC), antiplatelet (AP), or dual AC/AP therapy [2].

The holmium laser is a multipurpose laser and can be used not only for tissue cutting (as in the treatment of urinary strictures) and ablation (treatment of urothelial tumors) but also for fracturing of stones [3, 28, 29]. Ureteroscopy with laser lithotripsy has become the most common surgical approach for the treatment of nephrolithiasis [30]. Holmium technology is universally available to urologists. Nevertheless, to perform HoLEP in an efficient manner, a high-powered laser is recommended. Studies have shown that comparable intra and post-HoLEP outcomes are possible with a 30-W laser, but in general the dual energy Lumenis120H™ or the 100-W Versapulse holmium laser (Lumenis) are optimal (Fig. 15.1). Recent application of Moses laser technology developed by Lumenis shows further improvement in hemostasis and enucleation efficiency; however, publications are still lacking.

The holmium laser energy can be transmitted along flexible quartz fibers of varying diameters, ranging from 100 to 1000 μm. The ability to use multiple-sized fibers allows the holmium laser to be used not only with a cystoscope but also with rigid and flexible ureteroscopes. In general, larger laser fibers such as the 550 or 1000 μm SlimLine



Versapulse 100 W

Lumenis 120H™

Fig. 15.1 The 100-W Versapulse holmium laser and Lumenis 120H used to perform HoLEP

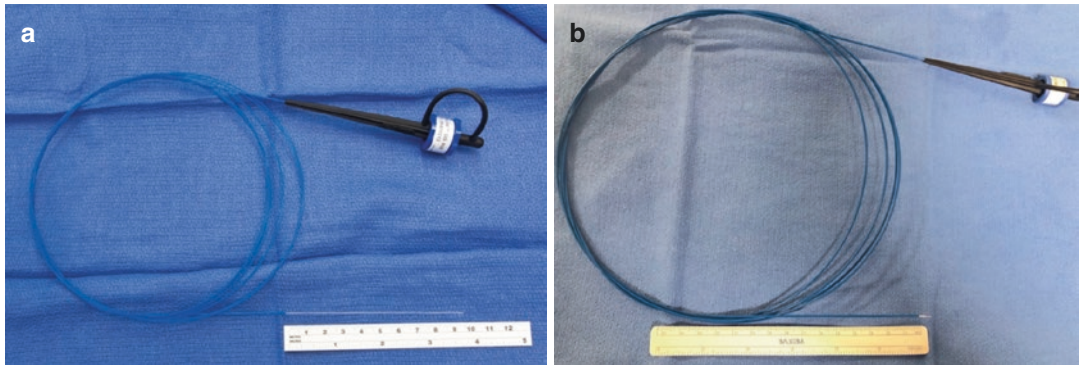


Fig. 15.2 The 550 µm (**a**) and 1000 µm (**b**) quartz laser fiber used to perform HoLEP

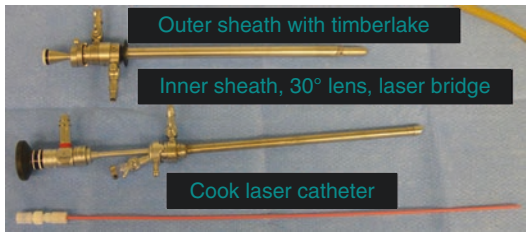


Fig. 15.3 The disassembled laser scope and protective laser catheter. The device shown is the Storz 28 Fr set consisting of a 28 Fr outer sheath, inner sheath with stabilizing ring, and 30-degree telescope lens. The laser catheter fits through the working element of the scope and is held in place by the stabilizing ring

end firing (Fig. 15.2) and more recently the 550 µm Moses fiber are generally preferred when performing a HoLEP. Several different companies offer both disposable and reusable quartz laser fibers. The ability to sterilize and reuse the holmium laser fibers up to 20–30 reduces equipment costs of HoLEP unlike other laser surgical technologies [25, 31]. When performing HoLEP, the laser fiber is routinely stripped of its protective cladding (5–6 cm) and placed through a 7 Fr stabilizing catheter (Cook, Spencer, IN). The catheter is secured in place with a Luer-Lok injection port (Baxter, Deerfield, IL). When using a 1000 µm fiber, the tip of the stabilizing catheter needs to be cut to allow the passage of the larger diameter fiber (Fig. 15.3).

Two different companies manufacture laser scopes that can be used to perform HoLEP. Olympus (Hamburg, Germany) has a 27 Fr, and Storz (Tuttlingen, Germany) produces a 26 and 28 Fr continuous flow resectoscope with a dedicated inner sheath that incorporates a laser channel (Olympus) and a laser ring (Stortz) to stabilize and centralize the laser fiber during enucleation (see Fig. 15.3). Regardless of the laser scope used to perform HoLEP, a 30-degree lens is necessary to adequately visualize the prostate and laser tip. Due to the extreme hand movements necessary to perform HoLEP, an endoscopic camera with a swivel base is recommended. High definition video systems, such as those provided by Stryker (Kalamazoo, MI) and Olympus (Hamburg, Germany), improve visualization of the surgical plane between true prostate and adenoma, facilitating enucleation and improving HoLEP efficiency. Since HoLEP is a laser-based therapy, normal saline irrigation is used in all cases.

Once enucleation of the prostate has been completed, the tissue must be removed using a tissue morcellator. Prior to the introduction of the tissue morcellator, the inner working elements of the laser scope are removed, leaving only the outer sheath traversing the length of the urethra. An offset long 26 Fr nephroscope with an adapter bridge and a 5 mm working channel is then used to visualize the intravesical tissue morcellation (Fig. 15.4a). There are two commercially available morcellators: the Piranha (Richard Wolf, Knittlingen, Germany) and the Versacut (Lumenis). The morcellator consists of a handpiece with reciprocating blades and controller box with suction pump and is operated by a foot pedal (Fig. 15.4b). Continuous flow irrigation is not utilized during morcellation. A third inflow

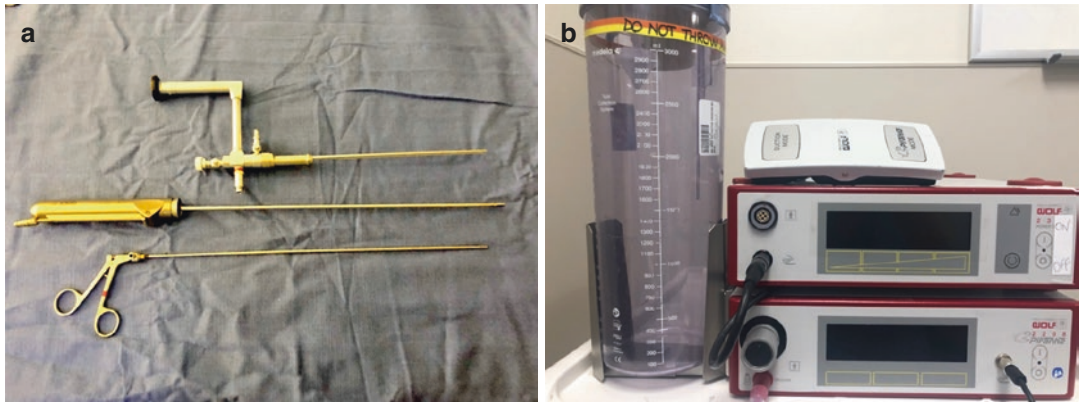


Fig. 15.4 (**a**) The long nephroscope shown here has a 5 mm working channel and a length adapter bridge and permits the passage of the morcellator and grasping forceps. The grasping forceps can be used to remove small fragments rather than morcellating. The Wolf Piranha morcellator is seen between the graspers and nephroscope. (**b**) The morcellator has a pump suction device that allows for a simultaneous removal of the prostate tissue at time of morcellation

line is attached to the outflow channel due to the intense suction potential of the morcellator. The Piranha system uses two pedals for suction only and suction/morcellation, whereas the Versacut consolidates the two functions into one pedal with partial depression initiating suction and complete depression causing the morcellator blades to cycle along with suction. Comparison of the two morcellators has demonstrated excellent tissue removal; however, in a comparative trial, the Piranha morcellator was more efficient and had fewer complications compared to the Versacut [32]. After all the tissues are removed, a 22 Fr three way urethral catheter is placed with 60 ml in the balloon for an average of 15 h and in the absence of any complication removed the morning after surgery to initiate a void trial.

HoLEP: Step by Step

Preoperative Evaluation

Prior to undergoing HoLEP, patients should have an appropriate preoperative evaluation. Though workup may be tailored to the individual patient, this should typically include a patient history, AUA symptom score (or appropriate validated metric), and urinary flow with postvoid residual. Laboratory evaluation, including complete blood count (CBC), electrolytes with creatinine, and serum prostate-specific antigen (PSA), should be obtained. Despite the evidence that HoLEP can be offered to patients with LUTS/BPH independent of gland size, it is recommended that a transrectal ultrasound (TRUS) volume study be obtained in patients without any prior imaging (computed tomography or magnetic resonance imaging). Once a surgeon masters HoLEP, he or she can expect operative times to range from 30–60, 90–120, and more than 120 min for prostate glands less than 80 g, 80–150 g, and greater than 150 g, respectively. In general, patients who have had prior transurethral procedures and/or those with a history or risk factors for urethral stricture should undergo a preoperative cystoscopy prior to surgery. Lastly, if patients suffer from severe urgency, frequency, incontinence or have other neurologic comorbidities, a full urodynamic study can be beneficial in differentiating between significant detrusor instability versus bladder outlet obstruction.

As with any surgical procedure, obtaining informed consent is required. HoLEP has been associated with high rates of transient urinary incontinence (1.3–44%) with persistent incontinence beyond 3 months postoperatively occurring in less than 2–5% of patients [33, 34]. Retrograde ejaculation is noted to range from 80% to 100% of patients, but erectile function is

preserved after HoLEP [19]. Though the risk of clinically significant bleeding is less than 1% [4], even in the setting of anticoagulation or bleeding diathesis [17], the possibility of transfusion should be discussed. Morcellation injury can have major ramifications; however, a recent study showed zero morcellation injuries with the Piranha system [35], which was similarly reported by Krambeck et al. in over 1000 HoLEPs where only one morcellation injury requiring an open repair occurred [36].

Operative Preparation

Patients are positioned in the dorsal lithotomy position. Spinal or general anesthesia with a laryngeal mask airway (LMA) or endotracheal tube are appropriate for patients undergoing HoLEP. An LMA with a combination of narcotics, benzodiazepines, and poropofol provides adequate anesthesia with expeditious induction and a gentle emersion after surgery. The urethra is dilated to 30–32 Fr in order to accommodate outer sheath of the continuous flow laser resectoscope. After instilling additional lubricant transurethrally with a Toomey syringe, the outer sheath is introduced with the Timberlake obturator. The laser resectoscope with 7 Fr laser stabilizing catheter is placed through, and attached to, the outer sheath. Several laser fibers, including a 550 or 1000 μm single, reusable, or Moses fiber, are available and fit through the 7 Fr laser guide. The cladding on the laser fibers is routinely stripped back 5–6 cm in anticipation of laser break back because of high-energy usage during HoLEP. The preferred irrigant is normal saline, which enters via Y tubing connecting two 3 l saline bags to the inflow port.

Assessment of Anatomy and Creation of Posterior Plane

Once the resectoscope has been attached securely with the external continuous flow sheath, the anatomy of the patient is assessed. Ideally, the surgeon should take note of variations in the structure of the prostate, such as a large median lobe, a high or tight bladder neck, or a defect from prior BPH surgery. In some instances, the patient's body habitus or prostate is too large to breach the bladder neck with the resectoscope. In this situation, a perineal urethrostomy can safely be performed prior to HoLEP and closed at the conclusion of the case. These patients should maintain a Foley catheter for 1 week.

Visualizing the ureteral orifices (UO) is good practice but should not prolong the case. Oftentimes the UOs are obscured by the intravesical projection of the prostate, particularly with a large median lobe. Evaluating if the patient has bilobar or trilobar hypertrophy will determine if a single 6 o'clock or a two-cut (5 and 7 o'clock) initial groove will be required. In the situation of a two-cut approach, enucleation of the median lobe should follow after the 5 and 7 o'clock grooves are connected. Removing the median lobe will create more space in the prostatic fossa and better demarcate the surgical capsule, which will expedite the subsequent lateral lobe dissections (Fig. 15.5).

Standard laser settings during the initial part of a HoLEP are 2 joules (J) and 40 hertz (Hz). The initial groove should be deepened until the

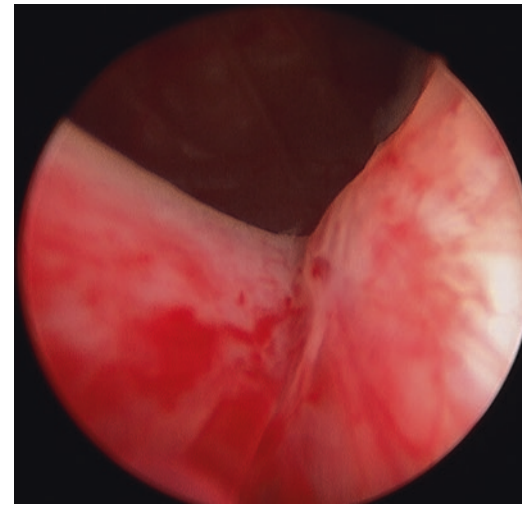


Fig. 15.5 View of the initial posterior incision, starting at the 6 or 5 and 7 o'clock positions, depending on the presence of a median lobe

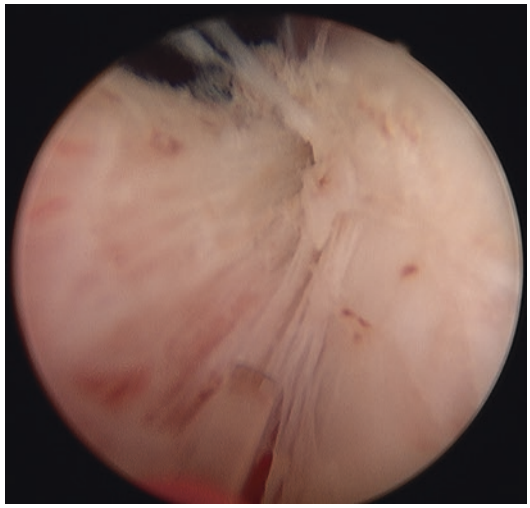


Fig. 15.6 Circular fibers at the bladder neck, identifying the capsule

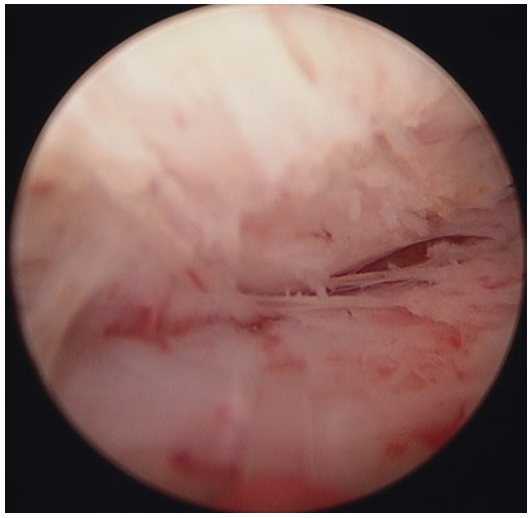


Fig. 15.7 The cobweb appearance with separation of the adenoma from the prostatic capsule

capsule is reached, which can be identified most readily by horizontal capsular blood vessels or circular fibers near the bladder neck (Figs. 15.6 and 15.7). This depth near the bladder neck should be familiar to surgeons with experience in ablative procedures of the prostate. Gentle movements with the beak of the scope during the initial incision can widen the initial groove to help identify the capsule. Once the 5 and 7 o'clock grooves are transversely

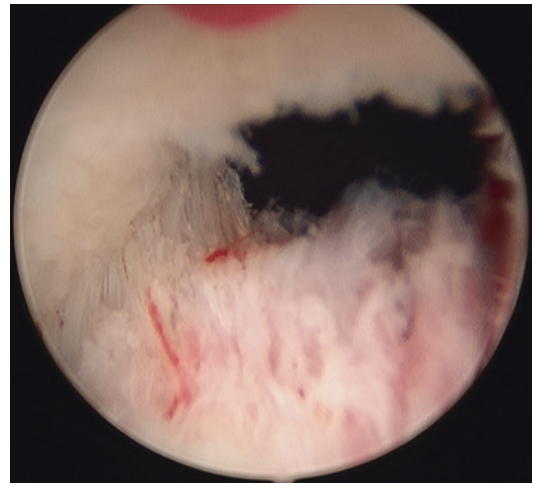


Fig. 15.8 The anterior plane of dissection carried from the 10 to 2 o'clock position through the bladder mucosa so that the scope enters the lumen of the bladder. Note the laser fiber and capsule superiorly and the adenoma inferiorly

connected, undermining the median lobe should proceed proximally using the beak of the scope to lift the adenoma upward while utilizing the thermal laser energy to release attachments between true prostate and prostate adenoma. The proper plane should demonstrate a cobweb appearance with separation of the adenoma from the prostatic capsule (Fig. 15.8). Once the posterior attachments between the median lobe and the surgical capsule have been released, the median lobe is pushed into the bladder lumen and remains tethered by mucosal tissue at the bladder neck. Separating the adenoma from the bladder neck requires precise lasering near the bladder neck to avoid dissecting up the backside of the median lobe. Tension needs to be applied to the median lobe in order to cut the mucosal attachments. Localizing the UOs during this step is critical as the resectoscope can recoil into the UOs, creating the potential for a laser injury to the ureter.

If the median lobe is small or moderately sized, it does not need to be enucleated separately. A single posterior groove can be made, and any posterior tissue can be enucleated with the lateral lobe tissue.

Enucleation of Lateral Lobes

After enucleation of the median lobe or after the single posterior incision has been completed, attention is then turned to the lateral lobe tissue. The lateral lobes are enucleated individually, beginning at the initial groove just proximal and lateral to the verumontanum. A superficial incision of the mucosa is created by making a short horizontal cut, just enough to allow the entrance of the beak of the scope. The laser energy should then be decreased to 2 J and 20 Hz to minimize potential damage to the external sphincter complex from direct iatrogenic laser injury or thermal injury from heat dispersion. The scope is gently rotated around the apex of the adenoma using a combination of blunt dissection and lasering until the scope is placed in the 2 o'clock position, with capsule residing above the scope and adenoma below. It is important to extend the anterior plane of dissection beyond the midline to facilitate enucleation of the second lobe. Once the anterior plane has been developed away from the sphincter complex, the laser energy is increased to the back to 2 J and 40 Hz. The anterior plane of dissection is then carried toward the bladder neck using the scope to apply downward pressure on the adenoma and the laser to separate any capsule attachments and cauterize any perforating vessels. It is important to maintain a broad plane of dissection from the 10 to 2 o'clock position when advancing the anterior plane toward the bladder neck. Once the vertical bladder neck fibers are incised to reveal the lumen of the bladder, the bladder neck should be formalized before entering back into the true prostatic lumen to incise the anterior commissure (see Fig. 15.8).

The two lobes are divided by repositioning the scope in the prostatic urethra and dividing the anterior commissure at the 12 o'clock position (Fig. 15.9). The incision is carried from the bladder neck to the apex. By incising the anterior commissure, the anterior plane should be visible posteriorly and provide a visual aid to avoid excessive dissection distally that might impact or injure the sphincter complex.

Once the lobes are divided, the mucosal strip of tissue attaching the adenoma to the area of the sphincter must be divided. The encircle technique is performed by positioning the scope inverted at the 12 o'clock position near the bladder neck. The scope is then rotated around the outer edge of the adenoma while hugging the capsule until it is oriented appropriately in the 6 o'clock position. The mucosal strip is now positioned to one side of the scope and the sphincter on the other. The scope is then pulled distally to allow the strip to fall in front of the scope where it can be transected safely at 2 J and 20 Hz without concern for sphincter injury.

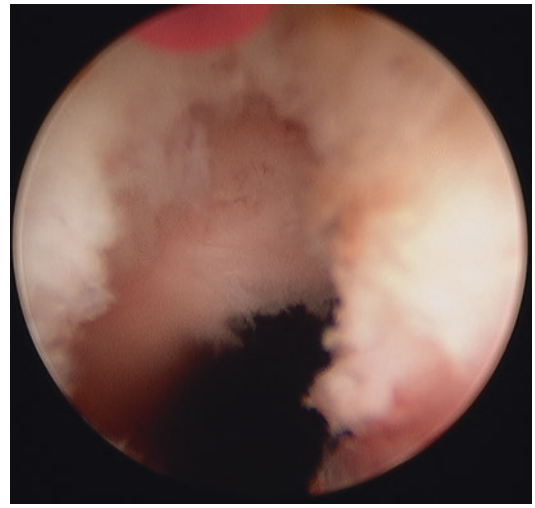


Fig. 15.9 The two lobes are divided by repositioning the scope in the prostatic urethra and dividing the anterior commissure at the 12 o'clock position

After the division of the mucosal strip, the remainder of the lobe is enucleated by joining the lateral and posterior planes, working proximally toward the bladder neck. Once the adenoma is nearly detached, the adenoma is pushed into the bladder using the beak of the scope. The final attachments at the bladder neck are severed and the adenoma is freed into the bladder (Fig. 15.10). Attention is then turned to the contralateral lobe, which is dissected in a similar fashion.

Once the enucleation is completed, hemostasis must be achieved. Though the holmium laser does an excellent job at sealing small vessels during enucleation, additional time is necessary at the conclusion of enucleation to locate and control small bleeders. Improvement in hemostasis

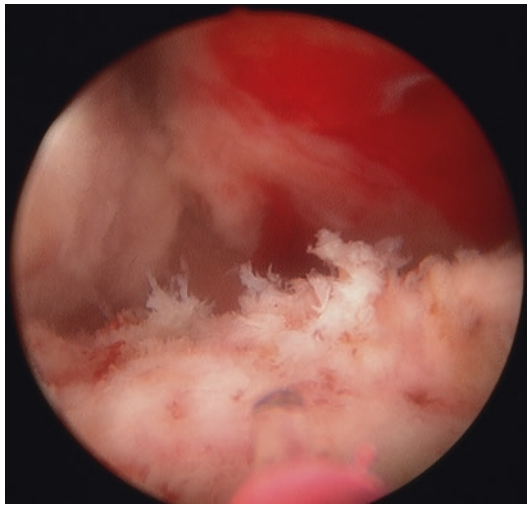


Fig. 15.10 View of the enucleated lateral lobes pushed into the bladder

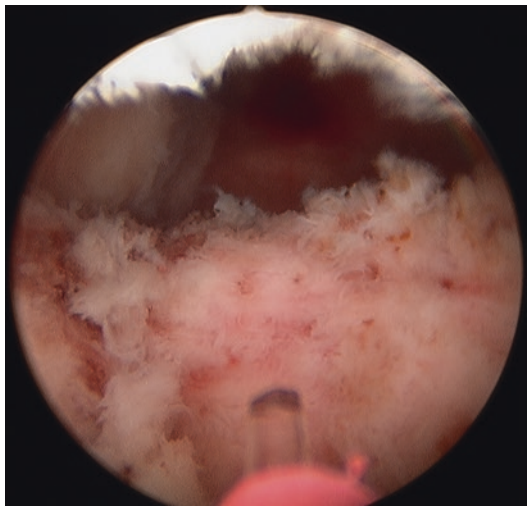


Fig. 15.11 View of the widely opened prostatic fossa

will set up morcellation success by improving visibility (Fig. 15.11).

Following enucleation, the resected tissue is removed using a tissue morcellator. As mentioned earlier, the inner working elements of the laser scope are removed and replaced with a modified offset long 26 Fr nephroscope with a 5 mm working channel. The tissue morcellator is then introduced through the 5 mm working channel. The morcellator uses a combination of suction and cutting blades to remove the tissue; therefore, care must be taken to have high fluid flow through the scope as the suction can rapidly deflate the bladder and bring the bladder wall into the proximity of the morcellator, resulting in a morcellation injury. Once the bulk of the tissue is removed, a final look in the prostatic fossa is recommended as small pieces of adenoma can remain hidden in the fossa obscured by clot.

Finally, a 22 Fr three-way catheter is placed over a mandarin catheter guide with 60 ml placed in the balloon. Continuous bladder irrigation may be necessary, depending on the degree of hematuria noted. To improve bladder neck hemostasis, some tension may need to be applied to the catheter for a brief period of time. The catheter is typically maintained overnight and is removed the following day. Patients must be able to void after catheter removal, and postvoid residual volume must be checked to ensure that there is no urinary retention.

Anticipate Postoperative Results

Since HoLEP is a complete resection of the adenomatous tissue of the prostate, long-term durability of symptom relief after HoLEP is unmatched by any other transurethral BPH surgery. After reviewing the literature for HoLEP, Naspro et al. reported durable results at a mean follow-up of 43.5 months. They found a mean postprocedure Qmax of 21.9 ml/s and mean reoperation rate of 4.3% (range 0–14.1%) [25]. The authors also noted a significant mean decrease in serum PSA levels from baseline (mean 6.3 to 1.63 ng/dl, postoperatively) and transrectal ultrasound prostate volume (mean: from 68 to 27.2 ml, postoperatively). At longest follow-up, the overall reintervention rate was low at 0–5.4%.

The group from Methodist Hospital in Indianapolis, Indiana, evaluated their experience with over 1000 HoLEP procedures performed [22]. The mean preoperative transrectal ultrasound prostate volume was 99.3 g (range 9–391), AUA symptom score 20.3 (1–35), and Qmax 8.4 cc/s (1.1–39.3). Overall complication rates were low, occurring in only 2.3% of the cohort. Mean follow-up was 287 days, ranging from

6 days to 10 years. At most recent follow-up, the mean AUA symptom score was 5.3, and Qmax was 22.7 cc/s. Only 3 (0.3%) of the patients were in urinary retention, and the authors site that all three patients had findings consistent with an atonic bladder, not obstruction. Only one patient underwent a second HoLEP procedure for bleeding prostatic regrowth, not obstruction. Urethral stricture and bladder neck contractures occurred in less than 2% of the cohort. Similarly, Elmansy et al. report rates of stricture and bladder neck contracture at 10-year follow-up of 0.8% and 1.6%, respectively [23].

Despite durable long-term results, postoperative incontinence is the most bothersome side effect of the procedure. Patients undergoing HoLEP can experience mild-to-moderate storage symptoms in the form of urgency and mixed incontinence. By 1 month postoperatively, the symptoms are present in approximately 30% of the patients and by 3 months only 5% [25]. The symptoms respond well to anticholinergic therapies and pelvic floor exercises and in general are self-limiting. The series of over 1000 HoLEP procedures reports a less than 5% overall incontinence rate at long-term follow-up [22]. Elmansy et al., in a review of 949 patients over 10 years, found that the presence of diabetes mellitus, larger volume prostate gland, and a greater reduction in postoperative PSA were all predictive of postoperative stress urinary incontinence [37]. Other potential complications that can occur at the time of surgery or in the immediate postoperative period are hematuria, clot retention, bladder or urethral injury, and any complication that can occur from general anesthesia (Table 15.1).

HoLEP appears to have limited impact on sexual function, similar to TURP and OP [25]. No difference in International Index of Erectile Function (IIEF) domain scores has been observed prior to 2 years postoperatively. However, patients should be counseled on the development of retrograde ejaculation, which has been noted in over 75% of patients followed over 6 years and can affect patient sexual satisfaction [7].

Table 15.1 Complications of HoLEP among a series with 10-year follow-up [22]

Complication	Occurrence (%)
Bladder perforation	0.1
Clinically significant hematuria	0.7
Urethral stricture	2.3
Bladder neck contracture	1.5
Significant short-term stress incontinence	12.5
Significant short-term urge incontinence	11.5
Significant long-term stress incontinence	1.8
Significant long-term urge incontinence	1.5
Re-resection due to adenoma regrowth	0.1
Persistent urinary retention[a]	0.03

[a]Three total patients, including two with documented atonic bladder and one who developed neurogenic bladder following HoLEP due to spinal cord injury

Summary

This chapter has outlined the utility of HoLEP as supported by the literature; provided a guide to performing HoLEP, including the standard required equipment; and reviewed the anticipated postoperative results of the procedure. HoLEP is a safe, effective, minimally invasive surgical treatment of BPH. It has demonstrated durable results, with such a significant degree of deobstruction that subsequent surgical revision is rare. With a relatively low morbidity compared to the standard TURP and the ability to resect large volumes of tissue, HoLEP continues to come under scrutiny for its steep learning curve, but once mastered, it is a comprehensive surgical option for LUTS/BPH and should be considered the gold standard of treatment.

