29 Robotic Pelvic Exenteration

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Introduction

Colorectal cancer is one of the most common causes of cancer death in the USA [1]. In addition, 15–20% of colorectal cancers present with adherence to or invasion of adjacent organs [2]. This is especially true for rectal cancer, since pelvic organs occupy the relatively narrow pelvic space around the rectum (e.g., anteriorly, urinary bladder, seminal vesicles, prostate, uterus, and vagina; posteriorly, sacrum, coccyx, sacral nerve roots, and piriformis muscle; and laterally, ureters, iliac vessels, obturator nerve, sacral plexus, sciatic nerve, and acetabulum (Fig. 29.1a, b)).

Locally advanced rectal cancers with local invasion of adjacent organs (T4) have significantly higher risk for positive resection margins and poorer oncologic outcomes [3, 4]. However, in selected patients, a curative intent treatment strategy can provide a chance for cure, better long-term oncologic outcomes, acceptable postoperative morbidity and mortality, and better quality of life [5, 6]. The curative intent treatment strategy includes two essential components: first, tailored pre-, intra-, and postoperative multimodality therapy including induction/consolidation chemotherapy, neoadjuvant long-course chemoradiation therapy, intraoperative radiation therapy, and adjuvant chemotherapy; second, oncologic surgical resection to achieve histologically negative resection margins (R0) and adequate lymph node removal. To this end, en bloc multivisceral organ resection or pelvic exenteration is usually needed for T4 rectal cancers [7, 8]. Pelvic exenteration is a technically demanding procedure, in which the dissection planes are wider than that for standard total mesorectal excision (TME) (Fig. 29.2). However, exenteration

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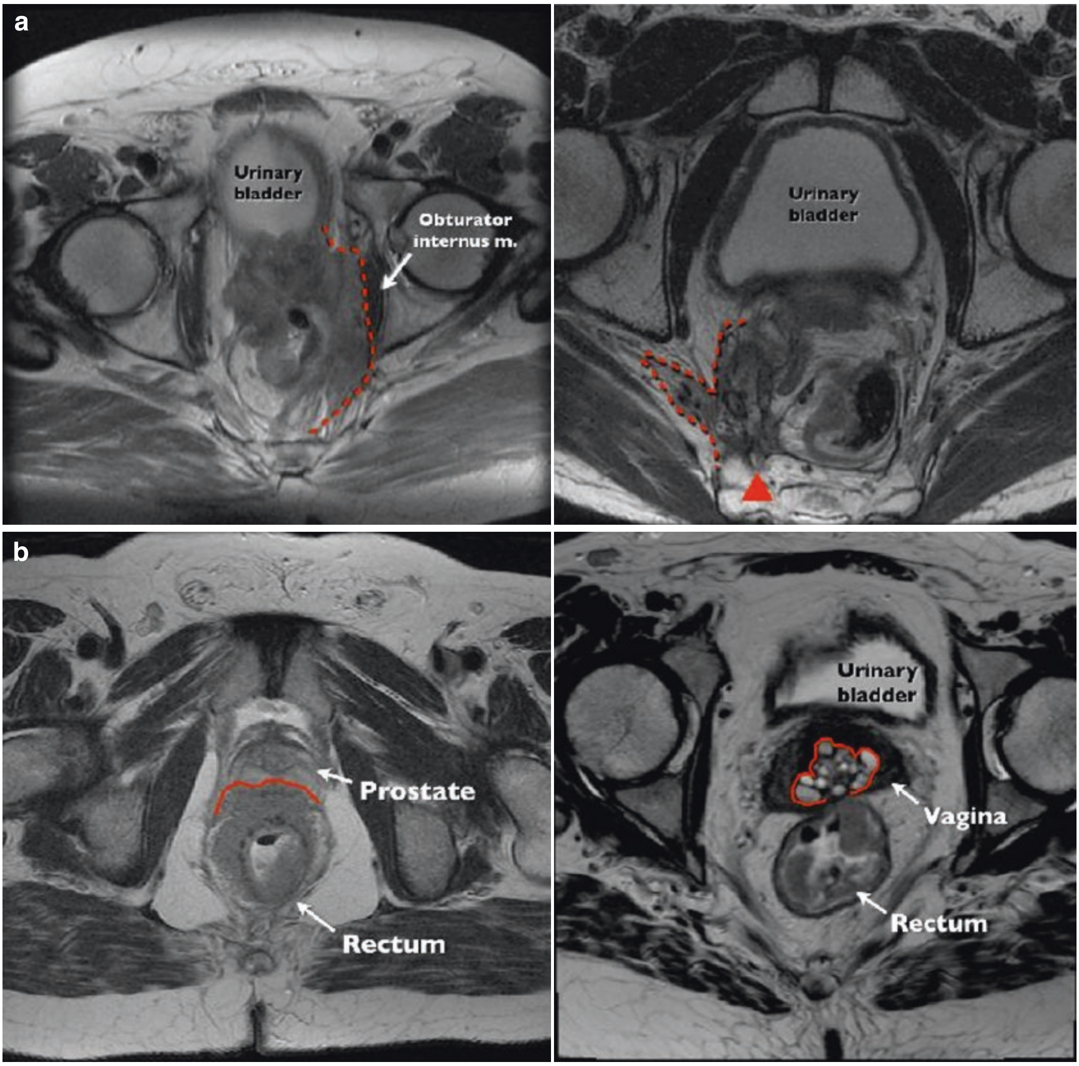

Fig. 29.1 (**a**) Examples of magnetic resonance imaging (MRI) demonstrate tumors that are not suitable for the robotic approach with regard to invasion into the lateral compartment (red broken line) and sacral nerve root (red arrow head). (**b**) Examples of MRI demonstrate tumors that are suitable for the robotic approach. The solid red line indicates location of central invasion to the prostate and vagina

can be accomplished successfully with acceptable outcomes in selected patients using a multidisciplinary team approach (including colorectal surgical oncologists, urologists, plastic surgeons, vascular surgeons, and neurosurgery/orthopedics) [9–11].

