Visceral and Gastrointestinal Complications of Laparoscopic and Robotic Urologic Surgery

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Keywords Injury · Complications · Bowel injury · Laparoscopy · Robotics

Introduction

The first laparoscopic procedures for urologic surgery were radical nephrectomy and a pelvic lymph node dissection for prostate cancer staging performed in 1991 [1, 2]. Since that time, laparoscopic and robot-assisted procedures have become commonplace in urologic surgery. Unfortunately, many different complications are seen in all types of laparoscopic and robot-assisted laparoscopic surgery. The focus of this chapter is on bowel and solid organ complications. Overall, bowel complications have been estimated to be 1.3/1,000 laparoscopic cases [3].

Patient Selection

Patients who have had intraperitoneal surgery are at an increased risk of forming intra-abdominal adhesions [4]. Although the presence of intraperitoneal adhesions can be daunting and add time to the procedure, there is no evidence that there is an increased incidence of bowel complications in patients undergoing laparoscopic or robot-assisted surgery. Several studies have shown that there is no increase in bowel complications in patients with previous abdominal surgery undergoing laparoscopic surgery compared with a controlled group that had not [5, 6]. Recently, Nazemi et al. evaluated this question and have shown that there is no increase in complications in patients undergoing robotic surgery who had undergone previous abdominal surgery compared with a controlled group that had not.

Anesthesia

An oro- or nasogastric tube is routinely placed to avoid bowel distention, especially during procedures involving the upper urinary tracts. Nitrous oxide is a useful inhalational anesthetic because of its analgesic effect, low cost, rapid onset of action, and ability to reduce the concentration of other anesthetic agents that may cause cardiorespiratory depression [7]. Unfortunately, the use of nitrous oxide is discouraged in laparoscopic and robotic surgery due to bowel distention, which can obscure the operative field. El-Galley et al. reported in a series of patients undergoing laparoscopic donor nephrectomy that 50% of the patients in the NO_2 group developed mild to moderate bowel distention compared to 6% in the control group. Furthermore, 25% of the NO_2 group developed severe bowel distention compared to 6% in the control group. Although there were no complications in either group, severe bowel distention may increase the risk of bowel injury and may increase post-operative bowel recovery. Accrual in this study was halted due to these findings [8].

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Bowel Complications Associated with Access

Access to the peritoneal cavity or the retro/extraperitoneal space and insufflation is necessary to create a working space for laparoscopic and robotic surgery. There are several techniques that are used to gain access to the peritoneum and retroperitoneum, including Veress needle placement, the Hasson entry, direct trocar entry, and the STEP procedure (the rapidly expanding access system). Complications associated with access include minor complications such as extraperitoneal or subcutaneous insufflation and minor skin or subcutaneous bleeding. Major complications include vascular injury, gastrointestinal injury, ureteral or bladder injury, solid organ injury, and gas embolism. Major complications are rare and have been well studied. A meta-analysis of access techniques found bowel injuries to occur in 0.18% of cases and vascular injuries to occur in 0.09% of cases [9].

The Veress needle approach is one of the most common access techniques used. The Veress needle is a blunt needle with a spring-loaded obturator. The Veress needle is placed blindly into the peritoneal cavity. The needle is most often placed either infra- or supra-umbilically. The skin and subcutaneous tissue may be lifted with penetrating towel clips or a suture in order to create tension on the skin and create some distance between the bowel/vasculature and the peritoneal cavity. Once the Veress needle is placed, a saline drop test is performed. A 5 cc syringe half-filled with sterile normal saline is placed on the Veress needle and the contents are aspirated to check for succus or blood. If nothing is aspirated, the sterile saline is irrigated into the cavity. If this freely irrigates into the cavity, then peritoneal placement is likely. The abdomen is then insufflated with CO_2. If the placement is correct, then the initial intra-abdominal pressure should be low – less than 9 mmHg. This may be higher in morbidly obese patients where the pannus increases baseline intra-abdominal pressure. High initial pressures in a patient with a normal BMI indicate incorrect placement of the Veress needle. This is most likely subcutaneous or extraperitoneal placement. If blood returns when aspirating the drop test syringe, the Veress needle is removed and replaced until placed correctly. The vasculature and bowel mesentery is then checked for active bleeding or hematoma. If succus returns after aspiration, the needle is removed without using any torque and replaced correctly. The area of injury is inspected. If there are no obvious enterotomies with spillage of succus, the injury may be treated conservatively and the case may proceed. If there is a large injury or spillage of succus, the injury must be repaired, either in a laparoscopic or in an open fashion. Failure of the syringe to irrigate easily suggests subcutaneous or extraperitoneal placement of the Veress needle and replacement until a positive saline drop test occurs must be performed. To avoid failures, the Veress needle should be placed away from any areas of previous surgery. Paramedian (lateral to the rectus muscles) and right and left upper quadrant placements are acceptable as a primary placement or a secondary placement when midline or periumbilical scars are present.

The Hasson technique was developed in 1971 as a safe way to gain entrance to the peritoneal cavity [10]. Generally, a 10–12 mm skin incision is made through the skin and subcutaneous tissue until the fascia is encountered. A fascial closing suture may then be placed in a longitudinal fashion on either side of the proposed site of the incision and the incision is then made. The sutures have the dual purpose of lifting the fascia away from the peritoneal catheter and as preplaced fascial closure sutures. Once the fascia has been opened, the peritoneal cavity is inspected and a finger is used to sweep the edges of the fascia to ensure there are no adhesions near the incision. A blunt-tipped Hasson cannula is then placed directly in the peritoneum and secured with sutures. The Hasson technique is used as a primary technique by many laparoscopic and robotic surgeons. For those who primarily use the closed, Veress needle technique, the Hasson technique is used when the patient has had multiple previous abdominal operations and the risk of intra-abdominal adhesions is high. The Hasson technique is also useful in morbidly obese patients, when Veress needle placement can be unreliable. The Hasson technique is also used to gain access to the retroperitoneum, as the retroperitoneum is a potential space that must first be created bluntly with the finger and then with balloon dilation before visual inspection is possible.