Disclosures T. Large: None
Krambeck: Boston Scientific, Consultant; Lumenis, Consultant; Cook Medical, Advisor

References

1. Anderson BB, Pariser JJ, Helfand BT. Comparison of patients undergoing PVP versus TURP for LUTS/BPH. Curr Urol Rep. 2015;16(8):55.
2. Foster HE, Barry MJ, Dahm P, Gandhi MC, Kaplan SA, Kohler TS, et al. Surgical management of lower urinary tract symptoms attributed to benign prostatic hyperplasia: AUA guideline. J Urol. 2018;200(3):612–9.
3. Kuntz RM, Lehrich K. Transurethral holmium laser enucleation versus transvesical open enucleation for prostate adenoma greater than 100 gm: a randomized prospective trial of 120 patients. J Urol. 2002;168(4 Pt 1):1465–9.
4. Cornu J-N, Ahyai S, Bachmann A, de la Rosette J, Gilling P, Gratzke C, et al. A systematic review and meta-analysis of functional outcomes and complications following transurethral procedures for lower urinary tract symptoms resulting from benign prostatic obstruction: an update. Eur Urol. 2015;67(6):1066–96.
5. van Rij S, Gilling PJ. In 2013, holmium laser enucleation of the prostate (HoLEP) may be the new "gold standard". Curr Urol Rep. 2012;13(6):427–32.
6. Elzayat EA, Habib EI, Elhilali MM. Holmium laser enucleation of the prostate: a size-independent new "gold standard". Urology. 2005;66(5 Suppl):108–13.
7. Gilling PJ, Aho TF, Frampton CM, King CJ, Fraundorfer MR. Holmium laser enucleation of the prostate: results at 6 years. Eur Urol. 2008;53(4):744–9.
8. Gilling PJ, Kennet K, Das A, Thompson D, Fraundorfer M. Holmium laser enucleation of the prostate (HoLEP) combined with transurethral tissue morcellation: an update on the early clinical experience. J Endourol. 1998;12(5):457–9.
9. Tooher R, Sutherland P, Costello A, Gilling P, Rees G, Maddern G. A systematic review of holmium laser prostatectomy for benign prostatic hyperplasia. J Urol. 2004;171(5):1773–81.
10. Matlaga BR, Miller NL, Lingeman JE. Holmium laser treatment of benign prostatic hyperplasia: an update. Curr Opin Urol. 2007;17(1):27–31.
11. Kuntz RM, Ahyai S, Lehrich K, Fayad A. Transurethral holmium laser enucleation of the prostate versus transurethral electrocautery resection of the prostate: a randomized prospective trial in 200 patients. J Urol. 2004;172(3):1012–6.
12. Ahyai SA, Lehrich K, Kuntz RM. Holmium laser enucleation versus transurethral resection of the prostate: 3-year follow-up results of a randomized clinical trial. Eur Urol. 2007;52(5):1456–63.
13. Montorsi F, Naspro R, Salonia A, Suardi N, Briganti A, Zanoni M, et al. Holmium laser enucleation versus transurethral resection of the prostate: results from a 2-center, prospective, randomized trial in patients with obstructive benign prostatic hyperplasia. J Urol. 2004;172(5. Pt 1):1926–9.
14. Gilling PJ, Mackey M, Cresswell M, Kennett K, Kabalin JN, Fraundorfer MR. Holmium laser versus transurethral resection of the prostate: a randomized prospective trial with 1-year followup. J Urol. 1999;162(5):1640–4.
15. Wilson LC, Gilling PJ, Williams A, Kennett KM, Frampton CM, Westenberg AM, et al. A randomised trial comparing holmium laser enucleation versus transurethral resection in the treatment of prostates larger than 40 grams: results at 2 years. Eur Urol. 2006;50(3):569–73.
16. Kuo RL, Kim SC, Lingeman JE, Paterson RF, Watkins SL, Simmons GR, et al. Holmium laser enucleation of prostate (HoLEP): the Methodist Hospital experience with greater than 75 gram enucleations. J Urol. 2003;170(1):149–52.
17. Elzayat E, Habib E, Elhilali M. Holmium laser enucleation of the prostate in patients on anticoagulant therapy or with bleeding disorders. J Urol. 2006;175(4):1428–32.
18. Kuntz RM, Lehrich K, Ahyai SA. Holmium laser enucleation of the prostate versus open prostatectomy for prostates greater than 100 grams: 5-year follow-up results of a randomised clinical trial. Eur Urol. 2008;53(1):160–6.
19. Elzayat EA, Elhilali MM. Holmium laser enucleation of the prostate (HoLEP): long-term results, reoperation rate, and possible impact of the learning curve. Eur Urol. 2007;52(5):1465–71.
20. Fraundorfer MR, Gilling PJ, Kennett KM, Dunton NG. Holmium laser resection of the prostate is more cost effective than transurethral resection of the prostate: results of a randomized prospective study. Urology. 2001;57(3):454–8.
21. Kuo RL, Paterson RF, Kim SC, Siqueira TM Jr, Elhilali MM, Lingeman JE. Holmium laser enucleation of the prostate (HoLEP): a technical update. World J Surg Oncol. 2003;1(1):6.
22. Krambeck AE, Handa SE, Lingeman JE. Experience with more than 1,000 holmium laser prostate enucleations for benign prostatic hyperplasia. J Urol. 2013;189(1 Suppl):027.
23. Elmansy HM, Kotb A, Elhilali MM. Holmium laser enucleation of the prostate: long-term durability of clinical outcomes and complication rates during 10 years of followup. J Urol. 2011;186(5):1972–6.
24. Aho TF, Gilling PJ. Current techniques for laser prostatectomy--PVP and HoLEP. Arch Esp Urol. 2008;61(9):1005–13. *[Article in Spanish].*
25. Naspro R, Bachmann A, Gilling P, Kuntz R, Madersbacher S, Montorsi F, et al. A review of the recent evidence (2006–2008) for 532-nm photoselective laser vaporisation and holmium laser enucleation of the prostate. Eur Urol. 2009;55(6):1345–57.
26. Shin DG, Kim HW, Park SW, Park CS, Choi S, Oh TH, et al. New surgical instruction method for homium laser enucleation of the prostate, "hand-grab navigated technique," to shorten the learning curve:

the results of multicenter analysis. Low Urin Tract Symptoms. 2018;10(3):247–52.
27. Kuntz RM. Current role of lasers in the treatment of benign prostatic hyperplasia (BPH). Eur Urol. 2006;49(6):961–9.
28. Wheelahan J, Scott NA, Cartmill R, Marshall V, Morton RP, Nacey J, Maddern GJ. Minimally invasive laser techniques for prostatectomy: a systematic review. The ASERNIP-S review group. Australian Safety and Efficacy Register of New Interventional Procedures--Surgical. BJU Int. 2000;86(7):805–15.
29. Wilson LC, Gilling PJ. From coagulation to enucleation: the use of lasers in surgery for benign prostatic hyperplasia. Nat Clin Pract Urol. 2005;2(9):443–8.
30. Oberlin DT, Flum AS, Bachrach L, Matulewicz RS, Flury SC. Contemporary surgical trends in the management of upper tract calculi. J Urol. 2015;193(3):880–4.
31. Elshal AM, Elkoushy MA, El-Nahas AR, Shoma AM, Nabeeh A, Carrier S, et al. GreenLight™ laser (XPS) photoselective vapo-enucleation versus holmium laser enucleation of the prostate for the treatment of symptomatic benign prostatic hyperplasia: a randomized controlled study. J Urol. 2015;193(3):927–34.
32. Rivera ME, Lingeman JE, Heinsimer K, York NE, Krambeck AE. A survey of morcellator preference and cost comparison of the Lumenis Versacut and Wolf Piranha morcellators. Urology. 2018;111:54–8.
33. Shah HN, Mahajan AP, Hegde SS, Bansal MB. Perioperative complications of holmium laser enucleation of the prostate: experience in the first 280 patients, and a review of literature. BJU Int. 2007;100(1):94–101.
34. Cho MC, Park JH, Jeong MS, Yi JS, Ku JH, Oh SJ, et al. Predictor of de novo urinary incontinence following holmium laser enucleation of the prostate. Neurourol Urodyn. 2011;30(7):1343–9.
35. Elshal AM, Mekkawy R, Laymon M, El-Assmy A, El-Nahas AR. Towards optimizing prostate tissue retrieval following holmium laser enucleation of the prostate (HoLEP): assessment of two morcellators and review of literature. Can Urol Assoc J. 2015;9(9–10):E618–25.
36. Krambeck AE, Handa SE, Lingeman JE. Experience with more than 1,000 holmium laser prostate enucleations for benign prostatic hyperplasia. J Urol. 2013;189(1 Suppl):S141–5.
37. Elmansy HM, Kotb A, Elhilali MM. Is there a way to predict stress urinary incontinence after holmium laser enucleation of the prostate? J Urol. 2011;186(5):1977–81.

Photoselective Vaporization of the Prostate

16

David R. Paolone and Daniel H. Williams IV

History

Laser vaporization of the prostate as a means of addressing bladder outlet obstruction from benign prostatic hyperplasia (BPH) was first described by Malek and colleagues at the Mayo Clinic [1]. This technique utilizes a laser with a wavelength of 532 nm, putting it in the visible green light spectrum. Energy at this wavelength is preferentially absorbed by oxyhemoglobin, but not by the irrigation fluid. Hence, the term photoselective vaporization of the prostate (PVP) is used to describe the endoscopic removal of obstructing prostate tissue using the GreenLight laser (Boston Scientific, Marlborough, Massachusetts, USA). The selective absorption of the energy by the oxyhemoglobin leads to superheating of the vascular prostate tissue and subsequent vaporization of the tissue. Heat-induced coagulation of superficial vasculature occurs at the same time, leading to excellent hemostasis as the tissue is removed. The depth of penetration of the 532 nm laser is only 0.8 mm, and extensive coagulative necrosis of the tissue is minimized. This leads to very efficient removal of obstructing tissue in a near bloodless operating field while reducing the potential for extended postoperative tissue sloughing.

The GreenLight laser wavelength of 532 nm is created by doubling the frequency of a 1064 nm Nd:YAG laser and hence halving its wavelength. This was achieved with the use of a potassium-titanyl-phosphate (KTP) crystal. The prototype was able to achieve 60 W of power, and the first commercially available system, the GreenLight PV system, utilized 80 W. While this device allowed for excellent vaporization, and early studies showed comparable results to standard treatments for BPH such as transurethral resection of the prostate and open prostatectomy [2–7], the relatively low power and thin beam made the treatment of larger or less-vascular prostates challenging.

The next iteration of the device was the GreenLight laser HPS generator (2006). This was able to achieve 120 W of power by utilizing a lithium triborate (LBO) crystal instead of KTP. The same ADD Stat fiber that was used with the initial generator was also used with the HPS. This silica laser fiber has a 1.75 mm outer diameter and a 600 μm conducting core diameter. It is side-firing with a 70° forward deflection. The higher-power HPS was able to achieve an 88% more collimated beam, a smaller spot size, and an 8% beam divergence versus 15% for the PV. This resulted in much greater power density in W/cm^2. The HPS also added a dual power mode with two foot pedals so that the surgeon could rapidly

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S. L. Best, S. Y. Nakada (eds.), *Minimally Invasive Urology*,
https://doi.org/10.1007/978-3-030-23993-0_16

alternate between vaporizing and coagulating tissue. A more compact air-cooled system replaced the previous need for water cooling of the laser generator.

The most recent advancement in photoselective vaporization of the prostate was the development of the GreenLight laser XPS system (2010). Like the HPS, it also quasi-continuously emits the 532 nm laser beam using a LBO crystal. Its 50% increase in power necessitated the improvement of the laser fiber to deliver the energy. The new MoXy fiber used with the XPS has a larger outer diameter of 2.10 mm, an increased conducting core diameter of 750 μm, and a metal cap. It is also continuously cooled with normal saline inflow. It has the same 8° divergence as the ADD Stat laser fiber, but the larger conducting core diameter creates a 50% larger spot size. The combination of 50% smaller spot size but 50% more power maintains the same power density in W/cm^2 as the HPS and ADD Stat. Hence, a greater volume of prostate tissue can be efficiently vaporized with the new GreenLight laser XPS and MoXy laser fiber.

Indications

Patients with symptomatic lower urinary tract symptoms (LUTS) have a variety of options from which to choose for management of their symptoms. These options include behavioral strategies such as caffeine and fluid restriction, alpha-blocker medication, 5-alpha-reductase medication, anticholinergic/antimuscarinic medication, beta-3 agonist medication, and surgical intervention. Surgical options include open simple prostatectomy, transurethral resection of the prostate (TURP), transurethral incision of the prostate (TUIP), transurethral microwave thermotherapy (TUMT), laparoscopic or robotic simple prostatectomy, transurethral holmium laser ablation of the prostate (HoLAP), transurethral holmium laser enucleation of the prostate (HoLEP), thulium laser enucleation of the prostate (ThuLEP), prostatic urethral lift (PUL), water vapor thermal therapy, and PVP.

Surgical intervention is indicated for patients with complications from their BPH and those who do not achieve satisfactory symptom relief from medical management. Complications requiring surgical intervention include renal insufficiency due to BPH, recurrent urinary tract infections, bladder calculi, and gross hematuria due to BPH urinary retention [8]. Bladder diverticula do not represent an absolute indication for surgery unless associated with recurrent urinary tract infections or progressive bladder dysfunction [8].

Preoperative Preparation and Evaluation

Assessment of a patient's LUTS can be easily achieved with a validated questionnaire such as the American Urological Association Symptom Index (AUA-SI) or International Prostate Symptom Score (IPSS). Preoperative assessment can confirm the severity of LUTS and the impact on quality of life, and it provides a baseline to which postoperative scores can be compared as a measure of improvement. Patients with predominantly storage symptoms (frequency, urgency, nocturia) should be informed of the possible persistence of these symptoms postoperatively and the need for antimuscarinic medications for relief.

Preoperative history is important to gauge the patient's risk of other complicating urological conditions such as urethral stricture, bladder cancer, urinary tract infection, urinary incontinence, urinary retention, and bladder calculi. A history of hematuria should be appropriately evaluated when present.

Physical examination should include palpation of the lower abdomen to assess for bladder distension, penile examination to detect severe phimosis or meatal stenosis, and digital rectal examination. A brief neurological assessment can detect overt derangement that might suggest a neurological condition affecting the patient's LUTS such as diabetes mellitus, spinal stenosis, or multiple sclerosis. Uroflowmetry and a check of the patient's post-void residual (PVR) by

ultrasound can help to confirm the diagnosis of bladder outlet obstruction, and they provide a means of assessing improvement if measured again postoperatively. Formal urodynamic testing is reserved for those patients with more complicated clinical scenarios.

A standard laboratory, cardiology, pulmonary, and imaging preoperative evaluation appropriate for any surgical patient should be performed prior to performing a PVP. Urinalysis and urine culture, if indicated, would also be appropriate as patients should be free of bacteriuria, if possible, prior to surgery. Additional unique considerations for those patients undergoing a PVP include an assessment of prostate size and shape, necessity of discontinuing anticoagulant medication, and prostate cancer screening.

Measurement of prostate size has implications for the feasibility of performing a PVP as well as for expected length of surgery. Digital rectal examination can provide a general idea of the size of the prostate, but it is notoriously unreliable and may significantly underestimate the size of a median lobe and an intravesical portion of the prostate. Transrectal ultrasound and CT scanning provide more reliable estimations of prostate size and should be employed prior to surgery in those cases where precise knowledge of the size of the prostate will alter surgical approach and planning. Although not routinely recommended for assessing a typical patient with LUTS, cystoscopy may provide additional preoperative information regarding the shape of the prostate, location of the ureteral orifices, and size of the intravesical portion of the prostate. Cystoscopy will also detect a urethral stricture or bladder stones as possible contributing factors to the patient's LUTS and is indicated in the evaluation of patients with hematuria prior to pursuing a PVP.

Patients who are candidates for surgical intervention for BPH are also likely to be within the age range where prostate cancer screening is considered appropriate. A thorough discussion of the risks and benefits of prostate cancer screening should be undertaken with every man with a greater than 10-year life expectancy prior to pursuing a PVP. A prostate biopsy should be pursued in those men with palpable prostate nodules or with serum prostate-specific antigen (PSA) elevation. PSA also can be a surrogate indicator of prostate size, in that a PSA >1.5 usually correlates to a prostate volume of about 30 g.

Although it is generally advisable to discontinue oral antiplatelet and anticoagulation medications prior to surgery when deemed safe for the patient's overall medical condition, one of the advantages of PVP is the ability to perform this procedure even in those patients who must continue taking these medications. Several studies have demonstrated the safety and effectiveness of PVP in patients undergoing the procedure while taking oral anticoagulation medication [9, 10].

Informed consent for PVP includes a thorough and detailed discussion about the surgical risks of transurethral prostate surgeries. Surgical complications are discussed below in detail, but those that should be discussed include a 20% risk of prolonged hematuria (lasting more than 2 weeks), a 20% risk of irritative voiding symptoms, an approximately 5% risk of urinary retention requiring placement of a Foley catheter, a urinary incontinence rate of about 1%, a postoperative urinary tract infection risk of 3%, and a rare chance of damage to the bladder neck or ureteral orifices [1, 5, 11–16].

Operative Technique

Successful completion of a PVP is dependent upon an attentive operating room staff and a properly maintained collection of equipment dedicated to photoselective vaporization of the prostate. First and foremost is the GreenLight laser XPS 180 W output device. A supply of MoXy laser fibers must also be kept on hand, with at least two fibers available for each PVP to be done in case of fiber breakage. The preferred cystoscope is a 23 Fr continuous-flow scope with a 30° telescope. A beak visual obturator is needed to allow initial passage of the scope. The working channel of the scope must be large enough to accept the MoXy fiber. An approximately 20 cm section of tubing is attached to the outflow valve of the scope to allow gentle drainage away from

the surgeon. Two room temperature 3 L normal saline bags are hung through a Y-tube adaptor to provide inflow irrigation. The operating room staff must remain attentive to the fluid levels throughout the case and replace empty bags as needed. A separate 1 L normal saline bag provides cooling to the MoXy fiber. A self-sealing nipple at the working port prevents leakage around the laser fiber. A high-definition video system with a laser filter placed between the telescope lens and camera allows optimal visualization during the procedure. Various styles of laser goggles are available, and the surgeon should choose one that allows excellent clarity and is comfortable to wear for potentially several hours. Urethral sounds should be available, and a 24 Fr or a 26 Fr resectoscope is also important to have as backup. At the completion of the procedure, an 18 Fr 2-way catheter is typically placed, but larger-sized 3-way catheters and continuous bladder irrigation should also be available should there be significant hematuria.

After induction of anesthesia, either general or spinal, the patient is placed in the dorsal lithotomy position. The genitals and perineum are prepped and draped in the standard fashion for cystoscopy. A 23 Fr continuous-flow cystoscope is introduced into the urethra and bladder. Dilation of the urethral meatus with sounds may be needed to facilitate passage of the cystoscope. A careful inspection of the entire bladder urothelium is undertaken, and the laser fiber for the procedure is only opened once a lack of any unexpected findings such as bladder tumors or calculi has been confirmed. Careful attention is paid to the location and position of the ureteral orifices, especially in relation to their proximity to the bladder neck and median lobe. The prostatic urethra is also carefully visualized to generate a strategy for completing the PVP (Figs. 16.1 and 16.2). Particular note is made of the length of the prostatic urethra to prevent vaporization proximal to the bladder neck or distal to the verumontanum.

After introduction of the laser fiber, the PVP is begun. General strategies for achieving the most efficient vaporization are pursued. These include maintaining only a 1–2 mm distance between the laser fiber and the tissue being treated, rotating the fiber no more than 30° from the neutral position to prevent diffusion of the laser beam, keeping the rotation of the fiber at a slow pace (0.5–1 sweeps/s), and withdrawing the cystoscope at a speed of only a few millimeters per second. The speed of the fiber rotation and the angle of the rotation have been shown to have effects on vaporization efficiency in ex vivo analysis [12, 13]. The fiber is marked with a blue arrow and a

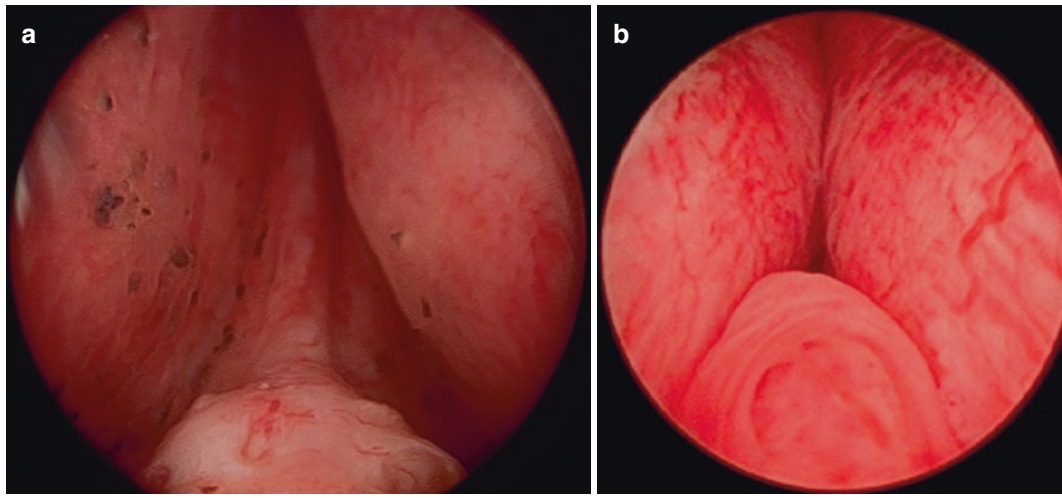

Fig. 16.1 Cystoscopy prior to initiating the photoselective vaporization of the prostate demonstrates significant benign prostatic hyperplasia with complete visual obstruction by the median lobe (**a**) and lateral lobes (**b**). The bladder neck is not visualized from the verumontanum

red stop sign (Fig. 16.3) to help prevent firing the laser toward the cystoscope lens, and careful attention must be given to observing these markings. In addition, the cystoscope is rotated within the prostatic urethra so that the beak of the scope is always 180° from the tissue being treated. The appearance of bubbles as the tissue is being treated is a reliable indicator of effective vaporization. The initial power settings are 80 W for vaporization and 30 W for coagulation. The vaporization power is increased to 120 W once enough tissue has been cleared in the prostate fossa that the working channel can be easily traversed without the laser fiber being forced into contact with the prostate tissue. The vaporization power is increased to 180 W as necessary for the largest or most fibrous glands.

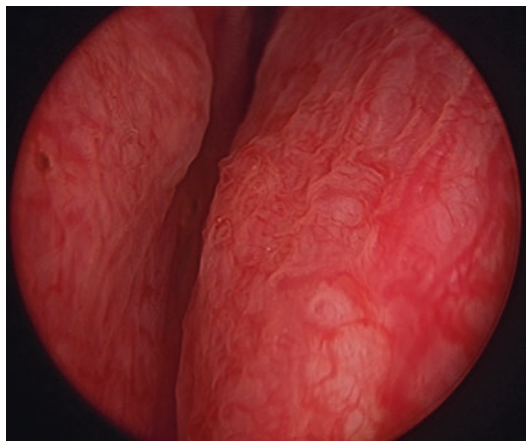

Fig. 16.2 Nodules of benign prostatic hyperplasia within the mid-prostatic urethra are visually obstructing the bladder neck

The authors' technique for completing the PVP begins first by performing vaporization at the 5 o'clock and 7 o'clock positions from the bladder neck to the level of the verumontanum in order to help distinguish the lateral lobes from the median lobe and to define the surgical level of the capsular fibers. The right and left lateral lobes are vaporized next by performing sweeps from the bladder neck to the verumontanum in a stepwise progression from the posterior aspect of the lobe to the anterior aspect of the lobe on each side. The treatment continues in this fashion until the circular fibers of the prostate capsule are recognized (Fig. 16.4). The median lobe of the prostate is then vaporized from a lateral to medial direction beginning at the bladder neck and proceeding distally to the verumontanum. The median lobe is approached from both lateral directions in this manner until the posterior bladder neck is completely flattened to the level of the trigone. Care is taken to recognize the ureteral orifices, which can be marked at the start of the

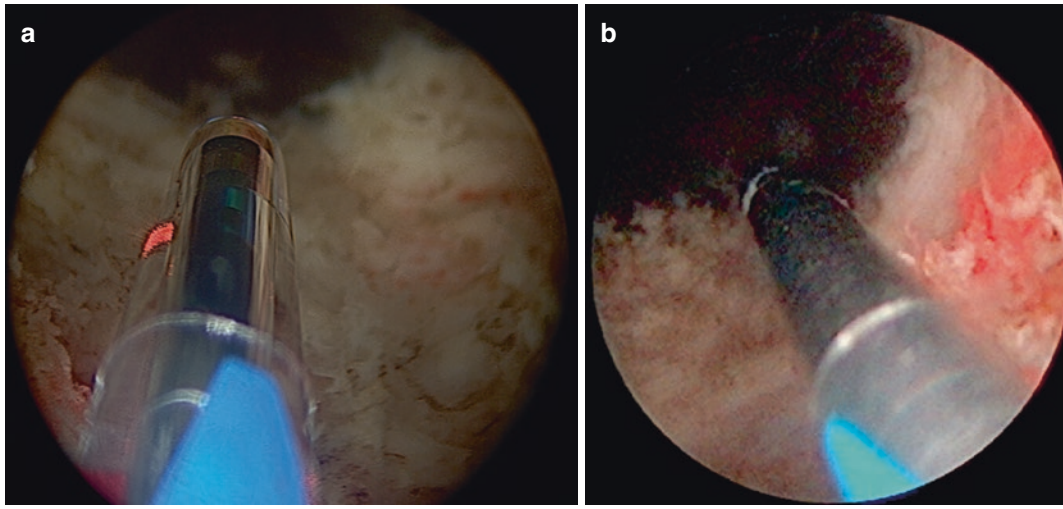

Fig. 16.3 The 120 W HPS 2090 fiber (**a**) and the 180 W XPS MoXy fiber (**b**) are shown at the optimal extension from the end of the cystoscope and the proper distance from the tissue being treated. The blue arrows demonstrate that the beams are aimed toward the tissue and away from the lens

procedure by applying a short burst of vaporization or coagulation energy to the nearby bladder mucosa. Any residual apical tissue is vaporized to complete the procedure and allow a fully unobstructed view from the verumontanum through the prostatic urethra (Figs. 16.5 and 16.6). This technique is very similar to that described by Malek [17] and the Basel technique [14]. Those patients with a large median lobe may require partial or complete vaporization of the median lobe prior to the lateral lobes in order to optimize visualization and irrigation.

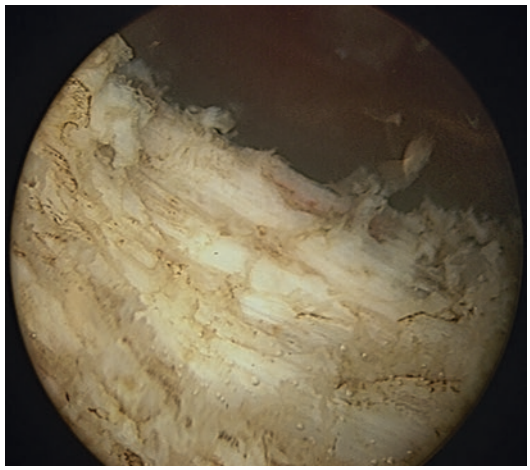

Fig. 16.4 The proper depth of surgical resection is reached once the circular fibers of the prostate capsule are seen

A modified technique that utilizes deep incisions into the prostate lobes has been described [10]. A midline incision that is carried down to the trigone is performed first. A second incision is then made lateral to the median lobe on one side, and the tissue in between these incisions is completely vaporized. The same maneuver is then performed on the contralateral side. Incisions high on the lateral lobes are then made, and the tissue of the lateral lobes is vaporized down to the floor of the prostate.

A spiral technique is another method to perform the PVP [18]. In this technique, a clear channel is achieved in a stepwise fashion, as if spiraling down through the prostate. A complete area of the prostate along its length is vaporized in a 360° manner beginning at the bladder neck, proceeding next to the proximal lateral lobes, and finishing with the floor of the prostate and the apex.