Although the feasibility of a laparoscopic approach for T4 rectal cancers has been recently reported [12–15], some studies have also demonstrated a significantly higher positive circumferential resection margin rate for laparoscopic surgery when compared to open surgery for locally advanced rectal cancer [16]. In fact, extension of rectal cancer beyond the TME plane is a major reason for conversion from laparoscopic to open surgery [17–19]. The higher conversion rate is also associated with poorer short-term and long-term oncologic outcomes [20, 21]. Therefore, the applicability of laparoscopic surgery for T4 rectal cancer remains controversial [22]. The potential benefits from a minimally invasive approach have to be weighed against the risk of having positive resection margins that compromise oncologic outcomes.

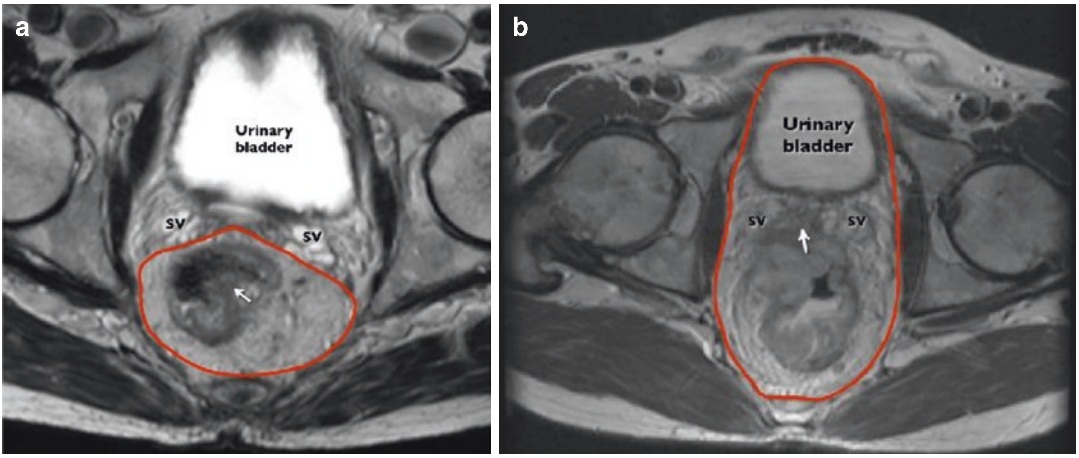

Fig. 29.2 (**a**) Magnetic resonance imaging demonstrates the standard total mesorectal excision (TME) plane. The red line shows the standard TME plane around the fascia propia of the rectum. The arrow points to the tumor that is confined within the TME plane. (**b**) MRI demonstrates extension beyond the standard TME plane (red line) with the arrow showing anterior invasion to the seminal vesicle. SV, seminal vesicle

There has been significant growth in the use of robotic surgery for rectal cancer worldwide. Emerging data appears to support the feasibility of robotic surgery for T4 rectal cancers with comparable short-term oncologic outcomes [23–26]. The advantages of robotic surgery over conventional laparoscopic surgery include better pelvic visualization by 3-D adjustable cameras and more degrees of freedom with wrist-articulated instrumentation, thus achieving more precise dissections. These benefits may compensate for some of the limitations of conventional laparoscopic surgery, especially during complex pelvic dissection. In carefully selected cases, the robotic approach may expand our ability to offer minimally invasive surgery to this subset of locally advanced rectal cancer patients. In this chapter, we clarify a step-by-step approach of robotic pelvic exenteration for T4 rectal cancers.

Patient Selection and Preoperative Preparation

This is a crucial step for any surgical procedure, but it is particularly important when extending the indications for this procedure. As a matter of principle, the indications for pelvic exenteration must be met before considering a robotic approach. Relative contraindications for pelvic exenteration for rectal cancer include high sacral/lateral bone involvement, distant/peritoneal metastasis, sciatic nerve or lateral compartment involvement beyond the vascular plane, encasement of common or external iliac vessels, common iliac or retroperitoneal lymph node metastases, and multifocal disease. Once the indication for pelvic exenteration has been established, three factors should be carefully examined when considering the robotic approach for pelvic exenteration.

Patient Factors

Beyond the common assessments of patient fitness for surgery and extent of previous abdominal surgery, specific anatomic considerations for these procedures must be evaluated. For example, flap closure of an exenteration defect may necessitate extensive abdominal wall tissue harvest, which would negate any potential benefit from smaller incisions for dissection. This can depend on patient body size and availability of other sites for tissue harvest and should be discussed with the involved plastic surgery service. In addition, the primary surgeon should thoroughly explain to the patient (as part of the informed consent process) the evidence for the robotic approach and potential benefits and limitations of this approach. Both patient and family expectations should be clarified.

Tumor Factors

The presence of distant disease should be ruled out with cross-sectional imaging with computed tomography (CT) and positron emission tomography (PET) scans as needed, and high-resolution magnetic resonance imaging (MRI) is needed to assess local resectability. The most appropriate tumors are those with central pelvic extension (e.g., prostate, vagina, uterus, urinary bladder, or limited lateral extension) and those with a single direction of extension. In contrast, very bulky tumors will limit the ability to retract and provide exposure around the tumor and are not good candidates for the robotic approach (Table 29.1, Fig. 29.1). However, the need for an extravascular approach is not an absolute contraindication.

Surgeon Factors

The primary rectal surgeon should have abundant experience with robotic rectal surgery prior to attempting robotic pelvic exenteration. In addition, every surgeon in the multi-surgical specialist team should be consulted with advanced notice to ensure that the indication is acceptable and the required expertise is available.

Table 29.1 Favorable and unfavorable factors for robotic exenteration

Favorable factors for robotic approach	Unfavorable factors for robotic approach
Central pelvic extension	Lateral compartment involvement beyond the vascular plane
Anterior invasion (e.g., prostate, vagina, uterus, or urinary bladder) Limited lateral/posterior extension	Encasement of iliac vessels High sacral bone involvement
Tumor with one direction of extension	Tumor with more than one direction of extension
Less bulky, mobile tumor	Bulky tumor with limited mobility
Good response to preoperative treatment	

Operating Room Setting

Setting up the operating room to allow sufficient free space between the robotic system and surrounding instruments is important. As with any robotic procedure, interference between the operating table, consoles, patient cart, and monitors should be avoided, as contamination or prolonged docking times may occur. In fact, a well-trained scrub nurse and assistant surgeon share critical roles in facilitating the operation and providing them a comfortable working space will facilitate surgical work flow. Figure 29.3a demonstrates the example of a room setting for robotic pelvic exenteration.