The anterior start technique initially begins with vaporization between the 11 o'clock and 1 o'clock positions from the bladder neck proximally to the level of the verumontanum distally [18]. Vaporization of the lateral lobes is performed

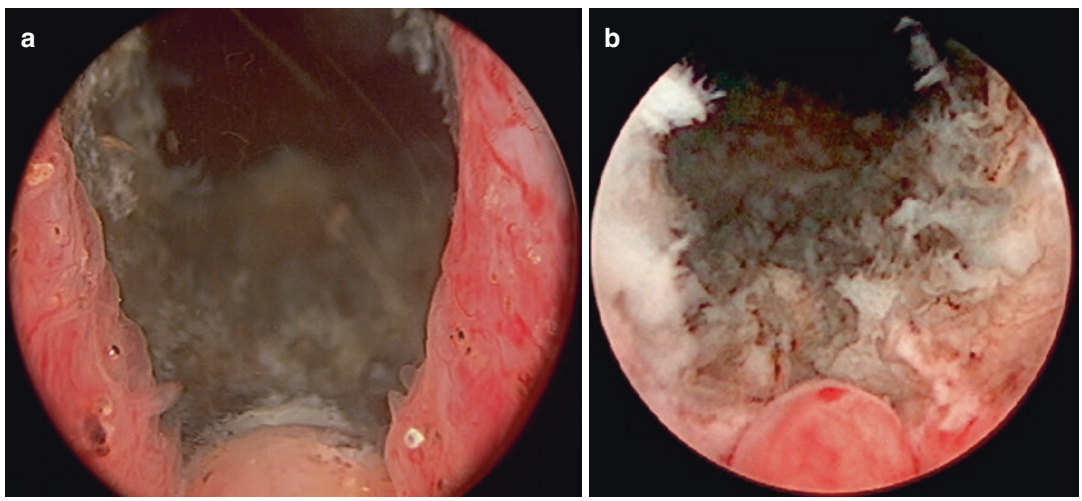

Fig. 16.5 The verumontanum is preserved during photoselective vaporization of the prostate (PVP) (**a**), and vaporization is not performed on tissue distal to it in order to minimize risk of thermal injury to the external sphincter. At completion of the PVP, an open channel is seen from the verumontanum to the bladder neck. It is not unusual to see a shaggy surface (**b**) within the fossa after a successful PVP

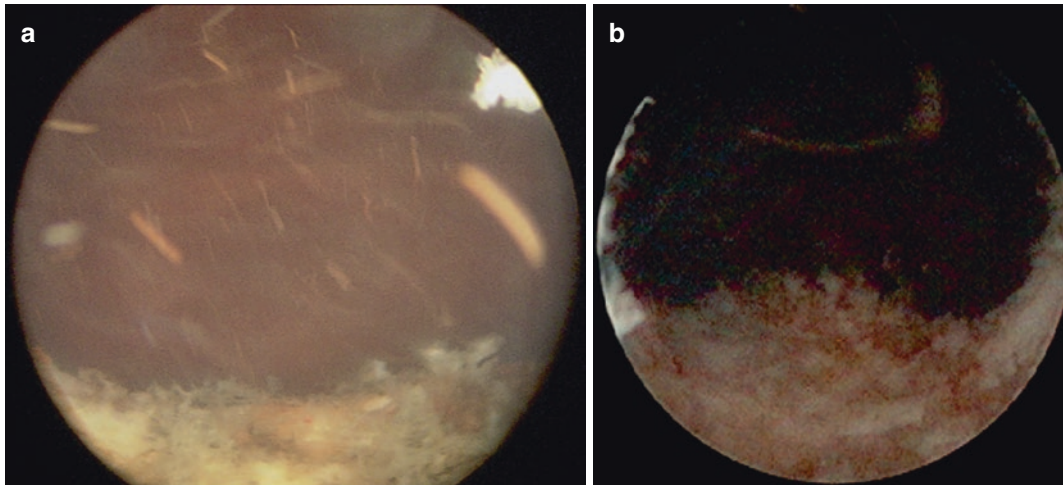

Fig. 16.6 When viewed from the mid-prostatic urethra, any visual evidence of obstruction by prostate tissue is absent (**a**), and the bladder neck is wide open at the completion of the photoselective vaporization of the prostate (**b**)

next. The median lobe is flattened, and creation of a midline incision through the median lobe then allows completion of its vaporization in a medial to lateral direction bilaterally.

Whichever technique a surgeon utilizes, it should be consistent and reproducible, yet also be applicable to prostates of various sizes and shapes. The procedure is assessed for completion when the inflow irrigation is stopped and the prostate fossa is viewed with the cystoscope placed at the verumontanum (which should still be preserved). A wide-open channel into the bladder should be seen with no remaining visually obstructing tissue present. A TURP-like defect is considered critical to reduce the risk of the patient needing a secondary procedure (see Figs. 16.5 and 16.6). The ureteral orifices are inspected to ensure they remain intact. Stopping the inflow irrigation also allows for assessment of bleeding from the prostate fossa.

There are various techniques for managing troublesome bleeding encountered during the PVP. Raising the height of the irrigation fluid will often improve visualization. Once the view becomes less bloody, the fluid may be lowered to its initial height. Specific sites of bleeding within the fossa may be vaporized using the coagulation setting of the laser. Care should be taken to avoid aiming the beam directly into a bleeding vessel. The vaporization setting can also be used to achieve hemostasis by moving the laser fiber an increased distance away from the tissue being treated and thus defocusing the beam. Coagulation rather than vaporization occurs as the working distance from the fiber to the tissue is increased. If visualizing is adequate to allow for continued safe vaporization, bleeding will often slow or stop as the prostatic channel size is increased, and the flow of the continuous irrigation becomes more vigorous. It is often helpful to focus on vaporizing the lateral lobe contralateral to an annoying bleeding site for a period of time and then periodically reassessing the status of the bleeding as the flow improves. If the degree of bleeding becomes significant enough that visualization is impaired to the point that vaporization cannot be safely continued, it may be necessary to remove the cystoscope and place a resectoscope to achieve hemostasis. Once the bleeding site has been fulgurated with the resectoscope, the cystoscope can be replaced and the PVP completed, or the procedure may be completed as a TURP. The need for placing the resectoscope to control bleeding should be a rare event and in the authors' experience occurs in less than 1% of cases.

Once the PVP is deemed complete, and the hemostasis at the end of the procedure deemed appropriate, the cystoscope is removed and an 18 Fr Foley catheter is placed. If no bloody drainage

is noted from the Foley after the bladder is completely drained, then it is connected to a gravity drainage bag and the patient reversed from anesthesia. If continuous bloody drainage is noted from the Foley, then several minutes of hand irrigation with a bulb or piston syringe is undertaken to see if this is able to clear the urine. If this maneuver is unsuccessful, then the 18 Fr Foley is removed and replaced by a larger-sized three-way catheter. If the urine appears to be clearing on moderate continuous bladder irrigation, then the patient is reversed from anesthesia. In the rare event that the urine does not clear with continuous bladder irrigation and an arterial bleeder is suspected, then a resectoscope should be placed and the bleeding site fulgurated if found.

The authors wish to highlight a few "tricks of the trade" points to keep in mind when performing PVP, especially early in the learning phase:

- Be sure to review the online physician videos and resource downloads on the Boston Scientific website (http://www.bostonscientific.com/en-US/products/lithotripsy/greenlight-xps/healthcare-professionals-resources.html).
- Take advantage of the GreenLight PVP simulator, as this should be useful for urologists learning this technique.
- At the start of the case, create a good working channel within the prostatic urethra in order to optimize flow of irrigation. The laser power may initially need to be kept low (80 W) when making this channel. The vaporization power can be increased (120 W or higher) once the channel is open enough to allow for good flow of irrigant.
- Control bleeding early and don't fall behind on this, as the combination of blood and saline irrigant makes endoscopic visualization difficult.
- Over time, one's efficiency of movement and sweeping of the laser fiber improves, and surgeons will find that they will spend more time with their foot on the firing pedal than not.
- Fully vaporize an area of tissue before moving on to another area, as previously treated tissue becomes more difficult to vaporize, thus decreasing laser efficiency.
- Choose straightforward cases to start with when early in the learning curve. These cases include patients with smaller glands, who are not on anticoagulation, who are not in retention, and who do not have significant median lobes.
- Emphasize practice-based learning and improvement strategies by videotaping your procedures and evaluating and critiquing yourself and others. Much can be learned by even a few minutes of doing so!

Postoperative Management

The need for postoperative catheterization following PVP done under general anesthesia is at the discretion of the surgeon. Those done under spinal anesthesia may benefit from overnight placement of a catheter given the increased risk of urinary retention following spinal anesthesia. It is the standard practice of the authors to leave a catheter overnight in patients undergoing PVP, and the patient is instructed to remove the catheter himself on the first postoperative morning if the urine does not demonstrate any significant hematuria. Those patients taking oral anticoagulant medication may benefit from a longer trial of catheterization in order to reduce the risk of clot retention. Those patients with preoperative urinary retention may also benefit from longer catheterization times and a formal trial of voiding in the office rather than self-removal of the catheter at home. Several clinical trials have demonstrated reduced mean catheterization times for patients undergoing PVP relative to TURP [4, 6, 19].

Those patients noted to have significant hematuria at the completion of the PVP often require additional interventions to help the urine to clear. Instilling more water into the catheter balloon and placing it on traction will often help to stop bleeding from the prostate fossa. Manual irrigation of the catheter is also often successful in slowing bleeding and preventing clot formation. However, for those patients in whom significant hematuria persists despite these maneuvers, a period of time utilizing continuous bladder irrigation may be necessary. The continuous bladder

irrigation may be weaned over several hours so that the patient may still go home the day of surgery, although in some cases overnight hospitalization may be necessary.

Patients are encouraged to increase their fluid intake as soon as they are transferred from the recovery room to the outpatient unit. This increased fluid consumption should be maintained for several days after surgery, and oral intake and diet can return to preoperative levels if the urine remains clear at home with the catheter out. Narcotic pain medications should be avoided if possible, but patients are given a prescription to fill if necessary. Patients are advised to limit postoperative activities for 1–2 weeks after surgery. Lifting should be restricted to less than 10 lb, and strenuous exercise should be avoided. Sexual activity is also discouraged for 1–2 weeks.

Patients can generally discontinue any medications they were taking for management of LUTS after they have undergone a PVP. Those patients who experience persistent gross hematuria may benefit from the initiation or resumption of a 5-ARI. Similarly, postoperative storage symptoms including urinary frequency, urgency, and urge incontinence may warrant continuation of an antimuscarinic medication in those taking these preoperatively or initiation of such medications for patients in whom these symptoms develop de novo after surgery. Resumption of oral anticoagulant medications can be advised at the surgeon's discretion and as deemed appropriate by the patient's cardiologist or internist.

Patients are typically seen in 2–3 weeks following surgery for a postoperative visit or in 2–3 days if a formal trial of voiding is needed. Problems such as dysuria, storage symptoms, hematuria, tissue sloughing, or other concerns are addressed at the postoperative visit. A PVR is routinely checked to rule out impending urinary retention. The patients then return in 3 months for uroflowmetry, assessment of PVR, and assessment of LUTS with the AUA-SI. Any lingering concerns are sought, and those patients with poor symptom relief or very poor flow rates on uroflowmetry undergo cystoscopy to evaluate for incomplete tissue removal, urethral stricture, or bladder neck contracture. A serum PSA can be checked in appropriately selected patients to establish a new baseline for future screening.

Efficacy

Assessment of the efficacy of PVP with regard to improvement in LUTS and urodynamic parameters is limited by a paucity of randomized clinical trials comparing PVP to other established surgical treatment options. In addition, the studies which have been published do not typically utilize the latest iteration of the device, the 180 W XPS system. Nonetheless, the data thus far demonstrate comparable improvement to that achieved with TURP and OP, with potential benefit in regard to surgical complications.

In 2006, Bouchier-Hayes and associates published a randomized trial comparing TURP to PVP done with the 80 W system [4]. A similar reduction of approximately 50% in IPSS was seen for both the PVP and the TURP groups. The Qmax improved by 167% for the PVP patients and 149% for the TURP patients, a significant increase for both. Post-void residual volumes also showed significant decreases, and similar trends were seen in relation to bother and quality of life scores. The length of catheterization was less in the PVP group (mean of 12.2 h) than in the TURP group (44.5 h). A significant difference in length of stay was also noted, with the mean of the PVP group being 1.08 days and the mean of the TURP group being 3.4 days.

An early study comparing TURP to 80 W PVP in patients with large (>70 mL) prostates noted a significant difference in IPSS, Qmax, and PVR values at 6 months in favor of TURP [6]. The procedure was significantly shorter for the TURP group (mean of 51 min versus 87 min), but the length of hospital stay (4.8 days versus 2 days) and length of catheterization (3.9 days and 1.7 days) were shorter in the PVP group.

A study comparing 120 W PVP with TURP in patients with a mean prostate volume of approximately 60 mL shows more promising results [2]. As seen in the other studies, the mean catheterization time of 1.4 days in the PVP group was

significantly shorter than the 2.7 days in the TURP group. Mean hospital stay also favored PVP (2.3 days versus 4.1 days). Functional outcome with regard to increase in Qmax, decrease in IPSS, and decrease in PVR was notable for dramatic improvement in all three compared with preoperative values. The degree of improvement in both the PVP group and the TURP group was comparable at all time points of follow-up out to 36 months.

A second randomized clinical trial comparing 120 W PVP with TURP was published in 2011 and provided a 2-year follow-up [5]. Similar IPSS reduction was seen for both PVP and TURP at 2 years (−15.7 and − 14.9, respectively). There was no significant difference in the increase in Qmax between PVP and TURP (+14.5 and + 13.1 mL/s, respectively). Length of hospital stay and time to catheter removal were significantly shorter with PVP.

Similar symptomatic improvement and changes in urodynamic parameters have also been noted in PVP as compared to OP. Alivizatos and colleagues assessed men with prostate glands >80 mL in size who were randomized to either 80 W PVP or transvesical open enucleation at 1 year [3]. All functional parameters improved significantly compared to baseline values in both groups. The IPSS did not differ between the two groups at 3, 6, and 12 months postoperatively. There were no significant differences between the two groups in the Qmax and PVR after surgery. The prostate volume was significantly reduced to a greater degree in the OP group. Another trial evaluating PVP and OP in men with glands >80 mL provided an 18-month follow-up [7]. There was no difference in IPSS between the two groups at 3, 6, 12, and 18 months postoperatively. At 18 months there were no significant differences between the two groups in Qmax and PVR. As seen in the previous study, the prostate volume was lower in the OP group.

A study looking at the efficacy of the GreenLight laser XPS system showed excellent early functional improvement in key parameters up to 6 months following treatment [20]. Mean IPSS scores improved from 19.6 preoperatively to 9.4. Maximum urinary flow rate increased from 8.4 to 21.0 mL/s. There was also a drop in PVR from a mean of 190 mL to a mean of 35 mL. The study was notable for approximately a quarter of the patients having a prostate volume >80 mL. Statistically significant drops in both PSA values and prostate volume at 3 months postoperatively confirm the effectiveness of the XPS system in removing a large amount of prostate tissue.

More recently, the GOLIATH trial enrolled 291 patients at 29 centers in 9 European countries to assess noninferiority of PVP to transurethral resection of the prostate in IPSS at 6 months. A total of 281 patients were ultimately randomized, of which 269 received treatment. Noninferiority was maintained at 12 months [21]. In addition, maximum urinary flow rate, post-void residual urine volume, prostate volume, and prostate-specific antigen were not statistically different between the treatment arms at 12 months [21]. Furthermore, the complication-free rate at 1 year was 84.6% after photoselective vaporization of the prostate vs 80.5% after transurethral resection of the prostate [21].

Two-year results for the GOLIATH trial were published in 2016. Noninferiority in IPSS, maximum flow rate, and reductions in prostate volume and prostate-specific antigen were confirmed again at 24 months [22]. The proportion of patients free of complications through 24 months was 83.6% for photoselective vaporization of the prostate versus 78.9% for transurethral resection of the prostate [22]. This trial demonstrated a durable surgical benefit for photoselective vaporization of the prostate that compares favorably to transurethral resection of the prostate with regards to safety and efficacy.

Photoselective vaporization of the prostate has also been studied in men suffering from urinary retention prior to surgery. Ruszat and colleagues published a subgroup analysis of their results using PVP in men with refractory urinary retention [23]. At 24 months postoperatively, they found a peak urinary flow rate of 19.4 mL/s in men with retention versus 23.3 mL/s in men without retention who has also undergone the procedure. IPSS for the two groups was found to be 4.4 versus 6.5, respectively. Postoperative uri-

nary retention and complication rates were comparable for the two groups. Being in urinary retention also did not have any negative impact on the outcome of 180 W GreenLight laser PVP in the study by Bachmann and associates [20].

There are few studies examining the long-term durability of PVP. Hai reported on the 5-year outcomes on 246 of the first 321 patients who underwent PVP at his institution [24]. The average improvement in AUASS was 79%, while the average improvement in maximal flow rate was 172%. The overall retreatment rate was 8.9%; 19 of the 246 were treated with a repeat PVP due to re-obstruction from prostate adenoma, and 3 underwent transurethral incision of the bladder neck. A study of 500 consecutive patients with mean follow-up of 30 months found a retreatment rate of 6.8% because of insufficient first vaporization or regrowth of prostate tissue [25].

Complications

Complications related to PVP can be categorized as intraoperative, early postoperative, and late. All are relatively infrequent and comparable to those seen in other surgical interventions for BPH.

Intraoperative

Intraoperative bleeding may occur with PVP, but the need for blood transfusion is significantly less likely than what is seen with TURP [2, 26]. In a randomized, prospective trial using the 120 W laser, Al-Ansari et al. reported that 20% of TURPs needed blood transfusions, but none of the PVPs did [2]. In the same study, 16.7% of TURPs had capsular perforated capsule versus none with PVP, and 5% of TURPs had TUR syndrome versus none of PVPs. Even in those patients on anticoagulation, the occurrence of significant intraoperative bleeding is less than TURP [9, 10]. Conversion to TURP because of intraoperative bleeding is a potential adverse event that patients should be warned of prior to PVP. Conversion rates are generally low (<5%) but increase as gland size increases [26].

Other intraoperative complications of endoscopic surgery for BPH to be considered include capsule perforation and TUR syndrome. However, because the irrigating fluid used during PVP is isotonic to saline, the theoretical risk of TUR syndrome should be very low. The GreenLight laser is selective for oxyhemoglobin, and thus minimally vascular tissue such as the fibrotic prostate capsule should be much less susceptible to the effects of the treatment. This reduces the likelihood of capsule perforation compared to the electrocautery of TURP. One study comparing TURP and PVP found a 16.7% capsule perforation rate and 5% risk of TUR syndrome in the patients undergoing TURP with no patient in the PVP group experiencing these complications [2]. Another comparison found a 0.4% versus 6.3% capsular perforated capsule rate between the PVP and TURP groups, respectively [25].

Early Postoperative Complications

Early postoperative complications following PVP include urinary retention, hematuria, dysuria, urinary tract infection, ejaculatory dysfunction, recatheterization, and readmission.

Studies using the 80 W laser report rates of urinary retention ranging from 1% to 15.4%, transient hematuria in 4–18%, transient dysuria in 7–30%, culture-documented UTIs in 6%, and ejaculatory dysfunction (either decreased volume of ejaculate or retrograde ejaculation) ranging from 36% to 55% [19, 27–33]. In a large single-center study of 500 patients using the 80 W laser, Ruszat and colleagues reported early postoperative complication rates including hematuria (9.8%), transfusion (0.4%), immediate repeat surgery (0.6%), urosepsis (0.4%), dysuria (14.8%), urge incontinence (2.4%), and UTI (6.8%) [25, 26].

Studies using the 120 W laser report rates of urinary retention at 8%, UTI in 6%, a recatheterization rate of 1–5%, transient hematuria in 12% 120 W 12%, and the need for antimuscarinics to

control storage symptoms as being the same as in TURP [5]. In one study using the 120 W laser, the postoperative readmission rate was 6% (3 of 50 patients) including 2 for hematuria and 1 for a febrile UTI [5]. In another study using the 120 W laser, 60 patients (versus 60 TURPs) were followed for a mean of 36 months, and at follow-up, no patient had had clot retention (versus 10% of TURPS); however, 93% reported urgency or dysuria (versus 32% of TURPs) [2].

In a 2010 meta-analysis of published studies on PVP, Ahyai and colleagues found postoperative urinary retention in 9.9%, clot retention in 0%, secondary resection rates of 2.1%, secondary bleeding in 0.7%, urosepsis in 0%, and UTI with fever 12% [34]. Except for clot retention, these numbers were all higher than TURP, bipolar TURP, TUVP, and HoLEP but did not reach statistical significance.

The safety of photoselective vaporization of the prostate remains satisfactory for higher risk patients as well. A multicenter retrospective analysis of 941 men who underwent photoselective vaporization of the prostate specifically assessed the results of high medical risk men [35]. These men were considered high risk if they had an American Society of Anesthesiologists physical status score ≥3. They tended to be older, have larger prostate volumes, and were more likely to be on anticoagulant or antiplatelet medications [35]. At 6 months, the higher medical risk group had similar improvements in IPSS, maximum flow rate, post-void residual urine volume, and reduction in prostate volume as men in the standard risk group, and 90-day complication rates were comparable between the two groups [35]. Of note, the high medical risk group did have more hospital readmissions within 90 days of surgery.

Late Postoperative Complications

Urethral stricture represents one potential late complication from PVP. One study with long-term follow-up found an overall stricture rate of 4.4%, the vast majority of which were in the bulbar urethra (>90%) [25]. The stricture was noted in the first year in 86% of patients with a stricture. This group found that their urethral stricture rate fell significantly after switching from a 26 Fr cystoscope to a 22.5 Fr instrument. In one trial comparing PVP to TURP, urethral stricture was noted in 5.1% of the PVP patients and 8.1% of the TURP patients at 6 months follow-up [6]. These patients did undergo internal urethrotomy as treatment for the stricture. In a study by Alivizatos and associates comparing PVP to OP, only 2 of 65 patients in the PVP group and 1 of 60 patients in the OP group required treatment for urethral stricture [3]. Capitan et al. found that 2 of 50 patients developed urethral meatal stenosis, 6% developed a urethral stricture, 2% had urinary incontinence, and there were no bladder neck contractures [5].

Bladder neck contracture is another potential late complication of PVP. However, much like for urethral stricture, the incidence is generally low. No patient experienced a bladder neck contracture in one comparative study of PVP versus TURP with a 2-year follow-up, while 4% of the TURP patients experienced this complication [5]. In a randomized clinical trial comparing PVP to OP with an 18-month follow-up, 0% versus 3.3% of patients were noted to have bladder neck contractures in the PVP and OP groups, respectively [7].

Patients undergoing PVP should be informed about the possibility of urinary incontinence and erectile dysfunction as part of informed consent of the procedure. The actual incidence of these conditions appears to be quite low in the published literature. In comparison with both OP and TURP, PVP has demonstrated no significant difference in effect on erectile function [3, 4]. Like with TURP, retrograde ejaculation does occur commonly.

Ruszat et al. reported in their single-center study of 500 PVP procedures using the 80 W laser with a 2.5-year mean follow-up of late postoperative complication of bladder neck contracture in 3.6%, urethral stricture in 4.4%, retreatment rates of 6.8%, and incontinence in 1.2% [25]. Using the 120 W laser, Al-Ansari et al. reported in their 60 patients with a mean follow-up of 36 months rates of late complications of needing a redo procedure in 11%

and bladder neck contractures in 7.4% [2]. In a meta-analysis by Ahyai et al., rates of late postoperative complications included bladder neck contracture in 5%, urethral stricture in 6.3%, repeat procedure in 5.6%, and dysuria in 8.5% [34].

Special Considerations

Safety of PVP in Men Who Require Continuous Anticoagulation

One of the highly touted advantages of PVP over TURP is that its laser technology allows for a virtually bloodless tissue ablation technique. PVP therefore may be performed safely for patients with medical comorbidities, including a high-risk patient on anticoagulation and antiplatelet therapies [36].

In a two-center study of 66 medically comorbid patients with an ASA score of three or more, Reich et al. reported a 14-point IPSS score reduction and a 222% improvement in Qmax at 1 year, with an 11% recatheterization rate and one patient requiring a redo procedure [29].

In a study of 116 men who underwent PVP while continuing warfarin, aspirin, or clopidogrel therapies, no bleeding complications were observed and no patients required blood transfusions. Of note, these patients did have higher rate of postoperative bladder irrigation (17% versus 5.4% of controls) resulting in longer postoperative catheterization time [9]. These findings have been confirmed in other studies [10, 37].

Safety and Efficacy of PVP in Men with Large Prostates

A number of studies have demonstrated the safety and efficacy of PVP on large prostates. Significant improvements in Qmax and IPSS scores have been reported [30, 38]. However, operating times, the probability of a staged procedure, and the number of laser fibers used to complete the procedure were higher in men with large prostates when compared with smaller prostate glands. Good functional outcomes were maintained, but the incidence of postoperative recatheterization was 5, and 23.1% of patients needed a reoperation within 1 year [30, 38]. These apparent drawbacks of treating large prostates with the early 80 W systems have been minimized with the advent of more powerful (180 W) laser systems.

Another study found a higher safety profile of PVP as compared with TURP [6]. When compared to open prostatectomy for glands >80 mL, PVP patients had longer operating times but shorter catheterization and hospitalization times [3]. Complications and improvements in voiding parameters were similar in both groups. The open prostatectomy group had a higher transfusion rate.

A more recent trial by Meskawi et al. reported on 438 men with prostate volumes greater than 100 mL on transrectal ultrasound who were treated at eight centers in Canada, the United States, and France with photoselective vaporization of the prostate. IPSS, maximum flow rate, and post-void residual urine volume were significantly improved at 6, 12, 24, 36, and 48 months [39]. The median prostate volume for this group of men was 121 mL, and the median prostate-specific antigen value was 6.3 ng/dL. Thirty-seven percent of the men had an indwelling catheter at the time of surgery. Surgical retreatment rates were only 5.4% at 24 months and 9.3% at 36 months [39].

Learning Curve

The learning curve for any surgery plays an important role in its overall acceptance. PVP has been shown to have a shorter learning curve than HoLEP, and this is likely the reason for the greater popularity of PVP [40]. Additionally, some consider PVP to be easier to learn and perform than TURP with reports of urologists feeling comfortable performing TURPs after about 50 procedures [41, 42] and others reporting competence in PVP after performing 10–20 (or fewer) procedures depending on gland size [41]. As with learning any new technique or procedure, the authors advise a mentorship training period to adequately and safely perform PVP.

Cost

An issue worth mentioning is the cost-effectiveness of PVP, as the generator and laser fibers are expensive. A number of studies have examined and summarized the issue of cost of PVP versus TURP [43]. A Swiss study showed similar financial costs for PVP and TURP. OR and postoperative care costs were higher for TURP, while the costs of disposable materials were higher for PVP [44]. Similarly, an Australian study showed that when performed as a same-day surgery procedure and despite the higher cost of equipment and disposables, PVP was less expensive than TURP. Cost savings with PVP generally were due to shorter hospital stays, shorter catheterization times, and lower complication rates [4].

A 2006 study examined the clinical outcomes and cost characteristics of PVP, TUMT, TUNA, interstitial laser coagulation, and TURP using a decision analytic Markov model. In this model, PVP resulted in the largest beneficial changes in IPSS, Qmax, and QoL scores, and the expected cost per patient at all time points was lowest for PVP. The cost savings of PVP was due to lower rates of adverse events and retreatments [45].

It is important to keep in mind that the cost-effectiveness of any treatment depends on the different reimbursement systems in different countries. Therefore, it is difficult to draw general conclusions that are applicable to every country or health-care delivery system.

Conclusions

PVP is one of a number of laser technologies available for the treatment of lower urinary tract symptoms due to benign prostatic obstruction. This treatment carries with it a quick learning curve, a low risk of bleeding, the ability to perform the surgery if men are unable to stop blood-thinning agents, a short postoperative catheterization, and a short hospital stay. However, the equipment is expensive, and there are increased retreatment and dysuria rates as compared to TURP. Urologists need to be aware of the advantages and disadvantages of not only PVP but of the array of technologies available for the surgical treatment of LUTS due to BPH. Ultimately, urologists needs to know and review their own outcomes with benign prostate surgeries and offer their patients the treatments that in their own hands have the best outcomes and fewest complications, particularly in the era of cost-conscious and evidence-based medicine.