Because of the procedure's length and complexity, anesthesia setup is another core requirement to ensure patient safety. The anesthesiologist needs to participate in decisions around patient positioning and access during the operation. This is particularly true for robotic cases without a synchronized moveable table, as patient position is difficult to change during surgery unless the robotic system is undocked. Arterial lines, intravenous access, and noninvasive monitoring devices should be protected from dislodgement or blockage and tested for function prior to robotic cart docking.

Patient Position

Patient position should be optimized before the docking process is undertaken. First, the patient should be positioned in lithotomy on a nonslip surface with the pelvis low enough on the table to provide coccyx accessibility. Both arms should be wrapped by the patient's side, while placing adequate padding around weight-bearing or prominent areas to avoid compression and nerve injury (Fig. 29.3b) [27]. Further strapping is required to secure the patient on the table because any accidental movement after docking could result in injury since the robotic arms are relatively fixed. Once the above is confirmed, right-side down Trendelenburg position is the position of choice, aiming to clear the small bowel out of the pelvis and retroperitoneal vascular pedicles. Only enough tilt as needed for exposure should be applied, taking care to avoid any extremes in positioning, particularly given the potential for prolonged surgery. Once enough exposure is obtained, the steepness of right-side down and Trendelenburg tilt should be reduced as much as possible.

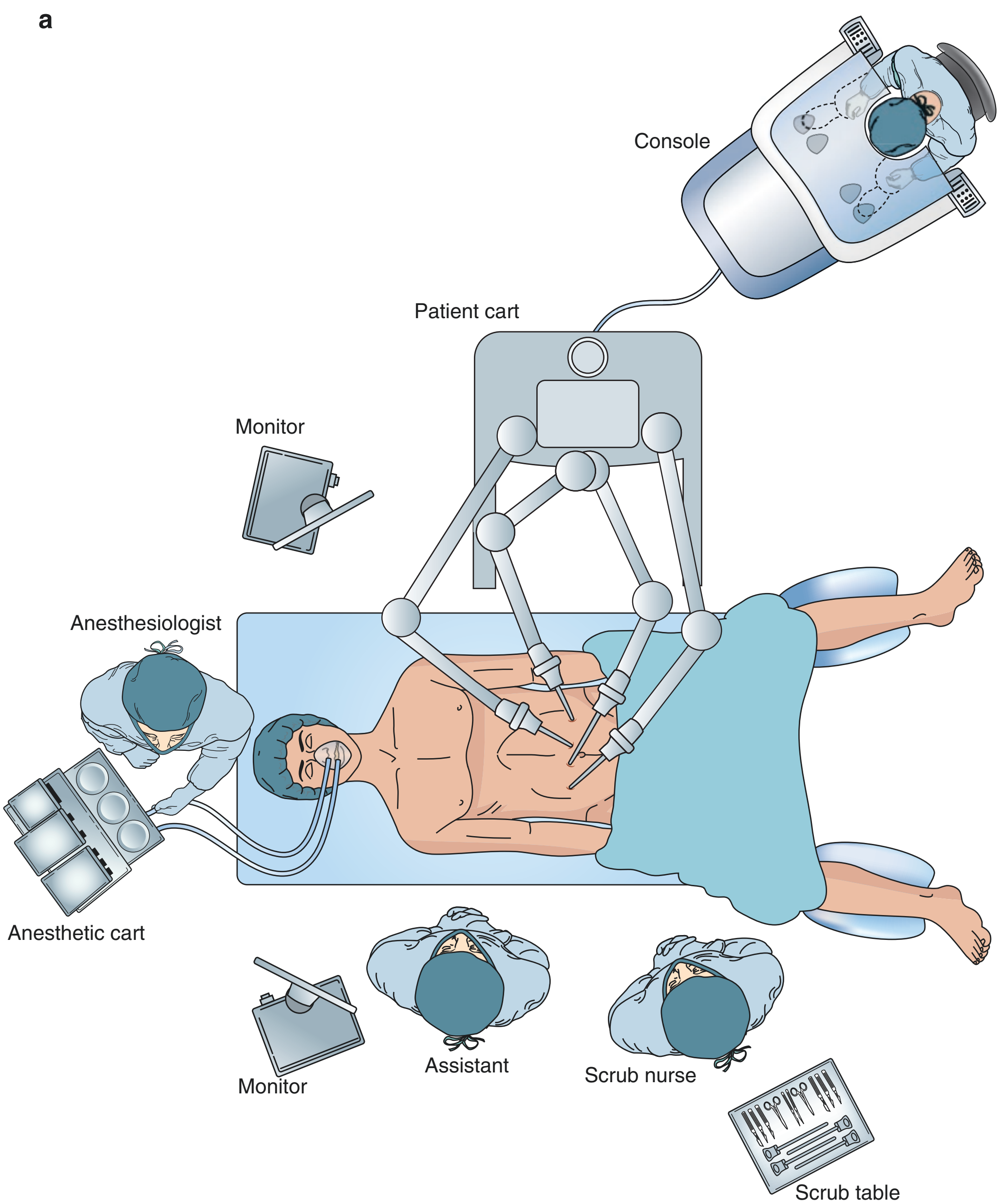

Fig. 29.3 (**a**) Robotic setup (daVinci Xi platform) for pelvic exenteration. The boom is rotated and robotic arms are set up oriented for pelvic surgery. (**b**) Patient positioning with adequate padding around weight-bearing and prominent areas to avoid compression and nerve injury

Fig. 29.3 (continued)