References

1. Malek RS. Contemporary management of the benign obstructive prostate: an overview. Mayo Clin Proc. 1998;73(6):589.
2. Al-Ansari A, Younes N, Sampige VP, Al-Rumaihi K, Ghafouri A, Gul T, et al. GreenLight HPS 120-W laser vaporization versus transurethral resection of the prostate for treatment of benign prostatic hyperplasia: a randomized clinical trial with midterm follow-up. Eur Urol. 2010;58(3):349–55.
3. Alivizatos G, Skolarikos A, Chalikopoulos D, Papachristou C, Sopilidis O, Dellis A, et al. Transurethral photoselective vaporization versus transvesical open enucleation for prostatic adenomas >80 ml: 12-mo results of a randomized prospective study. Eur Urol. 2008;54(2):427–37.
4. Bouchier-Hayes DM, Anderson P, Van Appledorn S, Bugeja P, Costello AJ. KTP laser versus transurethral resection: early results of a randomized trial. J Endourol. 2006;20(8):580–5.
5. Capitan C, Blazquez C, Martin MD, Hernandez V, de la Pena E, Llorente C. GreenLight HPS 120-W laser vaporization versus transurethral resection of the prostate for the treatment of lower urinary tract symptoms due to benign prostatic hyperplasia: a randomized clinical trial with 2-year follow-up. Eur Urol. 2011;60(4):734–9.
6. Horasanli K, Silay MS, Altay B, Tanriverdi O, Sarica K, Miroglu C. Photoselective potassium titanyl phosphate (KTP) laser vaporization versus transurethral resection of the prostate for prostates larger than 70 mL: a short-term prospective randomized trial. Urology. 2008;71(2):247–51.
7. Skolarikos A, Papachristou C, Athanasiadis G, Chalikopoulos D, Deliveliotis C, Alivizatos G. Eighteen-month results of a randomized prospective study comparing transurethral photoselective vaporization with transvesical open enucleation for prostatic adenomas greater than 80 cc. J Endourol. 2008;22(10):2333–40.
8. McVary KT, Roehrborn CG, Avins AL, Barry MJ, Bruskewitz RC, Donnell RF, et al. Update on AUA guideline on the management of benign prostatic hyperplasia. J Urol. 2011;185(5):1793–803.

9. Ruszat R, Wyler S, Forster T, Reich O, Stief CG, Gasser TC, et al. Safety and effectiveness of photoselective vaporization of the prostate (PVP) in patients on ongoing oral anticoagulation. Eur Urol. 2007;51(4):1031–8; discussion 8–41.
10. Sandhu JS, Ng CK, Gonzalez RR, Kaplan SA, Te AE. Photoselective laser vaporization prostatectomy in men receiving anticoagulants. J Endourol. 2005;19(10):1196–8.
11. Gu X, Strom K, Spaliviero M, Wong C. Intermediate outcomes of GreenLight HPS laser photoselective vaporization prostatectomy for symptomatic benign prostatic hyperplasia. J Endourol. 2011;25(6):1037–41.
12. Kauffman EC, Kang HW, Choi BB. The effect of laser-fiber sweeping speed on the efficiency of photoselective vaporization of the prostate in an ex vivo bovine model. J Endourol. 2009;23(9):1429–35.
13. Osterberg EC, Kauffman EC, Kang HW, Koullick E, Choi BB. Optimal laser fiber rotational movement during photoselective vaporization of the prostate in a bovine ex-vivo animal model. J Endourol. 2011;25(7):1209–15.
14. Shim M, Kwon T, Kim SC, Ha SH, Ahn TY. Changes in serum prostate-specific antigen levels after potassium-titanyl-phosphate (KTP) laser vaporization of the prostate. Korean J Urol. 2010;51(2):111–4.
15. Spaliviero M, Araki M, Culkin DJ, Wong C. Incidence, management, and prevention of perioperative complications of GreenLight HPS laser photoselective vaporization prostatectomy: experience in the first 70 patients. J Endourol. 2009;23(3):495–502.
16. Spaliviero M, Strom KH, Gu X, Araki M, Culkin DJ, Wong C. Does Greenlight HPS(™) laser photoselective vaporization prostatectomy affect sexual function? J Endourol. 2010;24(12):2051–7.
17. Malek RS, Kuntzman RS, Barrett DM. High power potassium-titanyl-phosphate laser vaporization prostatectomy. J Urol. 2000;163(6):1730–3.
18. Gomez Sancha F, Bachmann A, Choi BB, Tabatabaei S, Muir GH. Photoselective vaporization of the prostate (GreenLight PV): lessons learnt after 3500 procedures. Prostate Cancer Prostatic Dis. 2007;10(4):316–22.
19. Bachmann A, Schurch L, Ruszat R, Wyler SF, Seifert HH, Muller A, et al. Photoselective vaporization (PVP) versus transurethral resection of the prostate (TURP): a prospective bi-centre study of perioperative morbidity and early functional outcome. Eur Urol. 2005;48(6):965–71; discussion 72.
20. Bachmann A, Muir GH, Collins EJ, Choi BB, Tabatabaei S, Reich OM, et al. 180-W XPS GreenLight laser therapy for benign prostate hyperplasia: early safety, efficacy, and perioperative outcome after 201 procedures. Eur Urol. 2012;61(3):600–7.
21. Bachmann A, Tubaro A, Barber N, d'Ancona F, Muir G, Witzsch U, et al. A European multicenter randomized noninferiority trial comparing 180 W GreenLight XPS laser vaporization and transurethral resection of the prostate for the treatment of benign prostatic obstruction: 12-month results of the GOLIATH study. J Urol. 2015;193(2):570–8.
22. Thomas JA, Tubaro A, Barber N, d'Ancona F, Muir G, Witzsch U, et al. A multicenter randomized noninferiority trial comparing GreenLight-XPS laser vaporization of the prostate and transurethral resection of the prostate for the treatment of benign prostatic obstruction: two-yr outcomes of the GOLIATH study. Eur Urol. 2016;69(1):94–102.
23. Ruszat R, Wyler S, Seifert HH, Reich O, Forster T, Sulser T, et al. Photoselective vaporization of the prostate: subgroup analysis of men with refractory urinary retention. Eur Urol. 2006;50(5):1040–9; discussion: 9.
24. Hai MA. Photoselective vaporization of prostate: five-year outcomes of entire clinic patient population. Urology. 2009;73(4):807–10.
25. Ruszat R, Seitz M, Wyler SF, Abe C, Rieken M, Reich O, et al. GreenLight laser vaporization of the prostate: single-center experience and long-term results after 500 procedures. Eur Urol. 2008;54(4):893–901.
26. Ruszat R, Wyler SF, Seitz M, Lehmann K, Abe C, Bonkat G, et al. Comparison of potassium-titanyl-phosphate laser vaporization of the prostate and transurethral resection of the prostate: update of a prospective non-randomized two-centre study. BJU Int. 2008;102(10):1432–8; discussion 8–9.
27. Bachmann A, Ruszat R, Wyler S, Reich O, Seifert HH, Muller A, et al. Photoselective vaporization of the prostate: the basel experience after 108 procedures. Eur Urol. 2005;47(6):798–804.
28. Malek RS, Kuntzman RS, Barrett DM. Photoselective potassium-titanyl-phosphate laser vaporization of the benign obstructive prostate: observations on long-term outcomes. J Urol. 2005;174(4 Pt 1):1344–8.
29. Reich O, Bachmann A, Siebels M, Hofstetter A, Stief CG, Sulser T. High power (80 W) potassium-titanyl-phosphate laser vaporization of the prostate in 66 high risk patients. J Urol. 2005;173(1):158–60.
30. Sandhu JS, Ng C, Vanderbrink BA, Egan C, Kaplan SA, Te AE. High-power potassium-titanyl-phosphate photoselective laser vaporization of prostate for treatment of benign prostatic hyperplasia in men with large prostates. Urology. 2004;64(6):1155–9.
31. Sulser T, Reich O, Wyler S, Ruszat R, Casella R, Hofstetter A, et al. Photoselective KTP laser vaporization of the prostate: first experiences with 65 procedures. J Endourol. 2004;18(10):976–81.
32. Te AE, Malloy TR, Stein BS, Ulchaker JC, Nseyo UO, Hai MA, et al. Photoselective vaporization of the prostate for the treatment of benign prostatic hyperplasia: 12-month results from the first United States multicenter prospective trial. J Urol. 2004;172(4 Pt 1):1404–8.
33. Volkan T, Ihsan TA, Yilmaz O, Emin O, Selcuk S, Koray K, et al. Short term outcomes of high power (80 W) potassium-titanyl-phosphate laser vaporization of the prostate. Eur Urol. 2005;48(4):608–13.
34. Ahyai SA, Gilling P, Kaplan SA, Kuntz RM, Madersbacher S, Montorsi F, et al. Meta-analysis of

functional outcomes and complications following transurethral procedures for lower urinary tract symptoms resulting from benign prostatic enlargement. Eur Urol. 2010;58(3):384–97.
35. Rajih E, Tholomier C, Hueber PA, Alenizi AM, Valdivieso R, Azizi M, et al. Evaluation of surgical outcomes with photoselective GreenLight XPS laser vaporization of the prostate in high medical risk men with benign prostatic enlargement: a multicenter study. J Endourol. 2017;31(7):686–93.
36. Van Cleynenbreugel B, Srirangam SJ, Van Poppel H. High-performance system GreenLight laser: indications and outcomes. Curr Opin Urol. 2009;19(1):33–7.
37. Yuan J, Wang H, Wu G, Liu H, Zhang Y, Yang L. High-power (80 W) potassium titanyl phosphate laser prostatectomy in 128 high-risk patients. Postgrad Med J. 2008;84(987):46–9.
38. Pfitzenmaier J, Gilfrich C, Pritsch M, Herrmann D, Buse S, Haferkamp A, et al. Vaporization of prostates of > or =80 mL using a potassium-titanyl-phosphate laser: midterm-results and comparison with prostates of <80 mL. BJU Int. 2008;102(3):322–7.
39. Meskawi M, Hueber PA, Valdivieso R, Bruyere F, Misrai V, Fournier G, et al. Multicenter international experience of 532 nm-laser photo-vaporization with Greenlight XPS in men with large prostates (prostate volume> 100 cc). World J Urol. 2017;35(10):1603–9.
40. de la Rosette J, Alivizatos G. Lasers for the treatment of bladder outlet obstruction: are they challenging conventional treatment modalities? Eur Urol. 2006;50(3):418–20.
41. Bouchier-Hayes DM. Photoselective vaporization of the prostate — towards a new standard. Prostate Cancer Prostatic Dis. 2007;10:S10–4.
42. Rajbabu K, Chandrasekara SK, Barber NJ, Walsh K, Muir GH. Photoselective vaporization of the prostate with the potassium-titanyl-phosphate laser in men with prostates of >100 mL. BJU Int. 2007;100(3):593–8; discussion 8.
43. Alivizatos G, Skolarikos A. Photoselective vaporization of the prostate. Review of cost implementation to BPH treatment. Prostate Cancer Prostatic Dis. 2007;10:S15–20.
44. Ruszat R, Wyler S, Seifert H. Photoselective vaporization (PVP) vs. transurethral electroresection of the prostate (TURP): a comparative cost analysis. EAU Congress Paris Abstract No 996. Eur Urol Suppl. 2006;5:271.
45. Stovsky MD, Griffiths RI, Duff SB. A clinical outcomes and cost analysis comparing photoselective vaporization of the prostate to alternative minimally invasive therapies and transurethral prostate resection for the treatment of benign prostatic hyperplasia. J Urol. 2006;176(4 Pt 1):1500–6.

Nonlaser Transurethral Resection of the Prostate

17

Alexis E. Te, Dominique Thomas, and Bilal I. Chughtai

General Overview

Transurethral resection of the prostate is a general technique that utilizes a transurethral approach to a prostatectomy, which removes obstructive prostate tissue to facilitate improved voiding parameters. The two nonlaser techniques reviewed are an advancement to the traditional monopolar transurethral resection of the prostate or TURP, which employs a nonionic isoosmolar irrigation fluid during the procedure to resect prostate tissue. These two novel techniques utilize normal saline. Bipolar transurethral resection of the prostate (biTURP) is an endoscopic technique that is similar to monopolar TURP in resecting tissue. However, biTURP allows the use of normal saline for resection by using a bipolar electrical loop. Aquablation is a novel minimally invasive water ablation therapy combining image guidance and robotics (AquaBeam®; Procept BioRobotics, Redwood Shores, CA, USA) for the targeted and heat-free removal of prostatic tissue in men with lower urinary tract symptoms (LUTS) secondary to benign prostatic hyperplasia (BPH) [1].

Indication of the Procedure

The assessment of males presenting with lower urinary tract symptoms (LUTS) secondary to BPH begins with the medical history. This evaluation includes any causes that may lead to bladder dysfunction including cerebral vascular accidents, neurologic disorders, previous surgical procedures or trauma, and history of prostate disease. A complete review of patients' medications is necessary [2, 3].

Multiple guidelines recommend to assess severity and bother of LUTS using validated measures and questionnaires [3, 4]. The commonly used validated measure is the International Prostate Symptom Score (IPSS), which has been validated in many subpopulations, and is available in several languages. Scores categorize symptoms as either mild (score 0–7), moderate, (score 8–19), or severe (score 20–35) LUTS [3].

The assessment includes a general and focused physical examination and includes an

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S. L. Best, S. Y. Nakada (eds.), *Minimally Invasive Urology*,
https://doi.org/10.1007/978-3-030-23993-0_17

abdominal examination evaluating for a palpable bladder, which may be a sign of urinary retention. Attention for hernias, surgical scars, and genital abnormalities should be noted. Physical examination should always include a digital rectal exam (DRE). All men should undergo a urinalysis to rule out the presence of blood or urinary tract infection. In addition, patients should be worked up as per American Urological Association guidelines [3].

Surgical intervention is an appropriate treatment for patients with moderate-to-severe LUTS and for patients who have developed acute urinary retention (AUR) or other BPH-related complications, particularly those who have failed medical therapy. Surgery is recommended for patients who have renal insufficiency secondary to BPH; those who have recurrent UTIs, bladder stones, or gross hematuria due to BPH; and those who have LUTS refractory to other therapies. The presence of a bladder diverticulum is not an absolute indication for surgery unless associated with recurrent UTI or progressive bladder dysfunction.

Patient Preparation

The patient is brought into the operating room and positioned in the dorsal lithotomy position. Anesthesia is made in consultation with the anesthesiologist and based on patient's preference and medical history. In the absence of any spinal or neuromuscular problems with the patient, the selection of general or spinal/epidural anesthesia is a risk-benefit discussion involving the patient, surgeon, and anesthesiologist. Currently, Aquablation techniques are performed with general anesthesia [5].

Preoperative antibiotic use has become the standard of care prior to TURP. Patients without a history of positive urinary culture or symptoms preoperatively can be given a single parenteral dose of a first-generation cephalosporin. Several studies have evaluated the use of antibiotics preoperatively, and the majority supports the use of a single parenteral dose [6, 7]. Those with symptoms and a positive culture should be treated with culture-specific antibiotics prior to undergoing TURP. Penicillin-allergic patients can receive either gentamicin alone or a fluoroquinolone. All patients should be given a single parenteral dose of antibiotics prior to TURP. Many authors recommend continuing at least oral antibiotic therapy until after the Foley catheter is removed [8].

Patient Positioning

Lithotomy Position

All bony areas should be adequately padded; care should be taken to avoid pressure on the lateral aspect of the knee. In addition, care should be taken to avoid hyperflexion of the hip and knee joint. Guidelines for deep venous thrombosis should be followed as per American Urological Association guidelines [3].

The following sections will be divided into two sections: first focusing on biTURP and the second on Aquablation.

The BiPOLAR TURP

Equipment List

- Continuous-flow resectoscope (22–27 French)
- 0° lens, 30° lens
- Sterile lubricant
- Otis urethrotome
- Male sounds (8–30 F)
- Bipolar resection system
- PK system (Gyrus/ACMI)
- biTURP plasma loop electrode
- biTUVP plasma button electrode (for TUVP cases)
- Bipolar resection system (Storz)
- biTURP loop electrode
- biTUVP roller electrode (for TUVP cases)
- Saline irrigant

- Sterile, pyrogen-free, reservoir 30 cm above the level of the symphysis
- Ellik evacuator

Bipolar TURP

Bipolar transurethral resection of the prostate (biTURP) is an endoscopic technique that is like monopolar TURP, available as the PK system by Gyrus/ACMI, an Olympus Corporation (Tokyo, Japan) subsidiary, the TURis system by Olympus Corporation (Tokyo, Japan), and a bipolar resection system by Karl Storz (Tuttlingen, Germany). biTURP requires the use of a 22–27 Fr continuous-flow resectoscope and specialized electrodes that contain the active electrode. The electrodes for the PK and the Storz systems also contain the return electrode, whereas the TURis system relies on a return electrode located on the inner sheath of the resectoscope.

All biTURP systems rely on the ability to generate a plasma corona vaporization field in normal saline media. The short distance between the active and return electrodes and the ionic media allows high current to be generated with little changes in voltage. These systems rely on specialized generators that measure impedance and allow a constant current between electrodes with separate settings for "cutting" (200–280 W for TURis, 160–200 W for PK) and "coagulation" (120 W for TURis and 80 W for PK).

Electrosurgically based transurethral resection of the prostate (TURP) represents the gold standard in endoscopic treatment of symptomatic BPH. With the introduction of improved medical therapy and minimally invasive options, the number of TURPs performed in the United States has declined [9], but the procedure remains the most effective treatment option after failure of conservative management or medical therapy. In this section, we will focus on the bipolar TURP technique. The electrode is classically similar in a loop design for resection to attain tissue for biTURP. The electrode for biTUVP is typically a large surface configuration such as a mushroom or rollerball shape.

Surgical Technique

Insertion of Resectoscope

The outer sheath of the resectoscope is lubricated with sterile lubricant. The obturator is placed through the sheath to ensure there are no sharp edges when performing the initial urethroscopy. The instrument should pass atraumatically as possible and without force.

If there is difficulty with passing the instrument either male sounds or an Otis urethrotome should be used to either blindly perform a urethrotomy or dilate the urethra to one size larger than the resectoscope. Once the anterior urethra is adequately dilated or a urethrotomy performed, the resectoscope is passed under direct vision. The anterior urethra, bulbar urethra, verumontanum, external urethral sphincter, and prostatic urethra should be evaluated. Following this, a pan cystoscopy is performed to evaluate the position of the ureteral orifices and intertrigonal ridge. The bladder should also be inspected for any foreign bodies, stones, or mucosal lesions.

Operative Technique

The most important principle in performing a TURP is to formulate a plan and then proceed in an orderly, stepwise fashion. The initial procedure described by Nesbit and then reviewed and revised by Holtgrew is the method most commonly applied [10]. The resectoscope is positioned in the midprostatic fossa, and the loop is extended out to ensure adequate clearance of the bladder neck.

Resection begins at approximately 1 o'clock and is continued in a clockwise fashion to 5 o'clock. The depth of resection should be approximately far down enough to expose the fibers of the prostatic capsule around the bladder neck. Once this area is adequately resected, attention is turned to the 11 o'clock position, and a similar resection is carried out counterclockwise to the 6 o'clock position. Hemostasis should be achieved

at each area prior to advancing to the next point area of resection.

After the bladder neck has been resected, the prostate adenoma tissue is debulked in quadrants. The verumontanum is visualized, and the resectoscope is placed just proximal to this important landmark. We prefer to take long, deep swipes often angling the scope contralaterally to get adequate depth of the resection. The fibrous capsule can be visualized after resection to assess completeness. Pulsatile arterial bleeding often is encountered near the capsule and at the bladder neck as the prostate blood supply arises peripherally. Arteries should be cauterized immediately as the blood loss obscures the view and prevents precise resection. The length of resection should be premeasured with the resection swipes falling just short of the verumontanum.

Apical tissue that is just proximal to the external sphincter may remain and may extend distal to the verumontanum [11]. Resection in this area carries an increased risk of incontinence, thus discretion should be utilized by the operating physician. The verumontanum must not be cut or coagulated as this can result in painful ejaculation secondary to ejaculatory duct obstruction. Care must be taken not to injure the sphincter during resection because this may cause postoperative urinary incontinence. The tissue at the prostatic apex is carefully resected with short sweeps. At the completion of resection, the bladder should easily be visible with the resectoscope at the level of the verumontanum.

Once resection is completed, an Ellik evacuator is used to remove all adenoma chips from the bladder. All chips must be removed as any chip left in the bladder may later occlude the urinary catheter causing obstruction, bladder spasms, and increased postoperative hemorrhage. After several evacuations with the Ellik, the resectoscope is then replaced and the bladder visually inspected. Any remaining chips can be snared with the loop and removed, with care taken to inspect all bladder diverticula if present. Final hemostasis is achieved with careful coagulation of any bleeding points. The resectoscope is then removed with a final visual inspection of the bladder, prostatic fossa, and urethra. The bladder should be left full, and overly aggressive irrigation is not needed as this can disrupt clots that formed and increase bleeding.

A 24 Fr 3-way Foley catheter is left with 30–60 cc in the balloon at a slow rate of continuous bladder irrigation. More fluid can be placed in the balloon if a larger resection has been performed, but more volume often leads to increased number and severity of bladder spasms. If persistent bleeding results which does not readily clear with slow irrigation, gentle traction is placed on the catheter until the irrigant is clear. Traction can be placed with as gentle a maneuver as placing the hub of the Foley in one of a variety of catheter-securing devices on the leg or with the more traditional use of cloth tape on the calf. The minimum amount of traction to clear the irrigant of gross bleeding is the best used. Traction may also cause involuntary contractions that may contribute to bleeding. Short-acting antimuscarinic agents may be considered to decrease bladder spasms.

If vigorous bleeding continues despite irrigation and gentle traction, arterial bleeding may be the cause. Prior to leaving the operating room, the resectoscope should be reintroduced, and the prostatic fossa and bladder neck should be inspected for arterial bleeding.

The nonresection variation of a transurethral electrosurgical prostatectomy is transurethral vaporization of the prostate or TUVP. TUVP utilizes a larger surface electrode, either a roller ball, mushroom tip or thick loop, to basically use high current density to vaporize prostate tissue on contact without a classic TURP resection. A microprocessor-optimized generator for monopolar or bipolar is required, and these are typically designed to optimize proper delivery of high power current with high current density on contact to vaporize tissue. The broad trailing surface of the electrode coagulates tissue and provides a hemostatic vaporization of prostate tissue. While the original TUVP was monopolar, it is typically performed with a bipolar technique to eliminate dilutional hyponatremia risk with a bipolar mushroom configuration electrode. The technique and approach is similar to biTURP but without resecting tissue.

Postoperative Care

Immediately post-TURP, the patient is brought to the recovery room. The patients are monitored until the spinal/epidural anesthesia has begun to wear off. Electrolyte abnormalities are uncommon. Traction is usually released by 12–24 h post operation, and continuous bladder irrigation is slowly weaned off over the next 12–24 h. If the effluent is clear after irrigation is off for 3–5 h, the catheter can be discontinued. Patients are usually given a trial of voiding on postoperative day number one, and if they void, they are discharged.

Results

The introduction of a bipolar plasmakinetic system with saline irrigation fluid was intended to reduce conductive trauma and associated bladder neck stenosis and urethral strictures, lessen risk of capsular lesion, improve endoscopic orientation, and eliminate TUR syndrome [8]. It has been shown, in multiple studies, to improve perioperative hemostasis, in addition to reducing the risk of TUR syndrome [8, 12, 13], while maintaining improvements in IPSS, QoL, Qmax, and PVR [14], including over the course of several years [15, 16]. Bipolar transurethral vaporization of the prostate (TUVP) theoretically allows for longer surgeries on larger prostates while preserving the benefits of endoscopic surgery including shorter indwelling catheter times, less bleeding, and decreased risk for TUR syndrome [17].

Geavlete et al. completed a prospective, three-armed study with 510 randomized patients to compare monopolar TURP vs. bipolar TURP vs. bipolar TUVP. Patients undergoing bipolar TUVP produced statistically significantly better improvements in IPSS and Qmax than both monopolar and bipolar TURP at 18 months (by 3.3 and 2.9 and 3.5 ml and 3.1 ml, respectively, $p < 0.05$), although the QoL, PVR, and PSA of each group were found to be statistically similar ($p > 0.05$) [18]. Seckiner et al. performed a prospective, randomized study of 21 patients undergoing TURP vs. 23 with bipolar TUVP with 1-year follow-up; they observed comparable improvements in IPSS, QoL, and Qmax, but did not report whether those improvements were statistically significant [19]. Nuhoğlu et al. conducted a similar prospective, randomized study with 90 patients undergoing monopolar TURP vs. bipolar TUVP, demonstrating similar results in IPSS, Qmax, and PVR also with equivalence at 1 year ($p > 0.05$). However, patients who had undergone bipolar TUVP were significantly less frequently affected by hyponatremia ($p < 0.005$) and had significantly shorter catheter retention times (73.2 ± 13.4 vs. 54.3 ± 11.8, $p < 0.005$) [17]. In separate prospective, randomized trials, comparing monopolar TURP vs. bipolar TUVP, Hon et al. and Patankar et al. also reported similar improvement in IPSS, QoL, Qmax and PVR, and IPSS and Qmax, respectively, although with shorter or uncertain durations of follow-up [20, 21].

In the longest study reported comparing monopolar TURP vs. bipolar TUVP, Xie et al. found that in those patients treated with bipolar TUVP, there was a 15.55-point decrease in IPSS, a 2.66-point decrease in QoL, a 1.09 ng/ml decrease in serum PSA, a 16.55 ml/s increase in Qmax, and an 82.79 ml decrease in PVR after 5 years, statistically equivalent to those of the patients treated with monopolar TURP [16].

Only one study has reported inferior performance compared to TURP. Kaya et al. demonstrated worse IPSS and Qmax improvement at 3 years with bipolar TUVP, although their study was limited by a small sample size ($n = 25$ and 15) [15].

One of the largest studies with the longest duration of follow-up was reported by Erturhan et al. where 120 patients were randomized to either plasmakinetic biTURP or monopolar TURP for treatment of symptomatic BPH [6]. Catheterization time was shorter in the biTURP group (3 vs. 4.5 days, $p < 0.001$) as was time to discharge (3 vs. 5 days, $p < 0.001$) and operative time (36 vs. 57 min, $p < 0.001$). Improvement in Qmax was also better in the biTURP group (12.3 ml/s improvement vs. 11.3 ml/s, $p < 0.001$).

IPSS score improved similarly in both groups (20 points monopolar TURP group vs. 19 points biTURP group) after 12 months, as did both QoL scores (2 in both groups) and PVR (−110 cc for monopolar TURP vs. −99 cc for biTURP). Clot retention was significantly higher for patients undergoing monopolar TURP (17 vs. 2 patients, $p = 0.0001$) as well as bleeding requiring transfusion (7 vs. 1 patient, $p = 0.0001$) and severe dysuria (7 vs. 2 patients, $p = 0.025$). Not all complications however were confined to the monopolar TURP group. Interestingly, TUR syndrome was not significantly different between the two groups (2 vs. 0 patients, $p = 0.15$). More urethral injuries (3 vs. 0 patients, $p = 0.01$) and meatal strictures (3 vs. 2 patients, $p = 0.025$) occurred in the biTURP group. Overall, this study suggests that while symptom improvements are similar using both technologies, several of the complications are seen at a reduced rate with biTURP [3]. This study, like many of the early studies, is limited by relatively low number of patients and short duration of follow-up.

Another large randomized control trial reported by Michielsen et al. examined the use of bipolar TURis, i.e., bipolar resection performed in saline vs. monopolar TURP [22]. They found that, in contrast to the above study, there was no difference in the rates of complications, specifically clot retention (6 vs. 4, $p = 0.75$), blood transfusion (1 vs. 4, $p = 0.21$), TUR syndrome (1 vs. 0, $p = 1.0$), hospital stay (4.9 vs.5.1 days, $p = 0.591$), catheterization time (4.0 vs.4.5 days, $p = 0.2$), or urinary retention (5 vs.3, $p = 0.72$) in monopolar TURP vs. biTURP, respectively. The only difference seen between the groups was operative time, which was significantly shorter in the monopolar TURP group (44 min vs. 56 min, $p = 0.001$) at the cost of a larger decrease in serum sodium levels for monopolar TURP patients (−2.23 vs. −1.47, no p value given). The number needed to treat (NNT) to avoid an episode of TUR syndrome from monopolar TURP calculated in this study was 50 patients. There was no data regarding symptom score, Qmax, or PVR improvement in this study. This study did not have any long-term follow-up data as the presented data was only collected during these patients' initial hospital stay (no mean follow-up reported). The authors concluded that bipolar TURP is safe and efficacious compared to monopolar TURP although the difference in postoperative complication rates was not clinically significant [22].

Yoon et al. reported on a study of 102 men undergoing monopolar TURP ($n = 53$) vs. biTURP ($n = 49$) [7]. Improvements in IPSS (11.7 biTURP vs. 12.1 monopolar TURP, $p > 0.05$) and Qmax (10.1 biTURP vs. 10.2 monopolar TURP, $p > 0.05$) were no different between the two groups as were the rate of postoperative complications. The durations of both catheterization and hospitalization were significantly lower in the biTURP group (2.28 days vs. 3.12 days, $p = 0.012$; 3.52 days vs. 4.27 days, $p = 0.034$, respectively).

Complications

Geavlete et al. found that bipolar TUVP produced fewer complications than TURP (1.2% vs. 9.4% capsular perforation, $p = 0.004$; 23.5 h vs. 72.8 h catheterization period, $p = 0.0001$; and 0.5 g/dl vs. 1.6 g/dl hemoglobin drop, $p = 0.0001$, respectively) [18] while others observed statistically similar rates of complication between bipolar TUVP and TURP, e.g., Xie et al. reported similar rates of urinary retention ($p = 0.477$), UTI ($p = 1$), TUR syndrome ($p = 0.477$), and blood transfusion ($p = 0.477$) between monopolar TURP and bipolar TURP [16].

The Aquablation Transurethral Robotic Prostatectomy

Aquablation® therapy with the AquaBeam® Robotic System is a transurethral prostatectomy procedure that combines an integrated cystoscope with intraoperative ultrasound, providing the surgeon with pre- and perioperative

information for improved decision making and treatment planning [5]. The prostate is visualized in multiple views on an integrative robotic controlled monitor; the surgeon maps the exact treatment contour, personalizing the optimal tissue removal plan for each individual patient. Once treatment planning is complete, the surgeon monitors with confidence as the robotic system autonomously executes the treatment plan, resecting the identified prostate tissue with a heat-free, high-velocity waterjet [23]. The following is the methodology for Aquablation®, and as with any novel robotic technologically advanced procedure, it may modify with time based on manufacturer modification of the technology, and operative guidance should always be referenced for appropriate execution of the procedure.

Equipment List

AquaBeam® Robotic System components (Fig. 17.1)

- Rolling equipment stand
- Conformal planning unit (CPU) (monitor)
- Console
- Motorpack
- Handpiece articulating arm
- TRUS articulating arm
- Foot pedal
- AquaBeam® handpiece
- AquaBeam® scope

Equipment required

- Transrectal ultrasound system with biplane (side-fire) (TRUS) probe
- Cystoscope camera compatible with AquaBeam® Scope, light source, and video monitor
- Saline
- Drapes for patient and equipment
- Others, including ultrasound lubricant, evacuation syringe, hematuria urinary catheter, etc.

Surgical Technique

Transrectal and Transurethral Insertion

The rectal ultrasound probe is inserted into the patient using an articulating arm and TRUS stepper. Insertion occurs with transverse plane views, and the probe is advanced 2–3 cm beyond any prostatic tissue with the stepper guidance. Once in the appropriate fixed position, the ultrasound is switched to sagittal view for handpiece insertion. The surgeon then inserts the AquaBeam® Robotic System handpiece transurethrally under cystoscopic visualization. Once inserted into the bladder, the surgeon docks the handpiece assembly onto the handpiece articulating arm, which holds the device in place. The handpiece should be positioned anteriorly and centered on the midline of the prostate to maximize tissue resection. The integrated scope within the handpiece is then retracted and positioned proximal to the external sphincter, protecting the sphincter. It is important to have an optimized TRUS Image for the procedure and with the handpiece positioned correctly, the ultrasound probe may need to be repositioned for optimal imaging. The ultrasound probe and handpiece should be co-linear to one another when looking down at the instruments as they are placed in the patient.

Waterjet Alignment and Angle Planning

Viewing in the ultrasound transverse plane image on the robot monitor, the waterjet is aligned so that it fires along a 180° angle on both the left and right sides. Rotation of the waterjet is achieved by manipulating rotational adjuster on the handpiece articulating arm. Following handpiece positioning, the surgeon retracts the TRUS from the bladder neck towards the apex, locating the largest cross-section of the prostate. At the midprostate, the surgeon uses the robot monitor and keyboard to plan the angle of resection by manipulating the angle planning tool to conform to the

Fig. 17.1 AquaBeam® Robotic System components: (**a**) rolling equipment stand; (**b**) conformal planning unit (CPU; monitor), console, motorpack, robotic handpiece articulating arm, TRUS articulating arm; (**c**) robotic handpiece; (**d**) catheter tensioning device; (**e**) foot pedal. (Courtesy of AquaBeam®, Procept BioRobotics, Redwood Shores, CA, USA)

size of the adenoma. The surgeon can also plan angles for the bladder neck and median lobe cross-sections to optimize conformal treatment of the prostate. This conformal planning can also include planning to resect an intravesical middle lobe safely.

Waterjet Registration and Contour Planning

The waterjet is identified by the surgeon in the sagittal plane. The waterjet is fired at low velocity, which can be seen on the ultrasound. The surgeon marks the position of the waterjet in the software so that the system registers and tracks its position during Aquablation. In the sagittal plane, the treatment contour is set by adjusting the start and end guides along with adjustable boundary handles running the length of the posterior prostate. The markers indicate the desired cut depths. The robotic system automatically translates the programmed depths to specific waterjet speed levels. The surgeon also plans the resection to consider the location of the verumontanum by setting a veru protection zone pattern of resection. Within the zone, the water jet will resect one side of the apical tissue and then resect the other side with the intent of leaving the veru intact, preserving parafollicular structures (Fig. 17.2).

Treatment

With the contour planned, the surgeon depresses the foot switch to initiate Aquablation therapy. The yellow line on the screen signals the location and progress of the Robot enabling surgeon to actively monitor the treatment in real time. At any point during the treatment, the surgeon can pause Aquablation by lifting his or her foot off the pedal. The AquaBeam® Robotic System aspirates the fluid and tissue during Aquablation to help control fluid balance as well as collect tissue in real time.

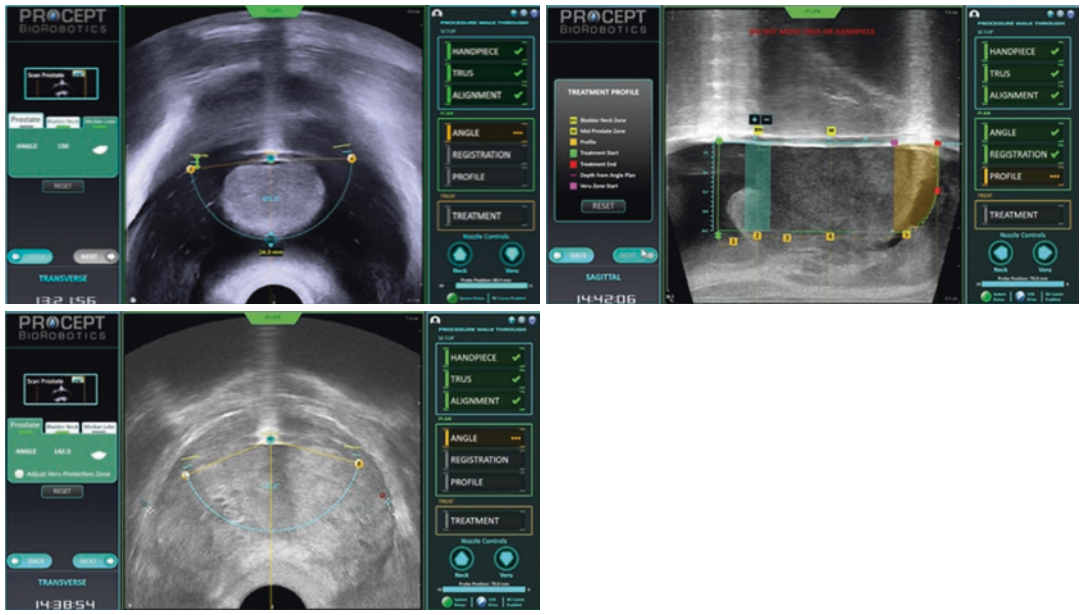

Fig. 17.2 Aquablation contour planning. Planning is performed with both scope and ultrasound in a fixed position and views obtained in the sagittal and transverse views with the scope centered and in view on ultrasound. Contour planning can include the intravesical middle lobe as shown in these console views. (Courtesy of AquaBeam®, Procept BioRobotics, Redwood Shores, CA, USA)

Handpiece Removal

Upon completion of Aquablation therapy, the scope is advanced all the way forward within the handpiece and then the handpiece is detached from the articulating arm and removed from the patient.

Clot Evacuation and Catheter Placement

The ultrasound probe is left in place as the surgeon removes clots using an Ellik evacuator, a Toomey syringe, or similar device. Once clots are removed, a Foley catheter can be inserted under ultrasound guidance to ensure proper placement. Then the catheter tensioning device (17.2×) by Procept BioRobotics is placed on the patient and holds the catheter at a specific tension set by the surgeon, and continuous bladder irrigation is used to help prevent the formation of new clots. Like any TUR procedure, if vigorous bleeding continues despite irrigation and traction, arterial bleeding may be the cause, and appropriate management including site-specific figuration of the arterial bleeding may be indicated. This significant arterial bleeding is usually found at the bladder neck. Prior to leaving the operating room, the resectoscope should be reintroduced, and the prostatic fossa and bladder neck should be inspected for arterial bleeding.

Finally, the rectal ultrasound probe is removed from the patient, ending the procedure.

Postoperative Care

Immediately post-Aquablation, the patient is brought to the recovery room; postoperative management is similar to TURP procedures in general. The patients are monitored until anesthesia has worn off. Electrolyte abnormalities are uncommon. Since the resection portion of the procedure is often accomplished in less than 15 minutes, bleeding requiring transfusion is unlikely since traction/catheter balloon management for hemostasis is employed immediately.

Traction is usually released by 12–24 h post operation, and continuous bladder irrigation is slowly weaned off over the next 12–24 h. If the effluent is clear after irrigation is off for 3–5 h, the catheter can be discontinued. Patients are usually given a trial of voiding on postoperative day number one, and if they void, they are discharged.

Results

Since the first study of the Aquablation technique completed by Faber et al. in canine models that demonstrated adequate resection potential with intact, healthy epithelium on histology and preservation of capsule and other underlying structures as well as short operative time, avoidance of thermal energy application, and finely tuned, computerized control as advantages of the therapy, the therapy has quickly advanced to clinical applications with several published clinical studies demonstrating efficacy and safety [24].

Gilling et al. published a first-in-man, single-center study of safety and feasibility in 15 patients with BPH/LUTS refractory to medical therapy [5]. All patients reported a preoperative IPSS of >12, Q_{max} ≤12 mL/s, Schaffer scale of ≥2, and prostate size of 25–80 mL. Independent review of adverse events produced an acceptable safety profile; all procedures were performed under general anesthesia and found to have succeeded from a technical standpoint, lacking serious or unexpected complication including blood loss and electrolyte imbalance. Eight of 15 patients experienced at least one of the following mild AEs common in MIT procedures within the 30-day postoperative window (Clavien-Dindo grade 1–11): dysuria (3/15), hematuria (3/15), pelvic discomfort (3/15), need for recatheterization (5/15), postoperative cardiac arrhythmia (1/15), and bladder spasms (1/15). No urinary incontinence, erectile dysfunction, or retrograde ejaculation were reported in any case based on International Index of Erectile Function (IIEF) and Incontinence Severity Index (ISI) questionnaires. One patient did require a second proce-

dure within 90 days due to a particularly conservative approach at first operation [8].

At the study's 6-month follow-up, mean IPPS score improved to 8.6 from a baseline of 23.1 ($P < 0.001$), while Q_{max} improved to 18.6 mL/s from 8.6 ($P < 0.001$). Mean detrusor pressure at Q_{max} was also measured, averaging 66 cmH2O at baseline and decreasing to 45 cmH2O at follow-up ($P < 0.05$). Mean prostate size assessed by TRUS was reduced by 31% to 36 mL *(*$P < 0.001$). These promising results lead to further development and studies due to the promising functional results in the first-in-man study and the possibility that automated prostate ablation technology could "significantly alter clinical practice."

The results of a larger multicenter trial of 57 patients, again executed by Gilling and colleagues, mirrored those above. Similar inclusion criteria were maintained though patients with prostate volume of up to 100 mL were treated. However, clinical and safety assessment was continued up to 1 year following surgery (in 33 subjects as of the most recent reporting). All procedures were technically successful without major complication and mean operative and resection times were 38 and 7 minutes, respectively. Mild perioperative adverse events were temporary and occurred at rates similar to those reported for more traditional therapies for BPH [25].

Again, no cases of retrograde ejaculation, urinary incontinence, or erectile dysfunction were recorded. In a comparison between values at baseline and most recent follow-up, IPSS decreased from 22.9 to 6.8, QoL from 5.0 to 1.6, and PVR from 105 to 57 mL; Q_{max} improved from 7.8 to 16.7 mL/s at 12 months. Investigators found Aquablation to be a feasible, safe, and increasingly efficient modality of minimally invasive surgical intervention for LUTS associated with BPH, remarking that further study in randomized controlled trials was warranted [25].

This led to the WATER Study, a prospective, multicenter, international double-blind randomized clinical trial. Men with LUTS due to BPH with a prostate size of 30–80 cc and a baseline IPSS score of at least 12 points were studied and randomized 2:1 to Aquablation with AquaBeam® Robotic System or standard TURP. One hundred and eighty-one subjects were enrolled, randomized, and treated, 116 to Aquablation and 65 to TURP. Baseline IPSS was 22 and baseline Qmax was 9 cc/sec. Mean prostate size was approximately 53 cc. Performed primarily with general anesthesia (94%) and some with spinal anesthesia (6%), procedure times were similar across groups, 33 (Aquablation) vs. 36 (TURP) minutes, $p = 0.2752$). Resection time was lower in Aquablation (mean 4 vs. 27 minutes, $p < 0.0001$). Hospital length of stay was similar at 1.4 days per group (p = NS) [26, 27].

In this study, the primary safety endpoint (Clavien-Dindo grade 1 persistent or grade 2 or higher event in the first 3 months) occurred in 29 Aquablation subjects (25.0%) and 26 TURP subjects (40.0%). The rate difference (Aquablation – TURP) was −15.0%, with a 95% CI of −29.2 to −1.0%. The upper confidence limits were less than the zero, therefore demonstrating statistical superiority of Aquablation vs. TURP. The proportion of men with a worsening of sexual function (decrease in MSHQ score of at least 2 points or decrease in IIEF-5 score of at least 6 points by 6 months) was 32.9% in the Aquablation group vs 52.8% in the TURP group. The proportion of men who experienced persistent anejaculation that were sexually active (Clavien-Dindo grade 1 persistent) in the first 3 months occurred in 8 Aquablation subjects (10%) and 16 TURP subjects (36%). By month 6, 8 (10%) Aquablation and 17 (38%) TURP subjects experienced anejaculation. Finally, the major adverse urologic event in the Aquablation group was noninferior to that of TURP [26, 27].

Mean (SD) IPSS reduction at 12 months was 15.1 (7.0) in the Aquablation group and 15.1 (8.3) in the TURP group ($p = 0.9898$ for difference). The mean percent reduction in IPSS score was 67% in both groups at 93% and 86.7%, respectively, had improvements of at least 5 points from baseline. Repeated measures analysis showed no statistically significant difference in postoperative change scores across groups nor any statistical interaction between time and treatment. Mean IPSS quality of life score improvement was also

similar in both groups (3.2 (1.7) vs. 3.5 (1.6), $p = 0.3179$) [26, 27].

In both groups, mean maximum urinary flow rates increased markedly postoperatively with mean improvements of 10.3 (11) cc/sec for Aquablation vs. 10.6 (11) cc/sec for TURP ($p = 0.8632$). The mean 12-month reduction in postvoid residual was 52 (79) and 63 (97) cc ($p = 0.4625$). In patients with an elevated (>100 cc) postvoid residual, mean reductions in postvoid residual were 107 and 114 cc, respectively. At 1 year, PSA was reduced significantly ($p < 0.01$) in both groups by 1 point; the reduction was similar across groups ($p = 0.9125$) [26, 27].

By month 3, fewer men in the Aquablation group had a persistent Clavien-Dindo grade 1 or grade 2 or higher adverse event compared to TURP (primary safety endpoint, 26% vs. 42%, $p = 0.0149$). Between month 3 and month 12, 40 urologic adverse events occurred. Of these, 8 and 12 were deemed probably or related to the index procedure, but the proportion of subjects with these events was similar across treatment groups. One TURP subject (1.5%) and three Aquablation subjects (2.6%) underwent surgical retreatment for BPH within 1 year from the study procedure (p = NS) [26, 27].

This study demonstrated that Aquablation for LUTS due to BPH provides sustained (12 months) symptom reduction efficacy with a low rate of late adverse events in men with prostates between 30 and 80 cc. Additionally, Aquablation may be a good alternative for men who wish to maintain their ejaculatory function [1].

The large multicenter study also inferred that larger prostates could be safety and effectively treated and lead to a WATER II prospective single-arm clinical trial of Aquablation therapy using the AquaBeam® Robotic System in larger prostates (80–150 cc) [1, 28].

The WATER II study is a prospective, multicenter, international clinical trial of Aquablation for the treatment of LUTS due to BPH in men 45–80 years of age with a prostate volume between 80 and 150 cc as measured by preoperative transrectal ultrasound. In this study and after treatment, study subjects were followed at in-clinic study visits at 1, 3, 6, and 12 months. The study's primary endpoints were calculated at 3 months [28].

One hundred and one subjects were enrolled and treated from 16 centers. Baseline IPSS was 23 and baseline Qmax was 9 cc/sec, indicative of moderate-to-severe BPH. Mean prostate size was approximately 107 cc.

The procedure was done primarily with spinal anesthesia (82%) with the remainder under general anesthesia (18%). Mean operative time (handpiece placement to urinary catheter placement) was 37 minutes and mean Aquablation resection time was 7.8 min. A Foley catheter single balloon placed in the bladder under mild tension was used for hemostasis in 98 (97.0%) cases. Bladder traction was maintained for an average of 18 hours. A prostatic balloon for direct tamponade was used in three cases for an average duration of 15 hours. No subject underwent post-Aquablation cautery for hemostasis. 59% of subjects were discharged within 1 day and mean length of stay was 1.6 days. Two patients went home the same day of surgery. Most patients (68%) were discharged home with a catheter; the catheter was removed on average 4 days post-Aquablation. Hemoglobin levels decreased from a mean of 14.8 at baseline to 11.9 prior to discharge (drop of 2.9 g/dL, $p < 0.0001$). Utilization rates for postoperative medications were: pain management (74%), bladder spasm (23%), and antihypertensive (3%) [1, 26–28].

The primary safety endpoint, defined as Clavien-Dindo Grade 2 or higher or any Grade 1 event resulting in persistent disability (e.g., ejaculatory disorder, erectile dysfunction, or permanent incontinence), at 3 months occurred in 45.5% of men, which met the study design goal of less than 65% ($p < 0.0001$). Ejaculatory dysfunction occurred in 19% of sexually active men. There were no erectile dysfunction events. There were no bleeding events reported beyond the 1-month report. Additionally, no repeat procedures for tissue removal were required as of the 3-month visits [1, 28].

The MSHQ-EjD change score was -2 ± 5.1 at 3 months, which met the prespecified endpoint ($p = 0.0026$) and thus preserved ejaculatory func-

tion in the study group. The IIEF-5 change score was 0.1 ± 6.4 at 3 months which met the prespecified endpoint ($p < 0.0001$) and thus preserved erectile function in the study group [1, 28].

Mean (SD) IPSS improved from 23.2 (6.3) at baseline to 6.7 (5.1) at 3 months (a 16.5-point improvement) which met the study's primary efficacy endpoint goal ($p < 0.0001$). IPSS QOL decreased from 4.6 at baseline to 1.8 at 3 months ($p < 0.0001$). Maximum urinary flow rate increased from 8.7 to 20.1 cc/sec (an improvement of 11.1 cc/sec, $p < 0.0001$) and postvoid residual decreased from 131 at baseline to 57 at 3 months (a 79 cc decrease, $p < 0.0001$) [1, 28]. Transrectal ultrasound, performed preoperatively and at 3 months, showed a prostate volume change from 107 ± 20 cc to 63 ± 26, a 42% reduction [1, 28]. There were 16 subjects entering the trial that utilized a urinary catheter within 45 days of treatment. At the 3-month visits, none of these patients required the use of a urinary catheter [1, 28].

In summary, current studies demonstrated that Aquablation for LUTS due to BPH provides sustained (12 months) symptom reduction efficacy with a low rate of late adverse events in men with prostates between 30 and 150 cc and is a viable robotic alternative to the standard TURP [1, 26–28].

Conclusion

While more long-term studies on the efficacy of biTURP and Aquablation are necessary, it appears that biTURP and Aquablation provide a reasonable, efficacious, and safer alternative for transurethral resection of the prostate when compared to traditional modalities.

References

1. Chughtai B, Thomas D. Pooled aquablation results for American men with lower urinary tract symptoms due to benign prostatic hyperplasia in large prostates (60-150 cc). Adv Ther. 2018;35(6):832–8.
2. Chughtai B, Forde JC, Thomas DD, Laor L, Hossack T, Woo HH, et al. Benign prostatic hyperplasia. Nat Rev Dis Primers. 2016;2:16031. https://doi.org/10.1038/nrdp.2016.31. Review.
3. McVary KT, Roehrborn CG, Avins AL, Barry MJ, Bruskewitz RC, Donnell RF, et al. Update on AUA guideline on the management of benign prostatic hyperplasia. J Urol. 2011;185(5):1793–803.
4. Gratzke C, Bachmann A, Descazeaud A, Drake MJ, Madersbacher S, Mamoulakis C, et al. EAU Guidelines on the Assessment of Non-neurogenic Male Lower Urinary Tract Symptoms including Benign Prostatic Obstruction. Eur Urol. 2015;67(6):1099–109.
5. Gilling P, Reuther R, Kahokehr A, Fraundorfer M. Aquablation-image-guided robot-assisted waterjet ablation of the prostate: initial clinical experience. BJU Int. 2016;117(6):923–9.
6. Erturhan S, Erbagci A, Seckiner I, Yagci F, Ustun A. Plasmakinetic resection of the prostate versus standard transurethral resection of the prostate: a prospective randomized trial with 1-year follow-up. Prostate Cancer Prostatic Dis. 2007;10(1):97–100.
7. Yoon CJ, Kim JY, Moon KH, Jung HC, Park TC. Transurethral resection of the prostate with a bipolar tissue management system compared to conventional monopolar resectoscope: one-year outcome. Yonsei Med J. 2006;47(5):715–20.
8. Rassweiler J, Schulze M, Stock C, Teber D, De La Rosette J. Bipolar transurethral resection of the prostate--technical modifications and early clinical experience. Minim Invasive Ther Allied Technol. 2007;16(1):11–21.
9. Merrill RM, Hunter BD. The diminishing role of transurethral resection of the prostate. Ann Surg Oncol. 2010;17(5):1422–8.
10. Holtgrewe HL. Transurethral prostatectomy. Urol Clin North Am. 1995;22(2):357–68.
11. Hawtrey CE, Williams RD. Historical evolution of transurethral resection at the University of Iowa: Alcock and Flocks. J Urol. 2008;180(1):55–61.
12. Mamoulakis C, Trompetter M, de la Rosette J. Bipolar transurethral resection of the prostate: the 'golden standard' reclaims its leading position. Curr Opin Urol. 2009;19(1):26–32.
13. Gilleran JP, Thaly RK, Chernoff AM. Rapid communication: bipolar PlasmaKinetic transurethral resection of the prostate: reliable training vehicle for today's urology residents. J Endourol. 2006;20(9):683–7.
14. Ho HS, Cheng CW. Bipolar transurethral resection of prostate: a new reference standard? Curr Opin Urol. 2008;18(1):50–5.
15. Kaya C, Ilktac A, Gokmen E, Ozturk M, Karaman IM. The long-term results of transurethral vaporization of the prostate using plasmakinetic energy. BJU Int. 2007;99(4):845–8.
16. Xie CY, Zhu GB, Wang XH, Liu XB. Five-year follow-up results of a randomized controlled trial comparing bipolar plasmakinetic and monopolar transurethral resection of the prostate. Yonsei Med J. 2012;53(4):734–41.
17. Nuhoğlu B, Balci MB, Aydin M, Hazar I, Onuk Ö, Taş T, Fikri O. The role of bipolar transurethral vaporiza-

tion in the management of benign prostatic hyperplasia. Urol Int. 2011;87(4):400–4.
18. Geavlete B, Georgescu D, Multescu R, Stanescu F, Jecu M, Geavlete P. Bipolar plasma vaporization vs monopolar and bipolar TURP-A prospective, randomized, long-term comparison. Urology. 2011;78(4):930–5.
19. Seckiner I, Yesilli C, Akduman B, Altan K, Mungan N. A prospective randomized study for comparing bipolar plasmakinetic resection of the prostate with standard TURP. Urol Int. 2006;76(2):139–43.
20. Hon NH, Brathwaite D, Hussain Z, Ghiblawi S, Brace H, Hayne D, Coppinger SW. A prospective, randomized trial comparing conventional transurethral prostate resection with PlasmaKinetic vaporization of the prostate: physiological changes, early complications and long-term followup. J Urol. 2006;176(1):205–9.
21. Patankar S, Jamkar A, Dobhada S, Gorde V. PlasmaKinetic Superpulse transurethral resection versus conventional transurethral resection of prostate. J Endourol. 2006;20(3):215–9.
22. Michielsen DP, Debacker T, De Boe V, Van Lersberghe C, Kaufman L, Braeckman JG, et al. Bipolar transurethral resection in saline--an alternative surgical treatment for bladder outlet obstruction? J Urol. 2007;178(5):2035–9; discussion 2039.
23. Yassaie O, Silverman JA, Gilling PJ. Aquablation of the prostate for symptomatic benign prostatic hyperplasia: early results. Curr Urol Rep. 2017;18(12):91. https://doi.org/10.1007/s11934-017-0743-2. Review.
24. Faber K, de Abreu AL, Ramos P, Aljuri N, Mantri S, Gill I, et al. Image-guided robot-assisted prostate ablation using water jet-hydrodissection: initial study of a novel technology for benign prostatic hyperplasia. J Endourol. 2015;29(1):63–9.
25. Gilling P, Desai M, AAnderson P, Tan A, Desai M. PD21-06 Mid-term results using Aquablation, an image-guided robot-assisted water jet ablation of the prostate, for the treatment of benign prostatic hyperplasia (BPH) (abstract). J Urol. 2016;195(4Suppl):e458.
26. Gilling P, Barber N, Bidair M, Anderson P, Sutton M, Aho T, et al. WATER: a double-blind, randomized, controlled trial of Aquablation® vs transurethral resection of the prostate in benign prostatic hyperplasia. J Urol. 2018;199(5):1252–61.
27. Gilling P, Barber N, Bidair M, Anderson P, Sutton M, Aho T, et al. Randomized controlled trial of Aquablation vs. transurethral resection of the prostate in benign prostatic hyperplasia: one-year outcomes. Urology. 2019;125:169–73.
28. Desai M, Bidair M, Bhojani N, Trainer A, Arther A, Kramolowsky E, et al. WATER II (80-150 mL) procedural outcomes. BJU Int. 2019;123(1):106–12.

18 New Alternative Treatments for Lower Urinary Tract Symptoms Secondary to Benign Prostatic Hyperplasia

Joseph T. Mahon and Kevin T. McVary

Definitions and Terms Used

Benign Prostatic Hyperplasia

Benign prostatic hyperplasia (BPH) and benign prostatic hypertrophy are often incorrectly used interchangeably. Benign prostatic hyperplasia is a histologic diagnosis defined as an increase in the total number of prostatic stromal cells and prostatic glandular epithelial cells within the transition zone. As a result of this hyperplasia, large, discrete prostatic nodules can be appreciated in the prostatic transition zone, whereas benign prostatic hypertrophy is defined as a growth in the total size of the individual prostatic cells, thereby resulting in a global enlargement of the prostatic gland with no discrete nodularity. Through a combination of these two processes, benign prostatic enlargement (BPE) results. If that enlargement leads to obstruction of the bladder neck, in the absence of prostate cancer, benign prostatic obstruction (BPO) results.