Port Placement

Appropriate port placement aimed to maximize space and freedom of motion between the robotic arms is desirable. This can avoid not only internal collision of instruments but also external collision of bulky robotic arms, while improving instrument reach. We recommend linear placement of the ports optimized for pelvic surgery as seen in Fig. 29.4. The camera port is placed immediately superior to the umbilicus. Two robotic working ports are placed to the right and left at the same horizontal level as the umbilicus, at least 8 cm away from camera port. A third robotic arm port is placed supero-medial to the left anterior-superior iliac spine (ASIS). One conventional laparoscopic assistant port is placed at the right lateral abdomen, and one 5-mm port in the right upper quadrant may facilitate retraction and suction by the surgical assistant. Port placement should be subtly adjusted depending on the patient's body

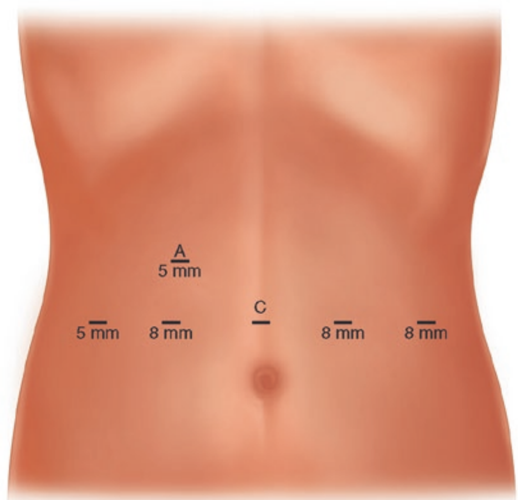

Fig. 29.4 Trocar/port placement for robotic total pelvic exenteration with the Xi platform. C, camera; 8-mm robotic ports; 5-mm laparoscopic assistant port to facilitate retraction and suction

habitus but should consider principles to maximize instrument clearance while optimally positioning for the primary target.

Robot and Assistants

The daVinci Xi robot is docked from the patient's left hip with the boom rotated to target the pelvis with the main robot tower and screen over the patient's left shoulder. The daVinci Si robot is docked with the cart between the legs. Both the scrub nurse and surgical bedside assistant stand on the patient's right side for the duration of the robotic dissection.

Surgical Approach

First Steps

Any oncological abdominal operation begins with diagnostic exploration. In this setting, careful inspection is performed to assess the resectability of the disease, as well as contraindications for pelvic exenteration. In particular, peritoneal carcinomatosis or small-volume distant metastatic disease that could not be detected on preoperative imaging studies should be actively sought. If the decision is made to proceed, optimizing the surgical exposure by elevating the omentum and transverse colon over the liver to uncover the small bowel is performed. The small bowel is then subsequently reflected to the right upper abdominal quadrant and out of the pelvis. Gravity is used to hold the small bowel in place often with the assistance of a small gauze sponge which is carefully positioned at the right lower quadrant along the ileal mesentery. The bedside assistant can gently press down on the gauze sponge with a laparoscopic instrument to stop the small bowel from falling down into the pelvic cavity.

Medial Colonic Dissection

Dissection begins by using the assistant robotic arm (arm #4) to retract the rectosigmoid colon laterally and out of the pelvis and by using the left working robotic arm (arm #3) to tent the peritoneum and create appropriate tension at the base of the superior rectal artery (Fig. 29.5a). Then, the peritoneum is scored along the right side of the base of the mesosigmoid over the sacral promontory (Fig. 29.5b, c). At this point, the assistant can help to tent the mesocolon up, providing a triangular force vector as needed to aid exposure of the dissection plane. The dissection will be subsequently performed along the retrovascular mesocolic plane in a medial to lateral fashion (Fig. 29.5d) until the lateral peritoneal reflection is reached. The hypogastric nerve plexus, ureter, and gonadal vessel are identified and preserved (Fig. 29.5e).

Division of the Inferior Mesenteric Artery

There are multiple options available to manage the inferior mesenteric artery (IMA). Routine low ligation of the superior rectal artery (ligation below the left colic artery take-off) with complete D3 IMA lymph node dissection is our standard approach [28]. The high ligation technique (ligation proximal to the left colic artery take off) provides better length for colorectal or coloanal anastomosis, but this is usually not required in exenteration surgery. To identify the origin of the IMA, the dissection should continue proximally in the same plane as the medial to lateral dissection until the junction with the aorta is identified. Our preference is to divide between locking clips.