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Lower Urinary Tract Symptoms

Lower urinary tract symptoms (LUTS) is a clinical term regarding the constellation of symptoms related to the bladder and the urethra. LUTS can be subdivided into symptoms of urinary storage (e.g., urgency, frequency, nocturia, etc.), symptoms of urinary voiding (e.g., straining to void, urinary intermittency, dysuria, hesitancy, etc.), and post-voiding symptoms (e.g., sensation of incomplete bladder emptying, post-void urinary dribbling, etc.). LUTS itself is a qualitative term, regarding the presence of these symptoms and thus implores a quantitative means of clinical evaluation. While a multitude of validated and non-validated questionnaires have been employed to quantitate the severity of LUTS, the most frequently utilized is the American Urological Association BPH Symptom Score Index (AUA-SI). The AUA-SI consists of seven question prompts to which the patient selects a quantitative score (0–5) corresponding to the frequency with which they experienced the symptom designated in the prompt. Symptom score totals 1–7 represent mild-, 8–19 moderate- and 20–35 severe-LUTS. An additional prompt measures the degree of intrusion or disruption the LUTS have on the individual and is referred to as its degree of bother or effect on quality of life (QOL). When this is included, the AUA-SI is then referred to as the International Prostate Symptom Score (IPSS).

S. L. Best, S. Y. Nakada (eds.), *Minimally Invasive Urology*,
https://doi.org/10.1007/978-3-030-23993-0_18

Epidemiology of Benign Prostatic Hyperplasia and Lower Urinary Tract Symptoms

Benign prostatic hyperplasia increases in prevalence as individuals age. Wei et al. estimated that nearly 70% of US men between the ages of 60 and 69 years had some degree of BPH and nearly 80% of men age ≥70 years [1]. The autopsy study from Guess and colleagues found a prevalence of histologically confirmed BPH in prostates with gross enlargement of 14%, 37%, and 39%, respectively, in men 50–59, 60–69, and older than 70 years [2].

Mirroring changes in BPH, the prevalence and severity of LUTS in men appear to be age-related. From the Boston Area Community Health Survey, LUTS affects 8% of men aged 30–39 years, with the prevalence increasing as individuals age [3]. The Baltimore Longitudinal Study [4] examined 1057 men and found that "prostatism" or BPH voiding dysfunction increased progressively from 26% in the fifth decade of life to 79% in the eighth decade of life. Prevalence of symptoms related to an enlarged prostate increased from 26% of men aged 40–49 to 46% of men over 70 in the Olmstead County Study [5]. This trend is supported by similar findings in the UrEpik study [6], showing a nearly 10% increase per decade prevalence of male LUTS with the study population, while McVary [7] estimated that 90% of men aged 45–80 years have some type/degree of LUTS. Furthermore, in a large international study across several Asian countries, Homma et al. [8] showed an increasing incidence of moderate-to-severe LUTS, a notion that is echoed in series across Europe and America as well.

The risk of surgery related to BPH was noted to be considerably greater for a man aged 80 years than a man aged 40 years in the Veterans Administration Normative Aging Study which was carried out prospectively from 1961 to 1982 [9]. The retrospective New Haven Hospital Study [10] also found an increasing incidence of surgery for BPH increasing through the eighth decade.

Pathophysiology of Benign Prostatic Hyperplasia and Lower Urinary Tract Symptoms

The complete pathophysiology of BPH remains to be elucidated but most agree that it is likely a multifactorial process. This process results in part from increased production of new epithelial gland formation, re-establishing the prostatic cells inductive potential; or it may be due to cell immortalization with a loss of programmed cell death though reality is likely a complex interplay of both processes. Through the work of Isaacs [11] androgens are implicated not only in the proliferation of prostatic cells, but also in the inhibition of cell death. In the prepubertal quiescence of testosterone and dihydrotestosterone (DHT), prostatic hyperplasia is prevented, while enlargement is appreciated during the postpubertal period when androgen levels are elevated. This has been further shown when looking at individuals who underwent castration prior to puberty or exhibit impairment in androgen production or their receptor as these individuals do not develop BPH in addition to the involution of prostatic tissue seen with androgen withdrawal.

Further mirroring BPH, LUTS is also likely a multifactorial process, with the prostate playing a significant but likely overemphasized role in its etiology. We have long known that underlying pathophysiology and experienced voiding symptoms exhibit a poor correlation [12]. Nevertheless, the prostatic contribution to LUTS can be thought of as two separate components: a static component, referring to enlargement of the prostatic gland leading to BPO, and a dynamic component consisting of increased smooth muscle tone and resistance. It has been shown that BPE with BPO can have secondary effects on detrusor activity, leading to detrusor instability, or overactive bladder (OAB) [12, 13]. This effect, in combination with age-related changes to detrusor contraction and compliance, only compounds BPH associated LUTS. It is important to note, however, that while the prevalence of BPH is high in the aging male, not all men with BPH go on to develop BPE. Furthermore, not all men with BPE will develop BPO. Therefore, in this subset of men, the prostate is not the driving force behind the

development of LUTS; as such, other diagnoses should be investigated which are reinforced through the works of Irwin et al. [14] and Lepor et al. [15] who both showed that age-matched women have a similar level of symptom frequency and severity to men.

Medical History

The evaluation of LUTS/BPH should always include a detailed medical history and focused physical examination, which should include a brief neurologic screen, abdominal exam and genitourinary exam including digital rectal examination (DRE). Urinalysis is another recommended test to screen for hematuria, proteinuria and urinary tract infection. Men with a predominant symptom of nocturia should complete a frequency/volume chart (voiding diary) to evaluate to nocturnal polyuria [16]. The specific goals for the patient should be clearly defined from both the standpoint of the patient and the treating physician. If the symptoms are not significantly bothersome or if the patient does not want treatment, no further evaluation is recommended.

The goals for treatment should be used to guide the clinical evaluation. During the evaluation, the patient's voiding pattern should be assessed along with any medical conditions or medications that may affect voiding patterns. The role of BPH in their overall voiding pattern should be assessed, particularly with respect to the possible benefits of any treatment. The necessity for treatment along with the probability of success of any treatment should be factored in and weighed against the risk of treatment. Finally, the physician's assessment along with the rationale should be explained to the patient using terms that the patient is able to understand.

Cardiovascular

Much like BPH/LUTS, the incidence of hypertension increases with age. Further investigation has shown that α-adrenergic fibers and receptors play important roles in both hypertension and symptomatic BPH. Indeed, autonomic hyperactivity is believed to be involved in the development of LUTS in the aging male [17]; furthermore, both heart disease and hypertension in the EpiLUTS study were associated with more severe LUTS [18]. An overall examination of the data remains inconclusive with further studies needed to elucidate the true relationship between cardiovascular disease and BPH/LUTS.

Also, of cardiovascular concern is the presence of heart failure, peripheral vascular disease and cardiac dysfunction. As a response to changes in cardiac ventricular pressure, B-type natriuretic peptide (BNP) is released. BNP acts as both a vasodilatory hormone and a diuretic, increasing sodium and water excretion. Additionally, as cardiac function decreases and peripheral vascular disease worsens, individuals may experience significant peripheral edema. When recumbent, this fluid shifts from the third space back into the intravascular domain. The cumulative result of these processes is that urine production greatly increases, particularly during nighttime hours [19].

Nephrologic

McConnell and colleagues [20] showed that 13.6% of individuals undergoing treatment for BPH exhibited renal insufficiency. As BPH leads to BPE and BOO, the resultant increase in outlet resistance leads to elevation in voiding pressures. With long-term obstruction, decreased detrusor compliance may result and therefore urinary storage pressures also increase. Increased lower tract pressure may prove detrimental to the upper urinary tract. Thus, a proper nephrologic history should be included in the initial evaluation of an individual suspected of suffering from BPH-related LUTS not only to elucidate preexisting renal conditions but also to understand the risk of persistent LUTS and obstruction [21].

Neurologic

As previously mentioned, LUTS is a clinical constellation of urinary symptoms. Normal micturition requires a complex interplay of the bladder outlet and the bladder itself. It is

therefore important to appreciate any neurologic that may exhibit an effect of detrusor function and stability.

Patients with Parkinson disease frequently develop voiding dysfunction. Loss of dopaminergic neurons from the substantia nigra is manifested classically by pill-rolling tremor, shuffling gate, cogwheel rigidity, bradykinesia and masked faces. The most common associated bladder pathology consists of neurogenic detrusor overactivity with impaired detrusor contractility. Bladder outlet procedures have long been thought to have a relative contraindication due to a high incidence of post-procedure urinary incontinence and worsened urgency. Multiple sclerosis (MS) involves demyelination of the central nervous system, thereby impairing neural conduction. The majority of MS patients will develop urinary symptoms at some point in the disease process. The most common urodynamic finding is neurogenic detrusor overactivity. Spinal stenosis results in compression of the spinal cord which can lead to a variety of clinical and urodynamic findings. Cerebral vascular accidents may result in a transient spinal shock-like period of detrusor areflexia placing the patient at risk for urinary retention, followed by most commonly neurogenic detrusor overactivity.

Understanding these and other neurologic conditions are important to the assessment of individuals with BPH-associated LUTS as they may add to the complexity of diagnosis and affect therapeutic decision making.

Metabolic

The relationship between metabolic syndrome (a constellation of obesity, glucose intolerance, dyslipidemia and hypertension) and BPH/LUTS has been of particular interest. Increased aromatization of circulating testosterone due to increased adipose stores alters the testosterone to estrogen ratio. Given the knowledge that testosterone provides, at least, a permissive role in the development of BPH, one could suggest that increased obesity with aromatization of testosterone may provide a beneficial adjustment to the testosterone to estrogen ratio. A preponderance of published evidence suggests strong positive associations of obesity with benign prostatic hyperplasia and lower urinary tract symptoms [22]. This evidence encompasses most established metrics of adiposity, including body mass index, waist circumference, and waist-to-hip ratio, and falls under three general categories, including prostate volume, clinical benign prostatic hyperplasia, and lower urinary tract symptoms:

1. Prior studies consistently showed that increased adiposity is positively associated with radiographically determined prostate volume and enlargement, suggesting that obesity promotes prostate growth.
2. Most studies revealed that obesity increases the risk of clinical benign prostatic hyperplasia by several measures, including the initiation of benign prostatic hyperplasia medical treatment, noncancer prostate surgery, physician diagnosed benign prostatic hyperplasia, histological diagnosis and urinary flow rate.
3. Prior studies demonstrated that obesity increases the risk of lower urinary tract symptoms, as measured by a validated questionnaire. Also, most studies showed that physical activity significantly decreases the risk of benign prostatic hyperplasia.

Long-standing, poorly controlled diabetes mellitus (DM) leads to decreased bladder sensation, decreased detrusor contractility and incomplete bladder emptying. Furthermore, increased filtration of glucose in the urine leads to an osmotic diuresis and polyuria, thereby potentially worsening LUTS due to increased urine production.

Sexual History

A thorough sexual history is also a component of the evaluation of a man with BPH-associated LUTS. The clinician should ascertain any past history of sexually transmitted infections (STIs), sexual habits, number of sexual partners, means

of contraception and prevention of STI, and any other concerns. Past history of STI is a risk factor for urethral stricture disease, which may produce similar LUTS to BPH.

Symptom Evaluation

Validated questionnaires should be utilized to measure subjective outcomes for BPH and LUTS by documenting response to medical or surgical therapies. The American Urologic Association (AUA) Symptom Score is the most commonly used and should be obtained at each visit. An AUA Symptom Score of 0–7 is considered mildly symptomatic, 8–19 moderately symptomatic, and 20–35 severely symptomatic. Flow rate and post-void residual are additional metrics that can supplement the history and physical exam. Cystoscopy should not be routinely performed unless it is being done to work up hematuria or evaluate whether the patient is a candidate for surgical therapy that is dependent on anatomic configuration. Per AUA BPH guidelines, 16 urodynamics are considered optional and best suited for patients who demonstrate multiple lower urinary tract symptoms in which the diagnosis of bladder outlet obstruction is unclear. Detrusor overactivity and detrusor underactivity are not contraindications for surgical intervention of BPH/LUTS but must be evaluated in the context of the clinical situation and the patient appropriately counseled.

Storage symptoms are experienced during the relaxation phase of detrusor function. The experienced alteration in bladder storage may be primarily during nighttime hours or during daytime hours. Urinary frequency is the term used when a patient voids more frequently than he would consider normal, a subjective measure. Urinary urgency is the sudden, overwhelming desire to empty one's bladder. Nocturia occurs when an individual wakes from sleep one or more times to void over the course of a night, while urinary incontinence refers to the involuntary expulsion of urine [23, 24]. Symptoms of urinary storage tend to be more bothersome than voiding symptoms, especially if associated with incontinence and more commonly associated with UTIs.

Voiding symptoms are experienced during the voiding phase. A slow urinary stream refers to a preserved reduction in the velocity of urination, while straining to void occurs when a coordinated effort by the patient is made to initiate or maintain urination through use of abdominal and pelvic musculature. Urinary intermittency occurs when the urinary stream stops and restarts once or more during a typical void. Urinary hesitancy occurs when a man experiences difficulty initiating his urinary stream despite the desire to. Splitting of the voiding stream may also be experienced, as well as terminal dribbling, in which the final stage of micturition is prolonged.

Post-void symptoms are experienced immediately following the conclusion of urination and may consist of a sensation of incomplete bladder emptying or post-void urinary dribbling [24].

Severity and degree of bother of LUTS related to BPH are most often graded as mild, moderate, or severe. It is important to remember that while a set of objective measures are available to assess bladder and outlet function, LUTS is a clinical diagnosis of subjective symptoms. Therefore, the resultant degree of bother is of upmost importance in understanding a patient's true symptom complex. Though rarely life-threatening, the effect of BPH-associated LUTS can exhibit a profound impact on a man's quality of life. O'Leary et al. showed that symptom severity and degree of bother represented significant motivations for those seeking BPH-related treatment across a number of community-based populations [25]. Therefore, both the degree of bother and severity of symptoms should be at the forefront of discussion when treatment is warranted. Classically, the severity of symptoms is summated as mild, moderate, or severe. While significant interpersonal variability and bias can be observed in the self-reporting of symptoms, it is largely those with moderate-to-severe symptoms who seek evaluation and consider intervention. It is this variability and bias that renders validated questionnaires invaluable in the evaluation and care of men with BPH and BPH-associated LUTS.

Validated questionnaires include the AUA Symptom Index Score (AUA-SI), also known as the International Prostate Symptom Score (IPSS), which is an internationally validated questionnaire consisting of seven symptom-related questions and one assessment of global quality of life [26]. Other widely utilized questionnaires include the International Consultation on Incontinence Questionnaire (ICIQ-MLUTS) and the Danish Prostate Symptom Score (DAN-PSS), both of which assess the bother of individual lower tract symptoms. As mentioned previously, validated questionnaires should be utilized both in the initial evaluation of a patient as well as the long-term monitoring of patients and assessment of response to therapy [27–29].

Importance of Distinguishing Nocturnal Polyuria

Polyuria is defined as >3000 ml of urine output over a 24-hour period. Nocturnal polyuria occurs when >33% of the daily urine output is expelled during nighttime hours. The presence of nocturnal polyuria should incite further evaluation for secondary causes. Involvement of a nephrologist may be advantageous.

Physical Examination

Motor and Sensory Evaluation

Pelvic and lower limb motor and sensory evaluation should be performed as part of the initial evaluation for any individual seeking care for LUTS. Given the complexity of the motor and neurological interplay involved in pelvic health and bladder maintenance, any abnormal finding should prompt further inquiry.

Digital Rectal Examination

Digital rectal examination (DRE) has long been employed as a clinical means of estimating prostatic volume. Roehrborn showed poor reliability between volume and digital rectal exam estimated volume, a sentiment supported by the PLCO trial [29, 30]. DRE generally overestimates small glands and underestimates large ones though Bosch et al. [31] did show that DRE was sufficient to identify individual's relationship to a prostate volume cutoff of 50 ml. Nevertheless, the DRE remains a cost-effective clinical tool, allowing clinician to follow prostatic growth over time, particularly when comparing to far costlier transrectal ultrasound and pelvic MRI. Furthermore, DRE may aid in the detection of coexistent prostate cancer or abnormalities in sphincter tone which may lead to further neurologic evaluation.

Laboratory Evaluation

Urinalysis The utilization of a properly performed urinalysis in the evaluation of a man with clinical LUTS serves to rule out confounding etiologies of LUTS. Detection of hematuria, pyuria, proteinuria, ketonuria, or bacteriuria should direct the clinician to investigate alternative diagnoses for the patient's symptoms. As previously discussed, a magnitude of medical conditions may present with alteration in urine storage and volition; obtaining a urinalysis may hasten a proper diagnosis.

Serum PSA Screening of men for prostate cancer has become a more controversial topic in recent years. The AUA BPH guidelines recommend the consideration of screening appropriately aged men with a life expectancy of greater than 10 years presenting with LUTS. The most recent guidelines for the detection of prostate cancer recognized that the greatest benefit for prostate specific antigen (PSA) screening is for men between 55 and 69 years of age [32]. This screening should include DRE and serum PSA if the patient so elects after an informed discussion. If the PSA is elevated, prostate biopsy should be performed prior to proceeding with surgical therapy. Clinicians should also be aware of the effect of different surgical therapies on PSA, as this may influence prostate cancer screening in the future. While serum PSA has chiefly been used as

a screening tool for prostate cancer, it may also be used as a surrogate for prostate volume, which can be a critical factor in the choice of BPH therapy. For this reason, itself, we endorse its utility.

Metabolic Evaluation As previously discussed, long-standing bladder outlet obstruction may play a significant role in renal dysfunction though Comiter et al. reported that non-neurogenic-related voiding dysfunction is not an independent risk factor for azotemia [33]. Nonetheless, evaluation of renal function may play an important role in the long-term follow-up of these patients and thus should be considered to establish a baseline value.

Dynamic Testing

Pressure flow studies (PFS) testing is the most complete tool to determine the presence of bladder outlet obstruction. Non-invasive tools provide useful information, but only PFS can determine bladder function or lack thereof. While most patients can likely be managed and treated surgically without PFS, certain circumstances dictate more complex evaluation. Overactive bladder symptoms and incontinence can be sequelae of obstruction or secondary to non-obstructive etiologies. In addition, patients with catheter-dependent urinary retention may have compromised detrusor function. Surgery in these individuals may not lead to meaningful improvement, subject the patient to unnecessary surgery, and carry increased risk for incontinence and exacerbated voiding symptoms [34].

Voiding Diary A voiding diary, or frequency-volume chart (FVC), represents a patient-recorded record of urinary frequency and voided volume, in addition to other information which may include fluid intake, incontinent episodes, use of incontinence pads, and/or defecation frequency. Data is recorded typically for 2–7 days, as to create a most representative sample of typical fluid management [35]. The use of FVC may help avoid patient recall bias, provides the patient with a buy-in to their care while making them more cognizant of their voiding habits. A well-kept voiding diary may provide the clinician with substantial insight into a patient's total daily voided volume, daily urinary frequency, nocturnal fraction of voiding urine and functional bladder capacity.

Uroflowmetry Uroflowmetry measures the rate of flow generated by the patient and measures the total volume expelled. It is important to remember that uroflowmetry does not, however, identify the etiology of voiding dysfunction, as it represents the summation of outlet resistance and detrusor contractility. While flow rate <10 mL/s has shown moderate specificity and positive predictive value for bladder outlet obstruction, it lacks sensitivity. Furthermore, for inclusion in the clinical evaluation, the void must be representative of a "normal void" for the individual and consist of a minimum of 150 cc volume, a requirement that many argue is not reproducible in the office setting. Nevertheless, flow rates, the shape of the voiding curve and duration of micturition may be of value in practiced hands.

Post-void Residual Volume Post-void residual volume (PVR) refers to the volume of urine remaining in the urine at the completion of a normal micturition. This reflects both the adequacy of the outlet to open, allowing passage of urine, and the detrusor's ability to contract and expel the bladder's contents. The PVR can be measured with the aid of a "bladder scanner," which utilizes ultrasonography to estimate the bladder's volume, or by use of a catheter following the conclusion of a spontaneous void. The presence of moderate-to-severe LUTS has been shown to be associated with an increased occurrence of acute urinary retention. While the overall population has exhibited 6.8 episodes of acute urinary retention per 1000 patient years of follow-up, men with moderate-to-severe LUTS, particularly older men, of increasing age, have shown nearly a sixfold increase prevalence [2]. There is significant interpersonal variability to the significance of residual volume; as such each individual must be considered uniquely when utilizing PVR in the clinical assessment. Perhaps of greatest value

is the trend of residual urine over time. Increasing PVR overtime may indicate treatment failure or provide indication for surgical intervention. Both the MTOPS and ALTESS studies suggested a high baseline PVR may indicate a higher likelihood of symptomatic deterioration over time [36, 37].

Transrectal Ultrasound Transrectal ultrasound (TRUS) utilizes ultrasonography to measure the three-dimensional volume of the prostatic gland. While a number of different formulas have been historically used to calculate the prostatic volume, the prolate ellipsoid volume formula has been most ubiquitously accepted [38]. While the quality of ultrasonography technology has improved as well as ultrasonographer training, a significant amount of interobserver variation still exists. It is important to remember that the size of the prostate gland does not correlate with the degree of obstruction, nor the presence or severity of LUTS.

Urodynamic Studies

Flow/Volume Evaluation Utilization of indwelling urinary and rectal catheters allow for monitoring of bladder and abdominal pressures, respectively. When these metrics are combined with uroflowmetry, the relationship between detrusor function, bladder outlet resistance, pelvic floor and urethral function can be assessed. Evaluation of the detrusor compliance and contractility help to gain a better understanding of the complex interplay between bladder and outlet. Elevated detrusor pressures resulting in blunted uroflow are suggestive of bladder outlet obstruction, indicating the bladder outlet treatment may improve overall bladder health. Of further value is the identification of impaired bladder contractility.

Bladder Outlet Obstruction Index (BOOI) The Bladder Outlet Obstruction Index represents the pressure produced by the detrusor (Pdet) in relation to the maximum urinary flow rate (Qmax) that can be produced by the individual. This was first described by Abrams-Griffith. The BOOI is calculated using the equation: Pdet @ Qmax – 2 ∗ Qmax. The International Continence Society designed a nomogram for interpretation of BOOI which consists of BOOI >40 representing obstruction, BOOI 20–40 representing an equivocal result, and BOOI <20 indicating no outlet obstruction.

Bladder Contractility Index The Bladder Contractility Index (BCI) represents the contractional force the detrusor muscle is able to perform in a coordinated manner. The BCI can be calculated using the equation: Pdet @ Qmax + 5 ∗ Qmax. Interpretation of the BCI consists of a value >150 representing a strong detrusor contractility, BCI 100–150 representing a normal finding and BCI <100 indicating weak detrusor contractility.

Lifestyle Modifications

Fluid Management

It is generally recommended that an individual imbibe 1500–2000 ml of fluid but should adjust based on their voiding diary. Additionally, fluid intake should be adjusted for activities when micturition may be difficult or inconvenient such as long travel as well as during the evening prior to sleep. Fluid restriction 2 hours prior to sleep may greatly reduce nocturia. In the setting of peripheral edema, lying recumbent prior to attempted sleep may allow the individual to mobilize any third-spaced fluid as to avoid interruptions in sleep.

Voiding Practices

There are many self-guided bladder training programs that may prove beneficial to a man suffering from BPH-related LUTS. Timed voiding regardless of desire can help train the bladder to identify appropriate filling volume. Additionally, the maneuver of attempting a second attempted micturition after a brief period of rest in an effort to expel additional urine volumecan help limit stagnant residual urine. Men can be taught to milk the urethral to limit post-

micturition dribble. Pelvic floor exercises and/or distraction techniques may be employed to help control and stave off urinary urge. Perhaps equally as important to these voiding practices is the maintenance of voiding diary to monitor progress.

Concomitant Medication Use

As BPH-associated LUTS tends to affect men later in life, these individuals frequently exhibit multiple medical comorbidities that require multiple scheduled medications. It is of the upmost importance to identify those concurrent medications that may affect micturition patterns. As such communication with the patient's primary care provider is paramount in providing excellent and coordinated care. Changes in agents, dosages or schedules may be necessary to maximize the benefit and minimize adverse effects of BPH-related medications.

Role of Diet and Exercise

Obesity markedly increases the risk of benign prostatic hyperplasia. Since physical activity decreases the risk of benign prostatic hyperplasia, these observations support the development of novel prevention strategies and treatment targeted toward adiposity, weight loss, and lifestyle.

A number of substances used in everyday life have been identified as either diuretics, bladder irritants or both. With such knowledge, avoidance of these substances may decrease the severity and frequency of symptoms. These include caffeine, alcohol and spicy foods among other commonly consumed goods.

Active Surveillance

Many men with mild to moderate LUTS and even some with severe LUTS will not experience a significant degree of bother despite their symptomatology. In such an individual the morbidity of medical and/or surgical intervention may prove greater than any perceived benefit. These individuals may elect a period of active surveillance. The clinician should reassure the patient that a period of active surveillance is unlikely to result in irreversible damage to the urinary tract. The patient should be monitored with serial questionnaire assessment, monitoring PVR with or without uroflowmetry. This allows the patient to take an active role in his care and promote informed shared-decision making. Wasson and colleagues (1995) randomized 556 men with moderate BPH-associated LUTS to either transurethral resection of prostate (TURP) or watchful waiting. During the follow-up period, 3 years, 17% of the watchful waiting group exhibited a treatment failure (e.g., increasing PVR, increasing symptom score, etc.) compared to 8.2% of the TURP group. No evidence of renal deterioration was found in either group [39].

Medical Management of Lower Urinary Tract Symptoms and Benign Prostatic Hyperplasia

For much of history, BPH and BPH-associated LUTS have been primarily a surgical disease. However, with the potential for significant morbidity of surgical intervention much interest has been shown for refined medical treatment of the disease complex. Indeed, Emberton and colleagues in 2008 found that men prefer non-surgical options for their BPH-associated LUTS [40]. In an effort to spare the morbidity of surgery, both "natural" and pharmacological therapeutic options have been developed for men with BPH-associated LUTS. This chapter will address this important component in the treatment alternatives of LUTS/BPH.

Surgical Management of Lower Urinary Tract Symptoms and Benign Prostatic Hyperplasia

Over the years a number of surgical approaches have been applied to individuals suffering from BPH-associated LUTS. Indeed, prior to the

development of effective medical therapy, in the early days of BPH treatment, surgical prostatectomy represented a man's only option, an option riddled with surgical complications and morbidity. Thankfully, significant technological advancement has occurred in the surgical treatment of BPH with both tissue-ablative and tissue-sparing options available to patients. As medical therapy has continued to grow in utility, surgical intervention has decreased in frequency. From 2005 to 2008, there has been a 19.8% decrease in transurethral resection in the USA [41]. Even so, many indications for initial surgical intervention remain (renal insufficiency secondary to BPH, refractory urinary retention, recurrent bladder stones, recurrent gross hematuria, recurrent UTIs, etc.) Today, more than ever, a man suffering from BPH/LUTS has a magnitude to surgical options.

Minimally Invasive Therapies

The development of newer minimally invasive surgical treatments (MIST) strive for novel approaches that rival standard methodology, ideally providing effective therapy and fewer side effects. From the patient standpoint the hallmarks of a successful MIST might include:

1. Tolerability
2. Rapid and durable relief of symptoms
3. A short recovery time with rapid return-to-life activities
4. Minimal adverse events
5. Affordability

In addition to endorsing patient concerns, urologists are interested in:

1. Capacity for the procedure to be performed in an ambulatory setting under reduced anesthesia
2. A fast learning curve
3. Generalizability from randomized controlled trials (RCTs)
4. Ease of performance
5. Reasonable startup costs and payment [42]

Traditionally, the primary goal of treatment has been to alleviate bothersome LUTS that result from bladder outlet obstruction (BOO). While a MIST may not alleviate symptoms to the same degree or durability as more invasive surgical options, a more favorable risk profile and reduced anesthetic risk would make such a treatment attractive to many patients and providers. Since many men discontinue medical therapy, yet proportionately few seek surgery, there is a large clinical need for an effective treatment that is less invasive than surgery. With this treatment class, perhaps a significant portion of men with BOO who have stopped medical therapy can be treated prior to impending bladder dysfunction.

Transurethral radiofrequency thermal therapy or convective water vapor energy ablation, *the Rezūm System* (Boston Scientific, Maple Grove, MN), provides a minimally invasive thermal therapy without a discernible thermal gradient as seen with *conductive* heat transfer as in transurethral needle ablation (TUNA) and transurethral microwave therapy (TUMT). This transurethral *convective* thermal therapy utilizes radiofrequency to generate wet thermal energy in the form of water vapor (Fig. 18.1). Convection uniformly disperses the water vapor, intercalating the tissue interstices and rapidly disrupting tissue cell membranes effecting cell death and necrosis. The therapy can be targeted to defined

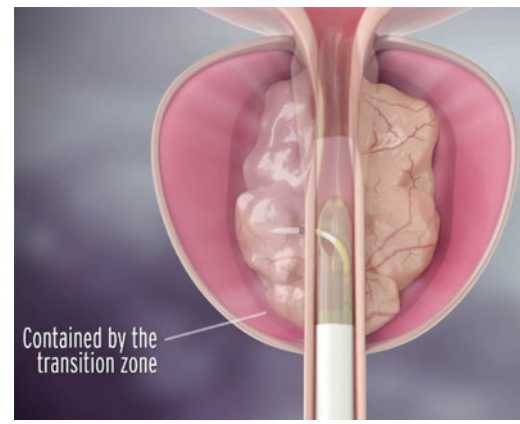

Fig. 18.1 Dispersion of steam ablation zone of the prostate with convective water vapor energy ablation. (Courtesy of Boston Scientific, Maple Grove, MN, USA)

areas such as the transition zone as steam will travel between cells until it encounters a barrier, such as a collagen pseudo-capsule or the planes between prostatic zones. No thermal effects occur outside the prostate or targeted treatment zone. The procedure can be performed in an office-based setting with minimal pain management or anesthetic. Under cystoscopic guidance a retractable needle is positioned at 90° to the area of interest and a 9-second injection of water vapor is achieved. The total number of injections may vary according to prostate size and length of the urethra, but in the trial the mean number of injections was 5.5. Unlike other MISTs, this technique can treat all critical prostatic zones including the middle lobe.

In a multicenter, randomized, controlled study, 197 men were enrolled and randomized in a 2:1 ratio to treatment with the Rezūm System or control [42]. The primary efficacy end point was a change in AUASI of 50% for the active treatment arm versus 20% for the controls (11.4 points vs 4.2 points, $p < 0.0001$). In the vapor arm *Q*max increased by 67% from 9.9 ml/sec to 16.1 ml/sec while *Q*max in the control arm increased from 10.4 ml/sec to 10.8 ml/sec ($P < 0.0001$) at the 3-month mark. These encouraging outcomes were sustained throughout the 1-year follow-up.

The adverse event profile was favorable with events documented to be mild to moderate and quickly resolved. In contrast to most of the novel minimally invasive techniques, all critical prostatic zones including the middle lobe were successful treated. Preservation of erectile and ejaculatory function was demonstrated by no change in mean IIEF score and a significant improvement in MSHQ-EjD at 1 year. The 2-year results confirmed durability of the positive clinical outcome after convective water vapor energy ablation. Thus, this novel technology is able to provide rapid and meaningful improvement of LUTS without significantly impacting sexual function. The long-term durability requires demonstration.

Prostatic urethral lift (UroLift® System, NeoTract, Pleasanton, CA) is a non-ablative approach to treating LUTS/BPH. This transprostatic tissue compression consists of a nitinol capsular anchor connected to a stainless steel urethral endpiece by a monofilament (PET) suture tensioned in situ which mechanically opens the prostate and relieves obstruction without ablation or resection. During trans-urethral deployment, a handheld delivery device is inserted through a cystoscope. The device deploys a spring-actuated implant that compresses the lumen of the prostatic urethra towards the prostatic capsule, which when repeated sequentially opens the urethra thus relieving the obstruction.

The UroLift System has published peer-reviewed 5-year data on its endoscopic device designed to treat men with bladder outlet obstruction.

Only a small number of studies comparing PUL versus TURP (BPH6 Study) have been published [43, 44]. The data indicate that a lower proportion of individuals in the PUL group responded to treatment at 12 months of follow-up compared to TURP as measured by the I-PSS reduction goal of ≥30% (73% versus 91%; $P = 0.05$). At 24 months of follow-up, the mean difference between PUL and TURP was 6.1 points (CI: 2.2, 10.0) favoring TURP; however, changes in I-PSS-QoL were similar between groups at all follow-up intervals. Additionally, *Q*max was significantly lower in participants allocated to PUL at all follow-up intervals, while changes in prostate volume were not reported. The need for reoperation due to symptom recurrence did not differ between groups over the 2-year study (RR: 2.4; CI: 0.5, 11.1). Although the incidence of serious and nonserious harms related to treatment, need for reoperation, and incontinence was similar between the PUL and TURP groups, reported incidence for incontinence for TURP was reported at 17.1% compared to 1.7% for PUL (CI: 0.3–18.0). In reviewing this study, one may note that "incontinence" was poorly defined as it relates to the unusually high incidence reported in the TURP arm. Additionally, one should note that the quality of evidence for nonserious harms related to the procedure is rated low while that for incontinence, need for reoperation, and serious harms related to treatment is rated very low.

Regarding PUL compared with sham (L.I.F.T Study), both mean change from baseline I-PSS (MD: −5.2; CI: −7.45, −2.95) and improvements in I-PSS-QoL (MD: 1.2; CI: 1.7, −0.7) favored PUL. Additionally, mean change in *Q*max at 3 months was higher for those who underwent the PUL procedure (4.3 mL/s) compared to the sham control (2.0 mL/s), $P = 0.005$. Of the participants randomized to PUL, 5-year follow-up data slightly decreases in mean I-PSS and QoL scores; however, both remained significantly improved from baseline. Only one treatment-related serious adverse event was reported during the double-blind phase of the study. In the short term, there were significantly more treatment-related harms, serious and non-serious, in the PUL group compared to sham (RR: 2.7; CI: 1.8, 3.9). Events included dysuria, hematuria, pelvic pain/discomfort, urgency, bladder spasm, UTI, and retention [45].

PUL provides durable relief of LUTS through 5 years with minimal side effects. Five-year follow-up data revealed only minimal deterioration of benefit, with significant improvement to baseline maintained. Reoperation due to symptom recurrence at 5 years was reported for 19 of 140 participants with 6 receiving additional PUL implants and 13 undergoing TURP or laser procedures. Removal of encrusted implants was required in 10 participants while 3 non-encrusted implants exposed to the bladder were removed prophylactically. Additionally, 15 participants were taking an alpha blocker or 5-alpha reductase inhibitor at 5 years. Given that approximately one third of the initial study population experienced unsatisfactory results necessitating further treatment, patients selecting PUL should be informed that this is a relatively new intervention for LUTS/BPH with uncertainties in long-term durability, though such uncontrolled data are available.

The universal applicability of PUL is limited by current contraindications including prostate volume >80 cc and the presence of an obstructive middle lobe. Additional studies are underway to help more fully elucidate the limitations but are not available for review. As with other technologies included in this review the long-term durability remains to be seen.

Transurethral needle ablation (*TUNA*) utilized radiofrequency energy to heat the prostatic tissue to stimulate tissue necrosis of the adenomatous tissue while preserving urethral mucosa. The energy is applied by inserting two needles via a cystoscopic device into the lateral lobes of the prostate. Depending of the volume characteristics of the gland itself, a single or multiple treatment cycles may be required. In the 2018 AUA BPH Clinical Guidelines, this technology was *not* recommended [46].

Transurethral microwave thermotherapy (*TUMT*) utilized microwave energy via a urethral catheter with mounted microwave antennae to heat the prostatic tissue to temperatures ranging from 45° to 70 °C, thereby stimulating tissue necrosis. Many of these systems have attempted different strategies to protect the urethral tissue, commonly utilizing a cold-water channel along the outer circumference of the catheter. Microwave technology has been developed by multiple manufacturers, and as a result, a significant amount of variability in the technology exists.

Success of TUMT relies heavily on patient selection, as variations in prostatic anatomy (e.g., oversized gland, median lobe, etc.) can distort the energy transmission. Furthermore, the microwave energy has the potential to interfere with other implanted devices such as pacemakers, defibrillators, penile prostheses and metallic joint implants.

Hoffman and colleagues performed a Cochrane review of six trials comparing TUMT and TURP; the mean improvement in AUA-SI was 65% for TUMT compared to 77% for TURP [47]. Similarly, TURP improved urine flow rates by an average of +119%, while TUMT improved by an average of 77%. Thus, TUMT appears to provide inferior improvement in patients' voiding yet holds the benefit of being performed as an office-based procedure requiring only local anesthesia. Thus, the AUA Guidelines Committee rendered the recommendation that TUMT be offered, with the caveat that the risk of reoperation be discussed in detail with the patient.

Transurethral Incision of Prostate (TUIP) The concept of incising the prostate at the level of the bladder neck to treat symptoms of BPH/LUTS was first presented by Guthrie in 1834, suggesting that disruption of the bladder neck to allow the bladder to empty without restraint. Ideally a unilateral or bilateral incision is made at the 5 and/or 7 o'clock position at the level of the bladder neck. The ideal situation would be a small but obstructing gland, <30 grams. The benefit of TUIP is preservation of antegrade ejaculation. Orandi and colleagues suggested that avoidance of the bladder neck entirely is the best means to preserve ejaculatory function [48]. Orandi also wrote that the median lobe does not represent a contraindication to TUIP, but that larger glands may achieve reduced benefit [49].

Prostatic Ablative Therapy

Transurethral resection of the prostate (*TURP*) utilizes electrocautery energy passed across a thin filament loop. With the current activated, the loop is passed through the adenomatous prostatic tissue from the level of the bladder neck to the verumontanum. The activated loop cauterizes the blood vessels feeding the prostatic tissue creating chips of resected tissue. The resection is continued circumferentially along the bladder neck prior to targeting the lateral prostatic lobes. One lobe is completely resected prior to performing an identical procedure on the contralateral lobe. The typical anatomic landmarks utilized to establish the field of resection include the bladder neck proximally, verumontanum distally and the prostatic capsule to establish the appropriate depth. Care is taken while resecting at the level of the bladder neck as to not extend the loop into the bladder lumen to avoid inadvertent injury to the ureteric orifices. At the conclusion of the resection, the produced prostatic chips are then evacuated from the bladder prior to placing a large caliber urethral catheter. The energy generator employed for the procedure may be of either monopolar or bipolar design.

Monopolar The use of TURP has been in practice since the early twentieth century. For many years monopolar was the sole energy source option. The current supplied by a monopolar resectoscope is carried from the resecting loop to the prostatic tissue and returned to a grounding previously placed on a patient. In order to ensure effective and efficient conductivity of this energy, a nonionic, hypo-osmolar irrigation solution must be employed. Typical solutions include sterile water, sorbitol and glycine. Given the extensive vascularity of the prostatic resection bed, this requirement risks substantial absorption of this hypo-osmolar fluid into the circulation. Excessive absorption can lead to a danger of dilutional hyponatremia, a condition later referred to as post-TURP syndrome. As such, it is recommended that postoperative serum electrolyte assessment be carried out in the postoperative care unit. In an effort to decrease the risk of post-TURP syndrome, resection times should be maintained less than 90 minutes [50].

Though the original outcomes research for monopolar TURP preceded many of the validated questionnaires for BPH-associated LUTS, TURP has long been believed to be an effective and durable BPH intervention. While post-TURP syndrome represents the most worrisome complication included in the adverse event profile for monopolar TURP, thankfully, it is uncommon. The most commonly cited complications of TURP include UTI, ejaculatory dysfunction, urethral stricture formation and urinary incontinence. Issa and colleagues (2008) found that up to 2.5% of individuals will require reoperation [51].

Bipolar The development of a bipolar working element allowed for the containment of the electrocautery current within the resecting loop rather than traveling through the patient to a previously placed grounding pad. This allows for the current to be maintained at the site of resection. As a result of this advancement, the use of hypo-osmolar irrigation solution was no longer required, thus allowing the surgeon to utilize iso-osmolar solutions (i.e., normal saline) reducing the risk of post-TURP syndrome while also

allowing for improved hemostasis. The increased efficiency of both resection and coagulation led to decreased operative times [52]. When comparing bipolar with the established monopolar energy system, Issa and colleagues looked at 10 years' worth of data noting similar outcomes in improvement of urinary flow rate, reduction of PVR, and improved AUA-SI and QoL scores [51, 52]. Recent metanalyses by Cornu and colleagues and Omar and colleagues reported similar results [53, 54].

Mamoulakis et al. did report, however, that bipolar TURP was associated with significantly less adverse events compared to monopolar TURP (15.5% vs. 28.6%, $P < 0.01$) [55]. Of the cited differences, perioperative bleeding appeared to be of significant importance (bleeding, transfusion, duration of indwelling catheter, need for continuous bladder irrigation, post-TURP syndrome). Similar to monopolar TURP, perioperative adverse events include TUI, urethral stricture formation, urinary incontinence, and need for repeat procedure.

Transurethral vaporization of the prostate (*TUVP*) represents a modification on the TURP platform. Using either monopolar or bipolar energy (bipolar far most commonly utilized), the current is applied to the prostatic tissue by an electrode to vaporize the prostatic tissue. By concentrating the tissue density, this design aims to increase the efficiency of tissue ablation while maintaining better visualization and providing improved hemostasis. The electrode is available in a variety of shapes; most commonly used include the button, rollerball, and the grooved roller. TUVP has gained popularity as a teaching tool, with many believing it provides an ideally controlled setting for the instruction of future urologists.

Over 20 RCTs have been performed evaluating TUVP versus TURP (both monopolar and bipolar) [56–80] with the majority indicating no significant difference in the overall effectiveness, need for reoperation, incidence of major complication, or need for blood transfusion.

Photoselective vaporization of the prostate (*PVP*) utilizes laser energy at a wavelength of 532 nm to vaporize the prostatic tissue. This is achieved by selective absorption of the laser energy by hemoglobin resulting in tissue ablation, leaving behind a thin layer of coagulation for hemostasis. Using a technique similar to TURP, a channel is created within the prostatic urethral allowing the bladder to expel urine with minimal outlet resistance. This technique was popularized using an 80 W energy generator, with subsequent advances leading to the 120 W and most recently 180 W generators available for more efficient tissue vaporization. The GOLIATH study [81–83] compared 180 W PVP with traditional TURP in a non-inferiority design. Though the investigators were not able to meet the non-inferiority criteria of a 3-point difference in IPSS, they did show that PVP was similar to TURP in adverse event incidence, need for blood transfusion rates, decrease in PVR, decrease in prostate volume (by both TRUS and PSA), and need for reoperation.

Many experts believe that PVP is best suited for older men with more complex medical comorbidity indices, those with long-term anticoagulation therapy and small- to medium-sized prostates. Attributed to the thin layer of coagulation effect of the PVP, many believe VP holds a reduced risk of bleeding complications. Furthermore, PVP has frequently been utilized as ambulatory procedure, thus providing significant cost savings on hospitalization as shown by van Melick et al. [65, 66].

Holmium laser enucleation of the prostate (*HoLEP*) utilizes energy via a holmium: yttrium-aluminum-garnet (Ho:YAG) laser with a wavelength of 2140 nm. The energy is absorbed by the irrigation fluid at the tip of the fiber creating a vaporization bubble allowing for destruction of the prostatic tissue with minimal deep tissue penetration [84]. The prostate is enucleated along its surgical capsule with the resultant tissue morcellated using a separate device. In comparison with TURP, HoLEP has demonstrated similarly improved voiding symptoms, shorter catheter indwell time, and shorter hospitalization, with similarly uncommon adverse events. TURP did have the benefit of shorter operative times [85–91].

A distinct benefit of HoLEP is its applicability to large prostate glands. In a 2008 trial by Kuntz and colleagues, HoLEP was compared to open prostatectomy for men with gland volume

>100 mL. The HoLEP group had significantly shorter hospital stays, catheter indwell times, and perioperative bleeding complications while maintaining similar improvement in both IPSS and urine flow rates [92].

Particularly in Europe, HoLEP has gained significant popularity. However, a perceived steep learning curve has limited its utilization in the USA.

Holmium laser ablation of the prostate (*HoLAP*) utilizes holmium energy with its vaporization bubble to ablate the prostatic adenomatous tissue. While the limited depth of penetration is considered a safety benefit of holmium-based laser systems, it also limits the efficiency of tissue destruction. As such the use of HoLAP, which incorporates a technique similar to TUVP, has fallen out of favor.

Simple prostatectomy/robotic approaches consist of enucleating the prostatic tissue with its capsule. Historically this has been achieved via an open surgical approach; however with the establishment of laparoscopy and subsequently robotically assisted approaches, simple prostatectomy has also evolved. Most commonly, simple prostatectomy is reserved for individuals with large prostates that would render more minimally invasive transurethral techniques difficult. Both open and laparoscopic/robotic approaches have been shown to greatly improve IPSS and urine flow rates with excellent long-term durability [93–96].

Limitations of simple prostatectomy of course include the requirement for major surgery and postoperative hospital admission. Significant perioperative blood loss represents the most commonly implicated complication, though development of urethral stricture disease (particularly bladder neck contracture) deserves significant consideration.

Alternative Drainage in Special Situations

Clean Intermittent Catheterization (CIC)

Clean intermittent catheterization (CIC) represents a means of bypassing an obstructed outlet. An inserted urethral catheter serves as a temporary conduit for bladder drainage. Clean intermittent catheterization (CIC) represents a means of bypassing an obstructed outlet. An inserted urethral catheter serves as a temporary conduit for bladder drainage and is useful for individuals who suffer from weak detrusor contractility in addition to the outlet obstruction. Though this approach does not address the underlying pathology, maintaining low urine storage pressure prevents deterioration of the upper tracts.

Intraprostatic Urethral Stent

Spanner® is a temporary indwelling prostatic stent designed to maintain urethral patency allowing the patient volitional voiding by decreasing urethral resistance (Fig. 18.2). The stent maintains its position by means of an anchoring balloon that rests at the level of the bladder neck, with a distal anchor device within the bulbar urethra. The device spans the distance from the bladder neck to just proximal to the external urethral sphincter, thereby decreasing outlet obstruction while maintaining a functional sphincter for continence. The device is placed in the office using an included introducer and may be removed by means of included retrieval sutures. It is approved by the U.S. Food and Drug Administration (FDA) for use in patients with BPH for a maximum indwelling time of 30 days. Goh and colleagues reported their initial experience with 16 men in whom the Spanner® was inserted. Fourteen of 16 patients experienced significant improvement in urine flow rates and PVR. Median duration of stent dwell time was 10 days. However, 12 of 16 stents were removed prematurely due to either severe symptoms or urinary retention, and 12 of 16 required endoscopic assistance for removal [97].

The *Urolume*™, constructed of a nickel superalloy wire mesh, was initially developed for use in men with bulbar urethral strictures and was quickly used in individuals with BPH gaining significant popularity; it has, however, been taken off the market due to stent encrustation and migration (complications common to most intraprostatic endoprostheses) [98–100].

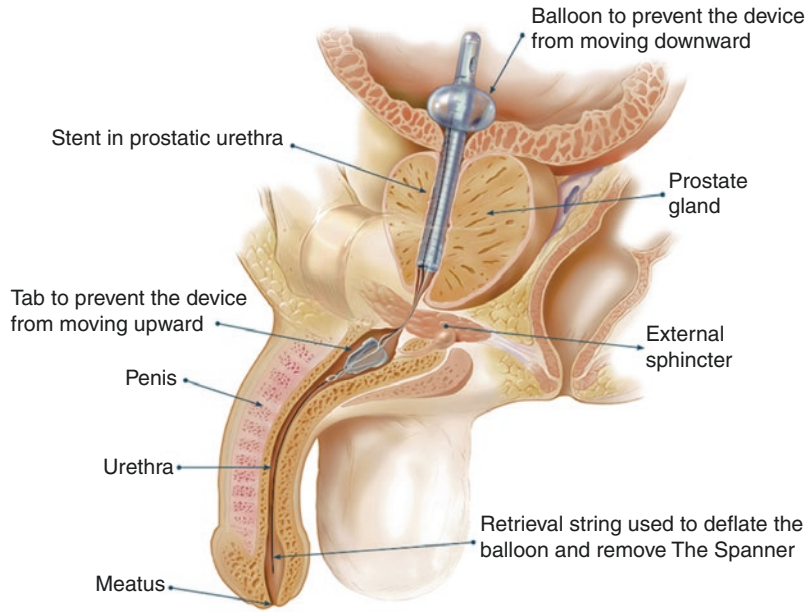

Fig. 18.2 Positioning of temporary indwelling prostatic stent. (Spanner®) (Courtesy of SRS Medical Billerica, MA, USA)

Other prostatic/urethral stents have utilized a variety of materials: nitinol, polyurethane, polyglycolic acid, and stainless steel [101]. The advantage of this approach is that these intraprostatic devices can frequently be placed as an office-based procedure without general anesthetic, an attractive option for individuals who may be poor surgical candidates. Most recently, the Allium™ intraprostatic stent has been developed. The Allium™ is a polymer-covered nitinol-based product, triangular in shape in an effort to prevent encrustation. Denmeade and colleagues in 2011 demonstrated significant improvements in both IPSS and urine flow rates [102].

Surgery in Special Populations

What to Do with Medically Complicated Patients and Those on Anticoagulants

Multiple studies have shown that the need for a blood transfusion (either peri- or postoperatively) was significantly less likely with HoLEP as compared to TURP (RR: 0.20; CI: 0.08, 0.47).

In addition, studies of holmium laser prostate surgery in patients maintained on anticoagulation therapy at time of surgery have supported a relatively low transfusion rate. In a 2013 retrospective review on a series of 125 patients treated with HoLEP (52 patients were on antithrombotic therapy at the time of surgery and 73 patients were not), only 4 men (7.7%) in the antithrombotic group required a blood transfusion compared to none in the control group [103]. A similar 2016 study compared 116 patients who required anticoagulation/antiplatelet therapy at the time of HoLEP to 1558 patients who did not. Other than a slightly increased duration of bladder irrigation and hospital stay, the use of anticoagulation/antiplatelet therapy did not adversely affect outcomes [104]. Lastly, a 2017 meta-analysis of patients on therapeutic anticoagulation/antiplatelet therapy when undergoing HoLEP supported that this approach can be performed safely on these patients but stressed that there are limited data surrounding the class of direct oral anticoagulants and safety [105].

PVP is performed using the KTP laser, which has a wavelength of 532 nm and a chromophore of hemoglobin. The depth of penetra-

tion with PVP is 0.8 mm. Multiple studies have found that PVP is safe and effective for patients who continue their anticoagulant/antiplatelet therapy, with negligible transfusion rates. However, surgeons should be aware that longer catheterization and irrigation with an increased rate of complications have been reported, and delayed bleeding is more pronounced in these patients [105–109]. A 2017 study confirmed these findings in 59 of 373 patients undergoing PVP. Overall, GreenLight PVP with the 180 W laser unit on patients therapeutic on heparin, warfarin, clopidogrel, dipyridamole, or new oral anticoagulant drugs revealed good safety outcomes [110, 111]. As expected, anticoagulated patients were older and had a higher American Society of Anesthesiologists (ASA) score than the control group, and although no patient required blood transfusion, there was a higher incidence of high-grade Clavien-Dindo events. Similar to other studies, the therapeutically anticoagulated group had a significantly longer length of hospital stay and duration of catheterization as compared to the controls.

Technologies in Development

Image-Guided Robot-Assisted Water-Jet Ablation of Prostate (Aquablation)

Aquablation is an emerging robotic, image-guided, highly engineered ablation of the prostate using a water jet, termed AquaBeam (Procept BioRobotics, Redwood Shores, CA) (See Chap. 17). The water jet is a high velocity hydrodissection tool that ablates prostatic parenchyma while sparing major blood vessels and the prostatic capsule. The urologist performs a surgical mapping of the prostate using transrectal ultrasound images. While still requiring general anesthesia and significant setup time and effort, the procedure is performed with remarkable efficiency.

In a single-arm multicenter pilot study, 21 men were enrolled and treated under general anesthesia. After 12 months, AUASI was reduced from 23.0 points at baseline to 6.8 points ($P < 0.001$). An increase from 8.7 ml/sec to 18.3 ml/sec in Qmax was demonstrated ($P < 0.0001$) No cases of urinary incontinence, erectile dysfunction or retrograde ejaculation were reported. Anatomical prostatic features like a prostate volume >100 cc, the presence of a large middle lobe and the anesthetic requirements are limitations to the technology [112]. Further randomized controlled trials are underway to evaluate efficacy, durability and safety of this approach.

Prostatic Arterial Embolization

Using digital subtraction angiography, the arterial anatomy and the appropriate prostatic arterial supply can be selectively embolized with various beads, gels, or non-spherical polyvinyl alcohol to infarct prostatic vessels and putatively reduce prostate volume, which may improve LUTS. Similar to all the options noted above, prostatic arterial embolization (PAE) can be performed in an outpatient setting. Technically, the most challenging part of PAE is to identify and catheterize the prostatic arteries. Prostatic arteries are very small arteries (1–2 mm in diameter) that may have variable origins from the collateral branches of the internal iliac artery. In contrast to uterine arteries, prostatic arteries lack pathognomonic findings and may be very difficult to identify with digital subtraction angiography before PAE.

Atherosclerosis, excessive tortuosity of the arterial supply and the presence of adverse collaterals are anatomical obstacles for the technical approach. Non-targeted embolization may lead to ischemic complications like transient ischemic proctitis, bladder ischemia, or seminal vesicle ischemia. Short-term complications, including urethral burning sensation, nausea and vomiting are common and have been coined the “post-PAE syndrome” [113]. The extended duration of the procedure with the requirement of fluoroscopy brings the risk of a relevant radiation exposure, which may result in skin irritation and even burns. Furthermore, contrast toxicity with the

need for angiography is another adverse effect that must be acknowledged.

Currently PAE is performed under sedation by interventional radiologists or cardiologists, most without the benefit of research protocols, IRB approval, or proper trial design and measures. The selection of LUTS patients who will benefit from PAE still need to be defined. However, a recently published systematic review with meta-analysis and meta-regression on available data concluded that PAE should still be considered an experimental approach due to the reduced efficacy when compared with control groups. RCTs of good quality are still required to justify this technique on an elective indication (Clinicaltrials.gov: NCT02054013). It is important to stress that all of the MISTs noted above are able to specifically target the critical areas of BOO secondary to BPH. In contrast, PAE impacts the entire prostate without the option for focused and controlled action on obstruction. This may explain the higher clinical failure rate compared to reference methods like TURP and the commonly observed complications like acute urinary retention in almost 26% of cases [114].

TIND: Temporary Implantable Nitinol Device

The TIND device (Medi-Tate, Israel) is an emerging device which is used to refashion the prostatic urethra, including the bladder outlet (Fig. 18.3). The TIND is a set of connected nitinol struts that are delivered cystoscopically and expanded within the prostatic fossa and then left in place for 5 days; after which the device is removed in a second cystoscopic procedure. The mechanism of action is to compress prostatic transition zone tissue to the point of ischemic necrosis along each strut. After removal, it is intended that a pattern similar to TUIP incisions remains, in the hope of creating durable relief of bladder outlet obstruction.

Three-year follow-up data was recently published concerning treatment of men with benign prostatic obstruction with the TIND [115]. All men were treated in the outpatient setting under "light sedation." After 12 months, mean changes relative to baseline values were 45% for AUASI and 67% for *Q*max. There were four postoperative complications (4/32 = 12.5%), including prostatic abscess (n = 1), urinary retention (n = 1), urinary tract infection (n = 1) and temporary incontinence (n = 1). This phase 1 trial demonstrated that implantation of CRD is a feasible procedure, and although encouraging, more mature and larger studies are required to assess this technology and are ongoing (Clinicaltrials.gov: NCT02145208).

ClearRing: Implantable Compressive Ring (ProArc Medical)

The ClearRing device (ProArc Medical, Israel) is an emerging device which is used to refashion the prostatic urethra, including the bladder outlet. The CRD is made from anchored nitinol rings that are deployed strategically within the urethra into shallow prostatic grooves customized using general anesthesia. The mechanism of action of the ring placement is to compress prostatic transition zone tissue. First in man studies have been conducted with no other information currently available.

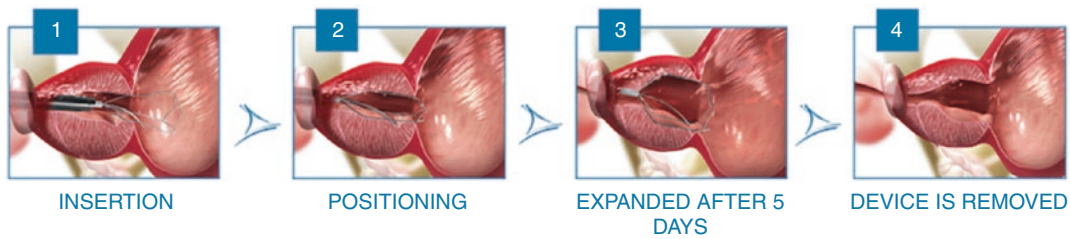

Fig. 18.3 Use of the Medi-Tate Temporary Implantable Nitinol Device (Courtesy of iTIND. Or Akiva, Israel)

The Spring

The Spring (Zenflow, South San Francisco, CA) is a permanent helical nitinol implant delivered through a flexible cystoscope. The nitinol composition creates internal tension that imbeds it into the wall of the prostatic urethra with a minimal footprint in the urethra, thereby resisting encrustation. A single wire, it facilitates easy adjustment or removal. The procedure is designed to be atraumatic, allowing a quick and catheter-free recovery. First in man studies are underway in New Zealand and Europe.