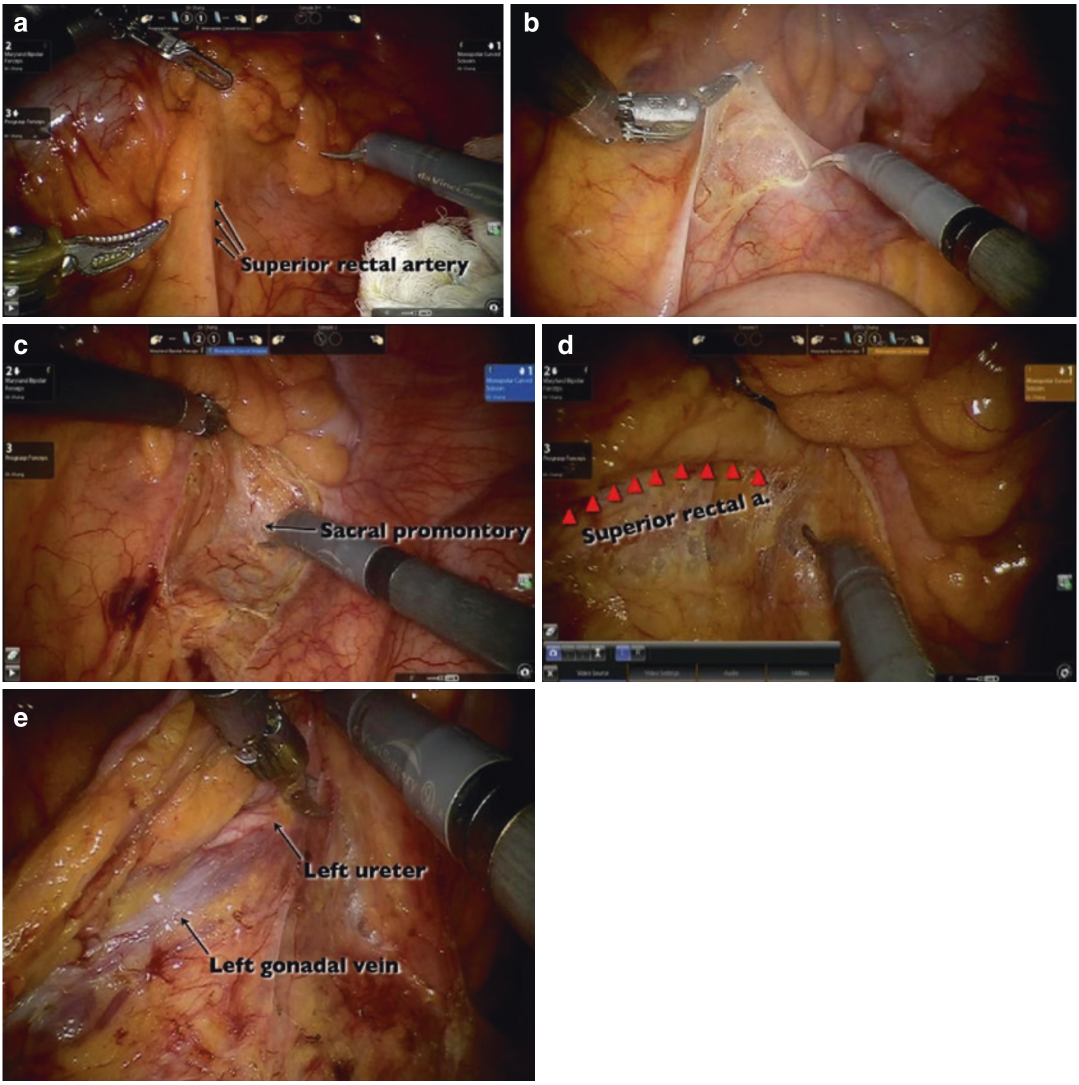

Fig. 29.5 (**a**) Intraoperative image demonstrating the left working robotic arm tenting the peritoneum and creating appropriate tension at the base of the superior rectal artery to expose its vascular pedicle. The arrows indicated the tented peritoneum at the base of the superior rectal artery. (**b**) Image showing the peritoneum dissected along the right side of the base of the mesosigmoid over the sacral promontory. (**c**) Image showing dissection over the sacral promontory. The arrow indicates the sacral promontory. (**d**) Image shows the dissection performed along the avascular plane just below the superior rectal artery. The red arrowheads indicate the inferior border of the superior rectal artery. (**e**) Image shows the dissection performed along the retrovascular mesocolic plane in a medial to lateral fashion, until the lateral peritoneal reflection is reached. The arrows indicate the ureter and gonadal vessel which are identified and preserved

Division of the Inferior Mesenteric Vein

Since most patients will undergo end colostomy formation, the inferior mesenteric vein (IMV) can be divided at the same level as the IMA or superior rectal artery. If a modified exenteration with sphincter-preserving reconstruction is performed, high ligation of the IMV at the inferior border of the pancreas aiming for colonic lengthening may be required. This sometimes requires re-docking the robot with orientation cephalad to mobilize the splenic flexure (see below).

Lateral Colonic Dissection

Lateral dissection is performed to mobilize the sigmoid and descending colon attachments, ultimately meeting the previously completed medial dissection plane along the mesocolon. Mobilization of the splenic flexure is not necessary unless sphincter preservation is planned, but can be performed after robotic re-docking as described above.

Posterior Pelvic Dissection

It is very important to assess tumor location on preoperative imaging and correlate anatomic landmarks with the area of tumor invasion to determine the extent of dissection and to avoid inadvertent tumor violation or unnecessary organ injury. It is appropriate to begin the posterior dissection at the sacral promontory which is the easiest location to find the plane. The conventional posterior dissection plane is between the fascia propria of the rectum and presacral fascia. However, if the tumor is close to the posterior surgical margin, the dissection plane should be taken deeper (between the presacral fascia and sacral periosteum/presacral veins) (Fig. 29.6). For tumors that directly invade the sacral bone, the posterior dissection has to be stopped before reaching the invasion area, and well-planned sacrectomy should be performed to remove the tumor *en bloc*.

Lateral Pelvic Dissection

The lateral pelvic dissection plane for pelvic exenteration may be wider than the usual TME plane depending on the clearance required (Fig. 29.2). Detailed understanding of lateral pelvic compartment anatomy is crucial. In particular, the relationship between the internal iliac vessels, obturator nerve, sacral nerve root, piriformis muscle, spinous process, and the sciatic notch should be clear. Large bulky tumors with significant lateral extension can pose significant difficulty for exposure and are not good candidates for the robotic approach.

In order to facilitate rectal retraction, a gauze is tied around the rectosigmoid junction, and this is retracted cephalad and laterally using the assistant's locking grasper. Next, the right lateral pelvic parietal peritoneum is opened just proximal to the sacral promontory area (Fig. 29.7), and the right ureter is identified

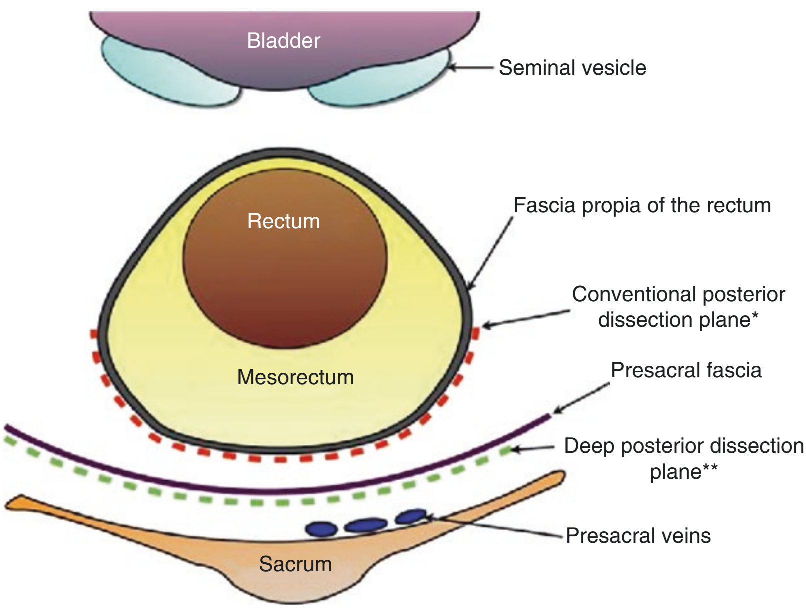

Fig. 29.6 Illustration of the posterior dissection plane. The red broken line shows the conventional posterior dissection plane or total mesorectal excision plane, which is between the fascia propria of the rectum and presacral fascia. The green broken line shows the deep posterior dissection plane. If the tumor is close to the posterior surgical margin, the dissection plane should be taken deeper between presacral fascia and sacral periosteum/presacral veins