References

1. Wei JT, Calhoun E, Jacobsen SJ. Urologic diseases in America project: benign prostatic hyperplasia. J Urol. 2005;173(4):1256–61.
2. Guess HA, Arrighi HM, Metter EJ, Fozard JL. Cumulative prevalence of prostatism matches the autopsy prevalence of benign prostatic hyperplasia. Prostate. 1990;17(3):241–6.
3. Kupelian V, Wei JT, O'Leary MP, Kusek JW, Litman HJ, Link CL, McKinlay JB, BACH Survey Investigators. Prevalence of lower urinary tract symptoms and effect on quality of life in a racially and ethnically diverse random sample: the Boston Area Community Health (BACH) Survey. Arch Intern Med. 2006;166(21):2381–7.
4. Arrighi HM, Metter EJ, Guess HA, Fozzard JL. Natural history of benign prostatic hyperplasia and risk of prostatectomy. The Baltimore Longitudinal Study of Aging. Urology. 1991;38(1 Suppl):4–8.
5. Chute CG, Panser LA, Girman CJ, Oesterling JE, Guess HA, Jacobsen SJ, Lieber MM. The prevalence of prostatism: a population-based survey of urinary symptoms. J Urol. 1993;150(1):85–9.
6. Boyle P, Robertson C, Mazzetta C, Keech M, Hobbs FD, Fourcade R, et al; UrEpik Study Group. The prevalence of lower urinary tract symptoms in men and women in four centres. The UrEpik study. BJU Int. 2003;92(4):409–14.
7. McVary KT. BPH: epidemiology and comorbidities. Am J Manag Care. 2006;12(5 Suppl):S122–8. Review.
8. Homma Y, Kawabe K, Tsukamoto T, Yamanaka H, Okada K, Okajima E, et al. Epidemiologic survey of lower urinary tract symptoms in Asia and Australia using the international prostate symptom score. Int J Urol. 1997;4(1):40–6. Erratum in: Int J Urol. 1997;4(2):232.
9. Glynn RJ, Campion EW, Bouchard GR, Silbert JE. The development of benign prostatic hyperplasia among volunteers in the Normative Aging Study. Am J Epidemiol. 1985;121(1):78–90.
10. Lytton B, Emery JM, Harvard BM. The incidence of benign prostatic obstruction. J Urol. 1968;99(5):639–45.
11. Isaacs JT. Antagonistic effect of androgen on prostatic cell death. Prostate. 1984;5(5):545–57.
12. de la Rosette JJ, Witjes WP, Schäfer W, Abrams P, Donovan JL, Peters TJ, et al. Relationships between lower urinary tract symptoms and bladder outlet obstruction: results from the ICS-"BPH" study. Neurourol Urodyn. 1998;17(2):99–108.
13. Wilt T, Ishani A, MacDonald R, Stark G, Mulrow C, Lau J. Beta-sitosterols for benign prostatic hyperplasia. Cochrane Database Syst Rev. 2000;2:CD001043.
14. Irwin DE, Milsom I, Hunskaar S, Reilly K, Kopp Z, Herschorn S, et al. Population-based survey of urinary incontinence, overactive bladder, and other lower urinary tract symptoms in five countries: results of the EPIC study. Eur Urol. 2006;50(6):1306–14; discussion 1314–5.
15. Lepor H, Machi G. Comparison of AUA symptom index in unselected males and females between fifty-five and seventy-nine years of age. Urology. 1993;42(1):36–40; discussion 40–1.
16. McVary KT, Roehrborn CG, Avins AL, Barry MJ, Bruskewitz RC, Donnell RF, et al. Update on AUA guideline on the management of benign prostatic hyperplasia. J Urol. 2011;185(5):1793–803.
17. Russell S, McVary KT. Lower urinary tract symptoms and erectile dysfunction: epidemiology and treatment in the aging man. Curr Urol Rep. 2005;6(6):445–53.
18. Coyne KS, Kaplan SA, Chapple CR, Sexton CC, Kopp ZS, Bus EN, Aiyer LP. Risk factors and comorbid condition associated with lower urinary tract symptoms: EpiLUTS. BJU Int. 2009;103(Suppl 3):24–32.
19. Hoshiyama F, Hirayama A, Tanaka M, Taniguchi M, Ohi M, Momose H, et al. The impact of obstructive sleep apnea syndrome on nocturnal urine production in older men with nocturia. Urology. 2014;84(4):892–6.
20. McConnell JD, Barry MJ, Bruskewitz RC. Benign prostatic hyperplasia: diagnosis and treatment. Agency for Health Care Policy and Research. Clin Pract Guide Quick Ref Guide Clin. 1994(8):1–17.
21. Hamm RS, MacDermott SM. Renal function in men with lower urinary tract symptoms at first presentation to urology out-patient department. Ann R Coll Surg Engl. 2004;86(3):182–5.
22. Parsons JK, Sarma AV, McVary K, Wei JT. Obesity and benign prostatic hyperplasia: clinical connections, emerging etiological paradigms and future directions. J Urol. 2013;189(1 Suppl):S102–6.
23. Abrams P, Cardozo L, Fall M, Griffiths D, Rosier P, Ulmsten U, et al; Standardisation Sub-Committee of the International Continence Society. The standardisation of terminology in lower urinary tract function: report from the standardization sub-committee

of the International Continence Society. Urology. 2003;61(1):37–49. Review.
24. Reynard JM, Yang Q, Donovan JL, Peters TJ, Schafer W, de la Rosette JJ, et al. The ICS-'BPH' Study: uroflowmetry, lower urinary tract symptoms and bladder outlet obstruction. Br J Urol. 1998;82(5):619–23.
25. O'Leary MP. LUTS, ED, QOL: alphabet soup or real concerns to aging men? Urology. 2000;56(5 Suppl 1):7–11.
26. Barry MJ, Fowler FJ Jr, O'Leary MP, Bruskewitz RC, Holtgrewe HL, Mebust WK, Cockett AT. The American Urological Association symptom index for benign prostatic hyperplasia. The Measurement Committee of the American Urological Association. J Urol. 1992;148(5):1549–57; discussion 1564.
27. Schou J, Poulsen AL, Nordling J. The value of a new symptom score (DAN-PSS) in diagnosing urodynamic infravesical obstruction in BPH. Scand J Urol Nephrol. 1993;27(4):489–92.
28. Donovan JL, Peters TJ, Abrams P, Brookes ST, de la Rosette JJ, Schäfer W. Scoring the short form ICS male SF questionnaire. International Continence Society. J Urol. 2000;164(6):1948–55.
29. Roehrborn CG. Accurate determination of prostate size via digital rectal examination and transrectal ultrasound. Urology. 1998;51(4A Suppl):19–22.
30. Pinsky PF, Kramer BS, Crawford ED, Grubb RL, Urban DA, Andriole GL, et al. Prostate volume and prostate- specific antigen levels in men enrolled in a large screening trial. Urology. 2006;68(2):352–6.
31. Bosch JL, Bohnen AM, Groeneveld FP. Validity of digital rectal examination and serum prostate specific antigen in the estimation of prostate volume in community-based men aged 50 to 78 years: the Krimpen Study. Eur Urol. 2004;46(6):753–9.
32. Carter HB, Albertsen PC, Barry MJ, Etzioni R, Freedland SJ, Greene KL, et al. Early detection of prostate cancer: AUA Guideline. J Urol. 2013;190(2):419–26.
33. Comiter CV, Sullivan MP, Schacterle RS, Cohen LH, Valla SV. Urodynamic risk factors for renal dysfunction in men with obstructive and nonobstructive voiding dysfunction. J Urol. 1997;158(1):181–5.
34. Prieto L, Romero J, Lopez C, Ortiz M, Pacheco JJ. Efficacy of doxazosin in the treatment of acute urinary retention due to benign prostate hyperplasia. Urol Int. 2008;81(1):66–71.
35. Yap TL, Cromwell DC, Emberton M. A systematic review of the reliability of frequency-volume charts in urological research and its implications for the optimum chart duration. BJU Int. 2007;99(1):9–16.
36. McConnell JD, Roehrborn CG, Bautista OM, Andriole GL Jr, Dixon CM, Kusek JW, et al; Medical Therapy of Prostatic Symptoms (MTOPS) Research Group. The long-term effect of doxazosin, finasteride, and combination therapy on the clinical progression of benign prostatic hyperplasia. N Engl J Med. 2003;349(25):2387–98.
37. Crawford ED, Wilson SS, McConnell JD, Slawin KM, Lieber MC, Smith JA, MTOPS RESEARCH Group. Baseline factors as predictors of clinical progression of benign prostatic hyperplasia in men treated with placebo. J Urol. 2006;175(4):1422–6; discussion 1426–7.
38. Sech S, Montoya J, Girman CJ, Rhodes T, Roehrborn CG. Interexaminer reliability of transrectal ultrasound for estimating prostate volume. J Urol. 2001;166(1):125–9.
39. Wasson JH, Reda DJ, Bruskewitz RC, Elinson J, Keller AM, Henderson WG. A comparison of transurethral surgery with watchful waiting for moderate symptoms of benign prostatic hyperplasia. The Veterans Affairs Cooperative Study Group on Transurethral Resection of the Prostate. N Engl J Med. 1995;332(2):75–9.
40. Emberton M, Marberger M, de la Rosette J. Understanding patient and physician perceptions of benign prostatic hyperplasia in Europe: The Prostate Research on Behaviour and Education (PROBE) Survey. Int J Clin Pract. 2008;62(1):18–26.
41. Malaeb BS, Yu X, McBean AM, Elliott SP. National trends in surgical therapy for benign prostatic hyperplasia in the United States (2000–2008). Urology. 2012;79(5):1111–6.
42. McVary KT, Gange SN, Gittelman MC, Goldberg KA, Patel K, Shore ND, et al. Minimally invasive prostate convective water vapor energy ablation: a multicenter, randomized, controlled study for the treatment of lower urinary tract symptoms secondary to benign prostatic hyperplasia. J Urol. 2016;195(5):1529–38.
43. Gratzke C, Barber N, Speakman MJ, Berges R, Wetterauer U, Greene D, et al. Prostatic urethral lift vs transurethral resection of the prostate: 2-year results of the BPH6 prospective, multicentre, randomized study. BJU Int. 2017;119(5):767–75.
44. Sønksen J, Barber NJ, Speakman MJ, Berges R, Wetterauer U, Greene D, Sievert KD, et al. Prospective, randomized, multinational study of prostatic urethral lift versus transurethral resection of the prostate: 12-month results from the BPH6 study. Eur Urol. 2015;68(4):643–52.
45. Roehrborn CG, Barkin J, Gange SN, Shore ND, Giddens JL, Bolton DM, et al. Five year results of the prospective randomized controlled prostatic urethral L.I.F.T. study. Can J Urol. 2017;24(3):8802–13.
46. Foster HE, Barry MJ, Dahm P, Gandhi MC, Kaplan SA, Kohler TS, et al. Surgical management of lower urinary tract symptoms attributed to benign prostatic hyperplasia: AUA Guideline. J Urol. 2018;200(3):612–9. https://www.auanet.org/guidelines/benign-prostatic-hyperplasia-(bph)-guideline. Accessed 19 Mar 2019.
47. Hoffman RM, Monga M, Elliott SP, Macdonald R, Langsjoen J, Tacklind J, Wilt TJ. Microwave thermotherapy for benign prostatic hyperplasia. Cochrane Database Syst Rev. 2012;9:CD004135.

48. Orandi A. Transurethral incision of prostate compared with transurethral resection of prostate in 132 matching cases. J Urol. 1987;138(4):810–5.
49. Orandi A. Transurethral incision of prostate (TUIP): 646 cases in 15 years—a chronological appraisal. Br J Urol. 1985;57(6):703–7.
50. Mebust WK, Holtgrewe HL, Cockett AT, Peters PC. Transurethral prostatectomy: immediate and postoperative complications. A cooperative study of 13 participating institutions evaluating 3,885 patients. J Urol. 1989;141(2):243–7.
51. Issa MM. Technological advances in transurethral resection of the prostate: bipolar versus monopolar TURP. J Endourol. 2008;22(8):1587–95.
52. Erturhan S, Erbagci A, Seckiner I, Yagci F, Ustun A. Plasmakinetic resection of the prostate versus standard transurethral resection of the prostate: a prospective randomized trial with 1-year follow-up. Prostate Cancer Prostatic Dis. 2007;10(1):97–100.
53. Cornu JN, Ahyai S, Bachmann A, de la Rosette J, Gilling P, Gratzke C, et al. A systematic review and meta-analysis of functional outcomes and complications following transurethral procedures for lower urinary tract symptoms resulting from benign prostatic obstruction: an update. Eur Urol. 2015;67(6):1066–96.
54. Omar MI, Lam TB, Alexander CE, Graham J, Mamoulakis C, Imamura M, et al. Systematic review and meta-analysis of the clinical effectiveness of bipolar compared with monopolar transurethral resection of the prostate (TURP). BJU Int. 2014;113(1):24–35.
55. Mamoulakis C, Ubbink DT, de la Rosette JJ. Bipolar versus monopolar transurethral resection of the prostate: a systematic review and meta-analysis of randomized controlled trials. Eur Urol. 2009;56(5):798–809.
56. Elsakka AM, Eltatawy HH, Almekaty KH, Ramadan AR, Gameel TA, Farahat Y. A prospective randomised controlled study comparing bipolar plasma vaporisation of the prostate to monopolar transurethral resection of the prostate. Arab J Urol. 2016;14(4):280–6.
57. Falahatkar S, Mokhtari G, Moghaddam KG, Asadollahzade A, Farzan A, Shahab E, et al. Bipolar transurethral vaporization: a superior procedure in benign prostatic hyperplasia: a prospective randomized comparison with bipolar TURP. Int Braz J Urol. 2014;40(3):346–55.
58. Geavlete B, Georgescu D, Multescu R, Stanescu F, Jecu M, Geavlete P. Bipolar plasma vaporization vs monopolar and bipolar TURP—A prospective, randomized, long-term comparison. Urology. 2011;78(4):930–5.
59. Geavlete B, Stanescu F, Moldoveanu C, Geavlete P. Continuous vs conventional bipolar plasma vaporisation of the prostate and standard monopolar resection: a prospective, randomized comparison of a new technological advance. BJU Int. 2014;113(2):288–95.
60. Hoekstra RJ, Van Melick HH, Kok ET, Ruud Bosch JL. A 10- year follow-up after transurethral resection of the prostate, contact laser prostatectomy and electrovaporization in men with benign prostatic hyperplasia; long-term results of a randomized controlled trial. BJU Int. 2010;106(6):822–6.
61. Karaman MI, Kaya C, Ozturk M, Gurdal M, Kirecci S, Pirincci N. Comparison of transurethral vaporization using PlasmaKinetic energy and transurethral resection of prostate: 1- year follow-up. J Endourol. 2005;19(6):734–7.
62. Kaya C, Ilktac A, Gokmen E, Ozturk M, Karaman IM. The long-term results of transurethral vaporization of the prostate using plasmakinetic energy. BJU Int. 2007;99(4):845–8.
63. Koca O, Keleş MO, Kaya C, Güneş M, Öztürk M, Karaman Mİ. Plasmakinetic vaporization versus transurethral resection of the prostate: six-year results. Turk J Urol. 2014;40(3):134–7.
64. Nuhoğlu B, Balci MB, Aydin M, Hazar I, Onuk Ö, Taş T, Fikri O. The role of bipolar transurethral vaporization in the management of benign prostatic hyperplasia. Urol Int. 2011;87(4):400–4.
65. van Melick HH, van Venrooij GE, Eckhardt MD, Boon TA. A randomized controlled trial comparing transurethral resection of the prostate, contact laser prostatectomy and electrovaporization in men with benign prostatic hyperplasia: analysis of subjective changes, morbidity and mortality. J Urol. 2003;169(4):1411–6.
66. van Melick HH, van Venrooij GE, Boon TA. Long-term follow-up after transurethral resection of the prostate, contact laser prostatectomy, and electrovaporization. Urology. 2003;62(6):1029–34.
67. Zhang SY, Hu H, Zhang XP, Wang D, Xu KX, Na YQ, et al. Efficacy and safety of bipolar plasma vaporization of the prostate with "button-type" electrode compared with transurethral resection of prostate for benign prostatic hyperplasia. Chin Med J. 2012;125(21):3811–4.
68. Ekengren J, Haendler L, Hahn RG. Clinical outcome 1 year after transurethral vaporization and resection of the prostate. Urology. 2000;55(2):231–5.
69. Hammadeh MY, Fowlis GA, Singh M, Philp T. Transurethral electrovaporization of the prostate—a possible alternative to transurethral resection: a one-year follow-up of a prospective randomized trial. Br J Urol. 1998;81(5):721–5.
70. Hammadeh MY, Madaan S, Singh M, Philp T. A 3-year follow up of a prospective randomized trial comparing transurethral electrovaporization of the prostate with standard transurethral prostatectomy. BJU Int. 2000;86(6):648–51.
71. McAllister WJ, Karim O, Plail RO, Samra DR, Steggall MJ, Yang Q, Fowler CG. Transurethral electrovaporization of the prostate: is it any better than conventional transurethral resection of the prostate? BJU Int. 2003;91(3):211–4.
72. Fowler C, McAllister W, Plail R, Karim O, Yang Q. Randomized evaluation of alternative electrosur-

gical modalities to treat bladder outflow obstruction in men with benign prostatic hyperplasia. Health Technol Assess. 2005;9(4):iii–v, 1–30.
73. Nuhoğlu B, Ayyildiz A, Fidan V, Ersoy E, Huri E, Germiyanoğu C. Transurethral electrovaporization of the prostate: is it any better than standard transurethral prostatectomy? 5- year follow up. J Endourol. 2005;19(1):79–82.
74. Erdağı U, Akman RY, Sargin SY, Yazicioğlu A. Transurethral electrovaporization of the prostate versus transurethral resection of the prostate: a prospective randomized study. Arch Ital Urol Androl. 1999;71(3):125–30.
75. Yip SK, Chan NH, Chiu P, Lee KW, Ng CF. A randomized controlled trial comparing the efficacy of hybrid bipolar transurethral vaporization and resection of the prostate with bipolar transurethral resection of the prostate. J Endourol. 2011;25(12):1889–94.
76. Gupta N, Sivaramakrishna, Kumar R, Dogra PN, Seth A. Comparison of standard transurethral resection, transurethral vapour resection and holmium laser enucleation of the prostate for managing benign prostatic hyperplasia of >40 g. BJU Int. 2006;97(1):85–9.
77. Gupta NP, Doddamani D, Aron M, Hemal AK. Vapor resection: a good alternative to standard loop resection in the management of prostates >40 cc. J Endourol. 2002;16(10):767–71.
78. Helke C, Manseck A, Hakenberg OW, Wirth MP. Is transurethral vaporesection of the prostate better than standard transurethral resection? Eur Urol. 2001;39(5):551–7.
79. Küpeli S, Yilmaz E, Soygür T, Budak M. Randomized study of transurethral resection of the prostate and combined transurethral resection and vaporization of the prostate as a therapeutic alternative in men with benign prostatic hyperplasia. J Endourol. 2001;15(3):317–21.
80. Perk H, Serel TA, Koşar A, Hoşcan MB. Comparative early results of the sandwich technique and transurethral electroresection in benign prostatic hyperplasia. Prostate Cancer Prostatic Dis. 2001;4(4):242–4.
81. Bachmann A, Tubaro A, Barber N, d'Ancona F, Muir G, Witzsch U, et al. 180-W XPS GreenLight laser vaporisation versus transurethral resection of the prostate for the treatment of benign prostatic obstruction: 6- month safety and efficacy results of a European Multicentre Randomised Trial--the GOLIATH study. Eur Urol. 2014;65(5):931–42.
82. Bachmann A, Tubaro A, Barber N, d'Ancona F, Muir G, Witzsch U, et al. A European multicenter randomized noninferiority trial comparing 180 W GreenLight XPS laser vaporization and transurethral resection of the prostate for the treatment of benign prostatic obstruction: 12-month results of the GOLIATH study. J Urol. 2015;193(2):570–8.
83. Thomas JA, Tubaro A, Barber N, d'Ancona F, Muir G, Witzsch U, et al. A multicenter randomized noninferiority trial comparing GreenLight-XPS laser vaporization of the prostate and transurethral resection of the prostate for the treatment of benign prostatic obstruction: two-yr outcomes of the GOLIATH Study. Eur Urol. 2016;69(1):94–102.
84. Krambeck AE, Handa SE, Lingeman JE. Experience with more than 1,000 holmium laser prostate enucleations for benign prostatic hyperplasia. J Urol. 2013;189(1 Suppl):S141–5.
85. Kuntz RM, Ahyai S, Lehrich K, Fayad A. Transurethral holmium laser enucleation of the prostate versus transurethral electrocautery resection of the prostate: a randomized prospective trial in 200 patients. J Urol. 2004;172(3):1012–6.
86. Tan AH, Gilling PJ, Kennett KM, Frampton C, Westenberg AM, Fraundorfer MR. A randomized trial comparing holmium laser enucleation of the prostate with transurethral resection of the prostate for the treatment of bladder outlet obstruction secondary to benign prostatic hyperplasia in large glands (40 to 200 grams). J Urol. 2003;170(4 Pt 1):1270–4.
87. Montorsi F, Naspro R, Salonia A, Suardi N, Briganti A, Zanoni M, et al. Holmium laser enucleation versus transurethral resection of the prostate: results from a 2-center, prospective, randomized trial in patients with obstructive benign prostatic hyperplasia. J Urol. 2004;172(5 Part 1):1926–9.
88. Humphreys MR, Miller NL, Handa SE, Terry C, Munch LC, Lingeman JE. Holmium laser enucleation of the prostate--outcomes independent of prostate size? J Urol. 2008;180(6):2431–5. discussion 2435.
89. Kuntz RM, Lehrich K, Ahyai SA. Holmium laser enucleation of the prostate versus open prostatectomy for prostates greater than 100 grams: 5-year follow-up results of a randomised clinical trial. Eur Urol. 2008;53(1):160–6.
90. Naspro R, Suardi N, Salonia A, Scattoni V, Guazzoni G, Colombo R, et al. Holmium laser enucleation of the prostate versus open prostatectomy for prostates >70 g: 24-month follow-up. Eur Urol. 2006;50(3):563–8.
91. Moody JA, Lingeman JE. Holmium laser enucleation for prostate adenoma greater than 100 gm.: comparison to open prostatectomy. J Urol. 2001;165(2):459–62.
92. Kuntz RM. Current role of lasers in the treatment of benign prostatic hyperplasia (BPH). Eur Urol. 2006;49(6):961–9.
93. Varkarakis I, Kyriakakis Z, Delis A, Protogerou V, Deliveliotis C. Long-term results of open transvesical prostatectomy from a contemporary series of patients. Urology. 2004;64(2):306–10. Review.
94. Gratzke C, Schlenker B, Seitz M, Karl A, Hermanek P, Lack N, et al. Complications and early postoperative outcome after open prostatectomy in patients with benign prostatic enlargement: results of a prospective multicenter study. J Urol. 2007;177(4):1419–22.

95. Mariano MB, Graziottin TM, Tefilli MV. Laparoscopic prostatectomy with vascular control for benign prostatic hyperplasia. J Urol. 2002; 167(6):2528–9.
96. Lucca I, Shariat SF, Hofbauer SL, Klatte T. Outcomes of minimally invasive simple prostatectomy for benign prostatic hyperplasia: a systematic review and meta-analysis. World J Urol. 2015;33(4):563–70.
97. Goh MH, Kastner C, Khan S, Thomas P, Timoney AG. First experiences with the Spanner temporary prostatic stent for prostatic urethral obstruction. Urol Int. 2013;91(4):384–90.
98. Milroy EJ, Chapple CR, Cooper JE, Eldin A, Wallsten H, Seddon AM, Rowles PM. A new treatment for urethral strictures. Lancet. 1988;1(8600):1424–7.
99. Badlani GH, Press SM, Defalco A, Oesterling JE, Smith AD. Urolume endourethral prosthesis for the treatment of urethral stricture disease: long-term results of the North American Multicenter UroLume trial. Urology. 1995;45(5):846–56.
100. Poulsen AL, Schou J, Ovesen H, Nordling J. Memokath: a second generation of intraprostatic spirals. Br J Urol. 1993;72(3):331–4.
101. Duvdevani M, Chew BH, Denstedt JD. Urethral stents: review of technology and clinical applications. In: Baba S, Ono Y, editors. Interventional management of urological diseases, Recent advances in endourology, vol. 8. Springer Japan: Tokyo; 2006. p. 191–206.
102. Denmeade SR, Egerdie B, Steinhoff G, Merchant R, Abi-Habib R, Pommerville P. Phase 1 and 2 studies demonstrate the safety and efficacy of intraprostatic injection of PRX302 for the targeted treatment of lower urinary tract symptoms secondary to benign prostatic hyperplasia. Eur Urol. 2011;59(5):747–54.
103. Bishop CV, Liddell H, Ischia J, Paul E, Appu S, Frydenberg M, Pham T. Holmium laser enucleation of the prostate: comparison of immediate postoperative outcomes in patients with and without antithrombotic therapy. Curr Urol. 2013;7(1):28–33.
104. El Tayeb MM, Jacob JM, Bhojani N, Bammerlin E, Lingeman JE. Holmium laser enucleation of the prostate in patients requiring anticoagulation. J Endourol. 2016;30(7):805–9.
105. Rivera M, Krambeck A, Lingeman J. Holmium laser enucleation of the prostate in patients requiring anticoagulation. Curr Urol Rep. 2017;18(10):77. https://doi.org/10.1007/s11934-017-0727-2. Review.
106. Lee DJ, Rieken M, Halpern J, Zhao F, Pueschel H, Chughtai B, et al. Laser vaporization of the prostate with the 180-W XPS-Greenlight laser in patients with ongoing platelet aggregation inhibition and oral anticoagulation. Urology. 2016;91:167–73.
107. Woo HH, Hossack TA. Photoselective vaporization of the prostate with the 120-W lithium triborate laser in men taking coumadin. Urology. 2011;78(1):142–5.
108. Ruszat R, Wyler S, Forster T, Reich O, Stief CG, Gasser TC, et al. Safety and effectiveness of photoselective vaporization of the prostate (PVP) in patients on ongoing oral anticoagulation. Eur Urol. 2007;51(4):1031–8; discussion 1038–41.
109. Brassetti A, DE Nunzio C, Delongchamps NB, Fiori C, Porpiglia F, Tubaro A. Green light vaporization of the prostate: is it an adult technique? Minerva Urol Nefrol. 2017;69(2):109–18. Review.
110. Knapp GL, Chalasani V, Woo HH. Perioperative adverse events in patients on continued anticoagulation undergoing photoselective vaporisation of the prostate with the 180-W Greenlight lithium triborate laser. BJU Int. 2017;119(Suppl 5):33–8.
111. Culkin DJ, Exaire EJ, Green D, Soloway MS, Gross AJ, Desai MR, et al. Anticoagulation and antiplatelet therapy in urological practice: ICUD/AUA review paper. J Urol. 2014;192(4):1026–34. http://www.auanet.org/guidelines/anticoagulation-and-antiplatelet-therapy. Accessed 8 May 2019
112. Gilling P, Anderson P, Tan A. Aquablation of the prostate for symptomatic benign prostatic hyperplasia: 1-year results. J Urol. 2017;197(6):1565–72.
113. Carnevale FC, da Motta-Leal-Filho JM, Antunes AA, Baroni RH, Marcelino AS, Cerri LM, et al. Quality of life and clinical symptom improvement support prostatic artery embolization for patients with acute urinary retention caused by benign prostatic hyperplasia. J Vasc Interv Radiol. 2013;24(4):535–42.
114. Zumstein V, Betschart P, Vetterlein MW, Kluth LA, Hechelhammer L, Mordasini L, Engeler DS, Kessler TM, Schmid HP, Abt D, et al. Prostatic artery embolization versus standard surgical treatment for lower urinary tract symptoms secondary to benign prostatic hyperplasia: a systematic review and meta-analysis. Eur Urol Focus. 2018; https://doi.org/10.1016/j.euf.2018.09.005. pii: S2405-4569(18)30277-3. [Epub ahead of print].
115. Porpiglia F, Fiori C, Bertolo R, Giordano A, Checcucci E, Garrou D, et al. 3-Year follow-up of temporary implantable nitinol device implantation for the treatment of benign prostatic obstruction. BJU Int. 2018;122(1):106–12.

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