underneath. When scoring the lateral pelvic parietal peritoneum laterally, the vas deferens or round ligament is identified, ligated, and divided (Fig. 29.8). The ureter accompanied with meso-ureter is then isolated and mobilized distally until the ureterovesical junction is reached (or as far distal as possible). If there is direct tumor invasion into the ureter, ureteric isolation should be stopped proximal to the area of invasion in order to preserve an adequate resection margin.

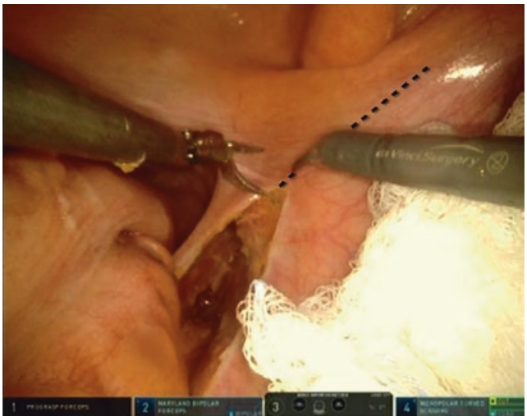

Fig. 29.7 Intraoperative image showing right lateral pelvic parietal peritoneum is opened just proximal to the sacral promontory area. Then the right ureter and vas deferens or round ligament will be identified underneath. The broken line indicates the scored line of the lateral pelvic parietal peritoneum laterally

Next, robotic arm 4 is used to retract the ureter medially, while at the same time, the assistant's grasper or suction instrument is used to gently push on the external iliac vessels laterally. This facilitates opening the lateral pelvic dissection plane. The dissection continues into this plane, and if required, internal iliac artery branches can be individually identified and selectively ligated and divided (Fig. 29.9a). If the tumor invades the central pelvic compartment in isolation, then only distal branches of the internal iliac artery are ligated (superior vesicle branches, posterior vesicle branches, middle rectal artery, and uterine vessels) (Fig. 29.9b). In contrast, if the tumors invade the lateral compartment, more proximal internal iliac branches may need to be ligated (origin of internal iliac artery, origin of anterior/posterior division, and superior/inferior gluteal artery) (Fig. 29.9c). However, lateral compartment invasion with a bulky tumor will limit adequate exposure for distal dissection and may be a contraindication for the minimally invasive approach.

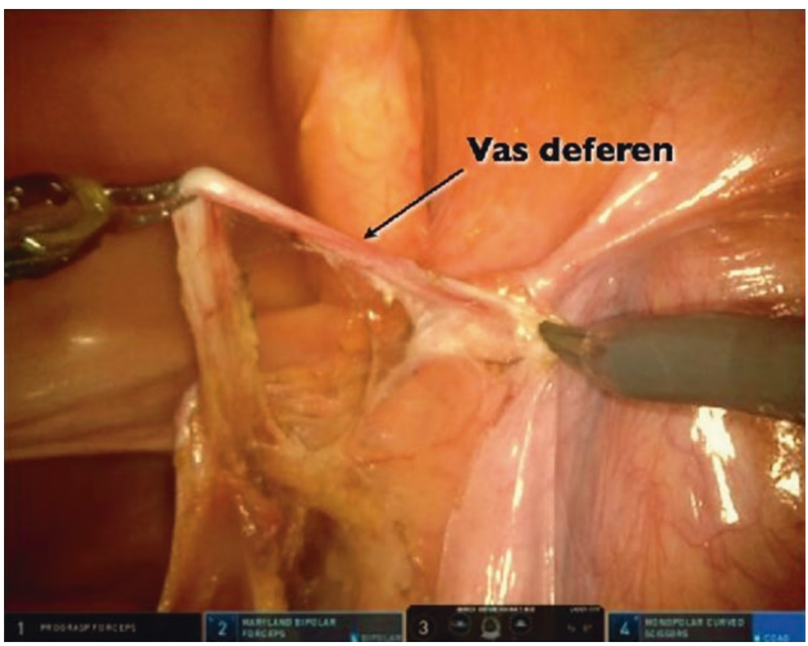

Fig. 29.8 Intraoperative image demonstrating identification of the vas deferens during scoring of the lateral pelvic parietal peritoneum

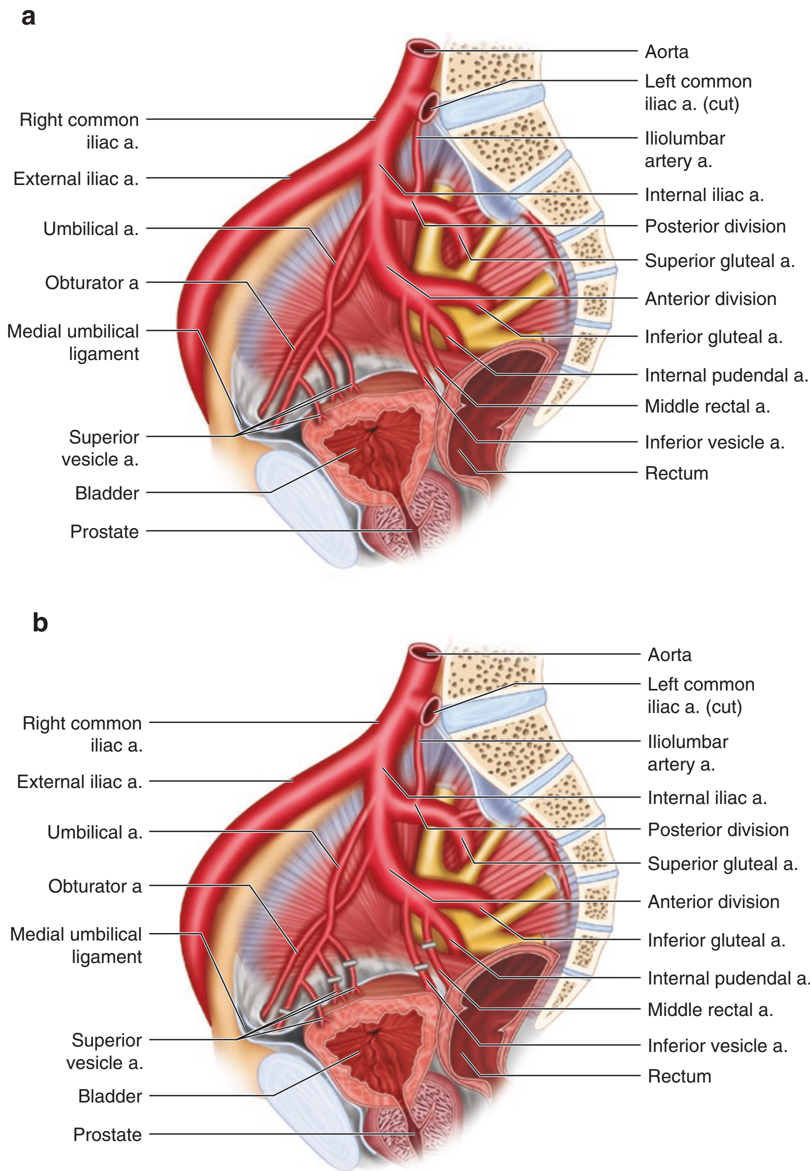

Fig. 29.9 (**a**) Illustration showing the branches of the internal iliac artery. During dissection into the lateral pelvic dissection plane, internal iliac artery branches can be individually identified, and selectively ligated, if required. (**b**) Illustration showing ligation of individual branches of the internal iliac artery in the event of tumor in the central compartment. The white lines indicate ligation of the distal branches of the internal iliac artery (i.e., superior vesicle branches, posterior vesicle branches, middle rectal artery, and uterine vessels). (**c**) Illustration showing ligation of the individual branches of the internal iliac artery in the event that tumor invades the lateral compartment. The white lines indicate ligation of more proximal internal iliac branches (i.e., origin of internal iliac artery, origin of anterior/posterior division, and superior/inferior gluteal artery)

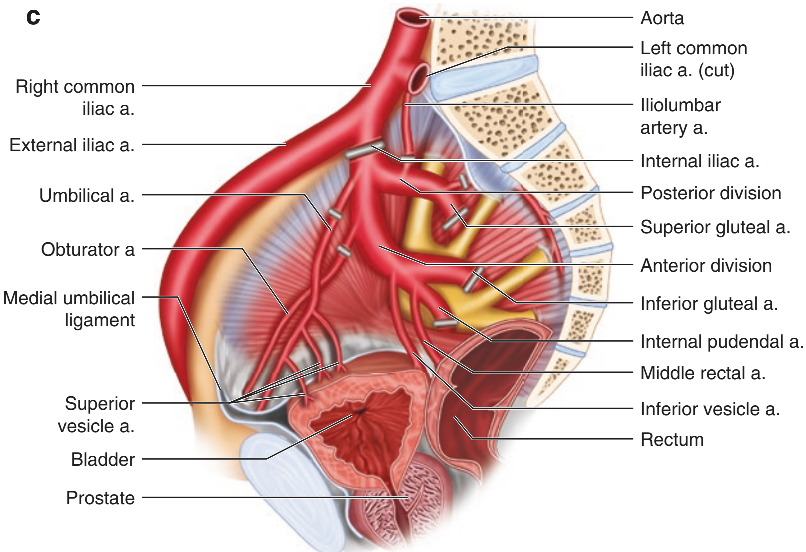

Fig. 29.3 (continued)

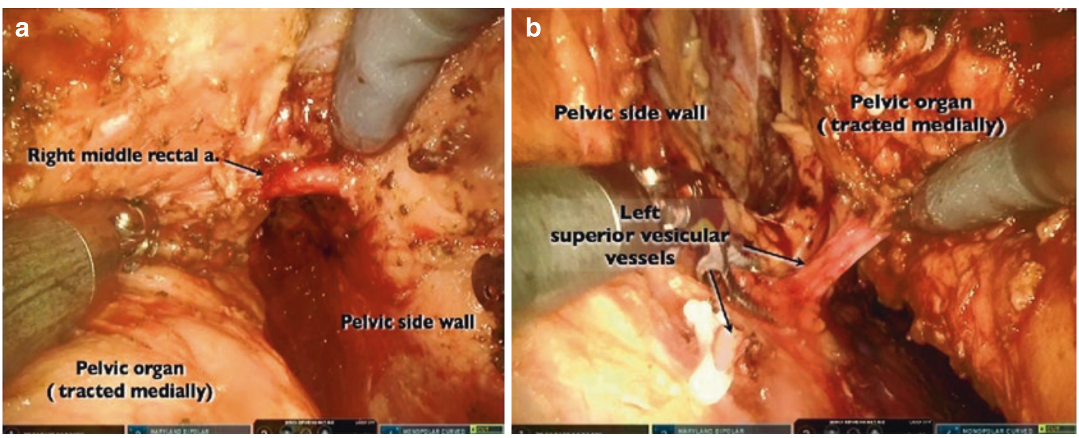

Fig. 29.10 (**a**) Intraoperative image shows individual ligation of the right internal iliac vessel branch. To open the right lateral pelvic dissection plane, the assistant's grasper or suction instrument retracts the pelvic side wall laterally and robotic arm 4 retracts the pelvic organ medially. The arrow indicates the right middle rectal artery. (**b**) Intraoperative image shows individual ligation of the left internal iliac vessel branches. To open the left lateral pelvic dissection plane, the assistant's grasper retracts the pelvic organ medially and robotic arm 4 retracts the pelvic side wall laterally. The arrow indicates superior vesicular vessels

Individual ligation of internal iliac venous tributaries can also be performed. These venous tributaries exhibit significant variation, low pressure, and high flow and are easily disrupted. Thus, slow meticulous dissection is very important at this step, otherwise massive bleeding can ensue obscuring the view for further dissection. The obturator nerve and vessels should be identified laterally and preserved unless invaded by tumor. Completing as much dissection as possible from the right side facilitates not only the dissection on the left side but also deep posterior dissection. Left side dissection is then performed in the same fashion as the right side dissection (Fig. 29.10a, b). The dissection continues circumferentially until the pelvic floor is reached posteriorly and bilaterally. At this point, the pelvic floor can be divided to enter the ischioanal fossa.

Retzius Space Dissection

Once the deep posterior and lateral dissections are complete, dissection is then performed in the plane anterior to the bladder. Cephalad-midline rectal traction by the assistant's grasper will again facilitate this dissection. The dissection continues down into the space of Retzius, after which the urethra is identified and transected. Suture ligature of the dorsal venous complex using a barbed suture can facilitate hemostasis during this step. The Foley catheter is then removed. In select supra-levator exenteration cases, rectal transection can be performed using an articulated laparoscopic stapler and colorectal or coloanal anastomosis can be performed at a later step. Then, the mesentery of the proximal colon is divided, and the proximal colon is transected by a laparoscopic or robotic stapler.

Perineal Dissection

In cases where an anastomosis is not possible, the perineal dissection can be performed in either lithotomy or prone jack-knife position. However, in patients who need additional sacrectomy x, prone jack-knife position may be required. The anus is closed by a purse-string suture to prevent perineal wound contamination. Perineal skin incision, as well as the ischioanal fat and pelvic floor dissection, is performed in the same fashion as abdominoperineal resection. However, in patients who need additional sacrectomy, the incision can be extended over the sacral area. The specimen is then retrieved through the perineal wound. A sponge is inserted to occlude the defect and pneumoperitoneum can then be re-established.

Pelvic Floor and Perineal Reconstruction

The residual pelvic cavity is a fixed space generally within an irradiated field, and there are three main issues that need to be addressed after specimen removal. First, to prevent perineal herniation (especially after additional sacrectomy) and potential small bowel obstruction, the pelvic inlet needs to be occluded. Second, the pelvic space beneath this area must be filled to guard against pelvic collections above the perineal skin repair. Third, reconstruction of the large perineal or vaginal defect is required recognizing that most of these patients have irradiated soft tissues that are prone to delayed wound healing.

There are several options available to deal with these three issues with inherent advantages and disadvantages. Detailed discussion of these issues is beyond the scope of this chapter. Briefly, an omental flap can be used to partially fill pelvic dead space and close the pelvic inlet but cannot restore the perineal defect. In low body mass index patients, the omentum is usually short and not sufficient. The vertical rectus abdominis muscle (VRAM) flap is able to fill the pelvic dead space and reconstruct the large perineal defect. However, the VRAM flap requires a large abdominal wall incision which needs to be reconstructed, with careful siting of the colostomy or the ileal conduit stoma. We generally prefer robotic-assisted VRAM flap or gluteal advancement flap in combination with omental flap support owing to its robustness and minimally invasive benefits [29]. Gluteal myocutaneous flaps, gracilis flaps, and posterior and anterior thigh flaps are helpful for perineal reconstruction but cannot close the pelvic inlet or fill the pelvic dead space. Nevertheless, they can be vitally useful in cases with larger perineal skin defects where additional skin is required. Free flaps are rarely needed but should be available in the armamentarium of the team.

Urinary and Colonic Reconstruction

An ileal conduit can be constructed intracorporeally by the robotic approach or extracorporeally via Pfannenstiel or low midline incision. Finally, an end colostomy is performed.

Complications

Complication rates of open pelvic exenteration have been consistently reported to be around 40% [30]. While there may be some potential gains from the robotic approach in terms of abdominal wound morbidity, this remains to be demonstrated and it is likely that major complication rates will not be influenced. Regardless of the approach, earlier detection of major complications with prompt rescue in an experienced unit is a vital component of the postoperative care of these patients.

Intraoperatively, major hemorrhage, while rare, is the most immediate life-threatening complication. The lateral pelvic sidewall vasculature and dorsal venous complex are the most common sites of troublesome bleeding during surgery. Prevention is the goal, and a detailed understanding of the anatomy of internal iliac branches and their possible variations is important. Meticulous dissection and utilization of appropriate energy devices, vascular clips, and adherence to vascular principles are key. Early conversion to open surgery while maintaining pressure on bleeding vessels should be performed in the event bleeding cannot be controlled robotically. However, the pneumoperitoneum should be maintained as long as possible during conversion to reduce bleeding complications. Bleeding from the dorsal venous complex during anterior dissection can be reduced by dissection close to the periosteum of pubic bone, as well as prophylactic suturing prior to division.

Postoperative complications such as anastomotic leak, urine leak, infected pelvic collection, and wound or flap failures are all possible as they are with open surgery. This is particularly true in patients who have some degree of underlying malnutrition which may affect wound healing. Appropriate pelvic drain placement be helpful in early control of urine leak issues and prevention of perineal wound failure due to serous fluid discharge. Early detection of urine leakage can be achieved by examining the creatinine level from the drainage fluid. Prompt management such as nephrostomy, ureteric stent, adequate drainage, or reoperation is required. A variety of operations exist for perineal wound complications such as vacuum-assisted suction dressing and debridement as required. The main aim of complication management is to facilitate patient recovery and to avoid potential delays to adjuvant therapy.

Conclusions

In highly selected patients, robotic pelvic exenteration is a feasible procedure which may provide some short-term benefits in eligible patients with locally advanced pelvic tumors. The principles of dissection, vascular control, reconstruction, and recovery are very similar to the open approach. This procedure should only be undertaken in centers experienced with both exenterative and robotic surgery.

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