The radially expanding access system (STEP™, InnerDyne, Sunnyvale, CA) was developed as an alternative to the Veress and Hasson techniques [11]. The STEP system uses a pneumoperitoneum needle with an outer, polymeric sleeve. Once the needle is correctly placed, much like the Veress needle, the inner needle is

removed and the outer sleeve is dilated to the required size. In theory, there is less tissue trauma and less of a risk of bowel and vascular injuries.

The bladeless optical trocar is a multi-component, integrated system that uses a trocar with an inner sleeve-handle system that accommodates a 5 or 10 mm lens. The bladeless optical trocar is placed at the entry site in the desufflated abdomen and the surgeon is able to visualize the various tissue layers until the peritoneal cavity is identified and entered. The bladeless optical trocar was designed to save time, cause less tissue trauma, and decrease bowel and vascular injuries [12].

Complications during access make up over half of the total complications in some series [13]. There have been many retrospective and well-designed randomized controlled trials in an attempt to identify the safest access technique. Recently, a meta-analysis of 17 randomized, controlled trials with a total of 3,075 patients was conducted evaluating the various methods of access [14]. The meta-analysis showed no evidence of an advantage using any single technique in preventing major complications. It did show that extraperitoneal insufflation is less likely to occur with direct trocar entry (Hasson and bladeless optical trocar). The radially expanding access system showed less trocar site bleeding when compared to other techniques. An advantage was shown to not lifting the abdomen when obtaining access with the Veress needle in terms of avoiding extraperitoneal insufflation. Major complications involving access are rare but serious. There is no clear evidence that the open technique (Hasson) is superior to the closed technique (Veress needle, STEP, or bladeless optical access system) in the gynecological literature, but there is level one evidence that open access is safer than closed access [15].

Gastrointestinal and Solid Organ Injuries During Laparoscopic and Robotic Surgery

A bowel injury during laparoscopic or robotic surgery may be life-threatening if not recognized and repaired during the procedure (Tables 1 and 2). In the

Table 1 Summary of ten patients with laparoscopic bowel injury

Injuries recognized at the time of surgery					
Patient No.	Procedure	Injury site	Injury type	Repair	Complication (post-op days to recognition)
1	Nephrectomy	Small bowel	Dissection abrasion	None	Abscess + fistula*
2	Pyeloplasty	Colon	Dissection abrasion	Oversewn	None
3	Pelvic lymph node dissection	Colon	Dissection abrasion	Oversewn	None
4	Pelvic lymph node dissection	Colon	Dissection abrasion	Oversewn	None
5	Pyeloplasty	Colon	Dissection abrasion	Oversewn	None
6	Pelvic lymph node dissection	Colon	Burn	Oversewn	None
7	Nephrectomy	Colon	Closure perforation	Drain	Enterocutaneous fistula (10)
8	Pelvic lymph node dissection	Colon	Scissor perforation	None	Sepsis, death (4)
9	Cholecystectomy	Duodenal	Scissor perforation	Laparotomy	Necrotizing fasciitis (3)
10	Pelvic lymph node dissection	Colon	Thermal perforation	Laparotomy	Sepsis, death (3)

*One patient who had a serosal abrasion considered insignificant at surgery presented with injuries 2 weeks later

Table 2 Location of injury, treatment, and outcome

No. injuries									
References	Specialty	No. of patients	Bowel	Small intestine	Colon	Stomach	Recognized	Unrecognized	Treatment (No. of patients/total no.)	No. of deaths
Harkki-Siren and Kurki	Gynecology	70,607	44	26	16	2	8	36	All laparotomy	
Bateman et al.	Gynecology	2,324	6	3	2	1				
Wolfe et al.	General surgery	381	2	1	1	0	0	2		2
Deziel et al.	General surgery	77,604	109	69	35	5			Laparotomy (85/109)	5
Phillips et al.	General surgery	51	0							
Schrenk et al.	Gynecology, general surgery	4,672	10	6	4	0	6	4	Laparotomy (9/10)	1
Penfield	Gynecology	10,840	6				4	2	All laparotomy	
Loffer and Pent	Gynecology	32,719	64	44	11	9			Laparotomy (47/64)	
Kaali and Barad	Gynecology	4,532	4						All laparotomy	
Casey et al.	Gynecology	93	4	2	1	1	0	4	All laparotomy	
Davis et al.	Gynecology	40	1				0	1	All laparotomy	
Chapron et al.	Gynecology	1,191	8	1	7					
Present series	Urology	915	8	1	7		6	4		
Totals		205,969	266	153	84	18	24	53		8

post-operative period, the recognition of a bowel injury may be difficult until the patient is quite ill. The presentation of a laparoscopic or robotic bowel injury is unique to minimally invasive surgery and its early recognition must be a part of the laparoscopic and robotic surgeon's skill set.

Bowel injury requiring repair is a rare occurrence in laparoscopic and robotic surgery, occurring in 0.1% of cases [3]. Unfortunately, the majority of the injuries are unrecognized. Bowel injury that occurs during access and is recognized was discussed earlier in this chapter. A recognized bowel injury that occurs during dissection is treated in a similar fashion. A notable exception is a thermal injury caused by electrocautery (Figs. 1 and 2). If there is an enterotomy made by electrocautery, a wide section of tissue must be excised before

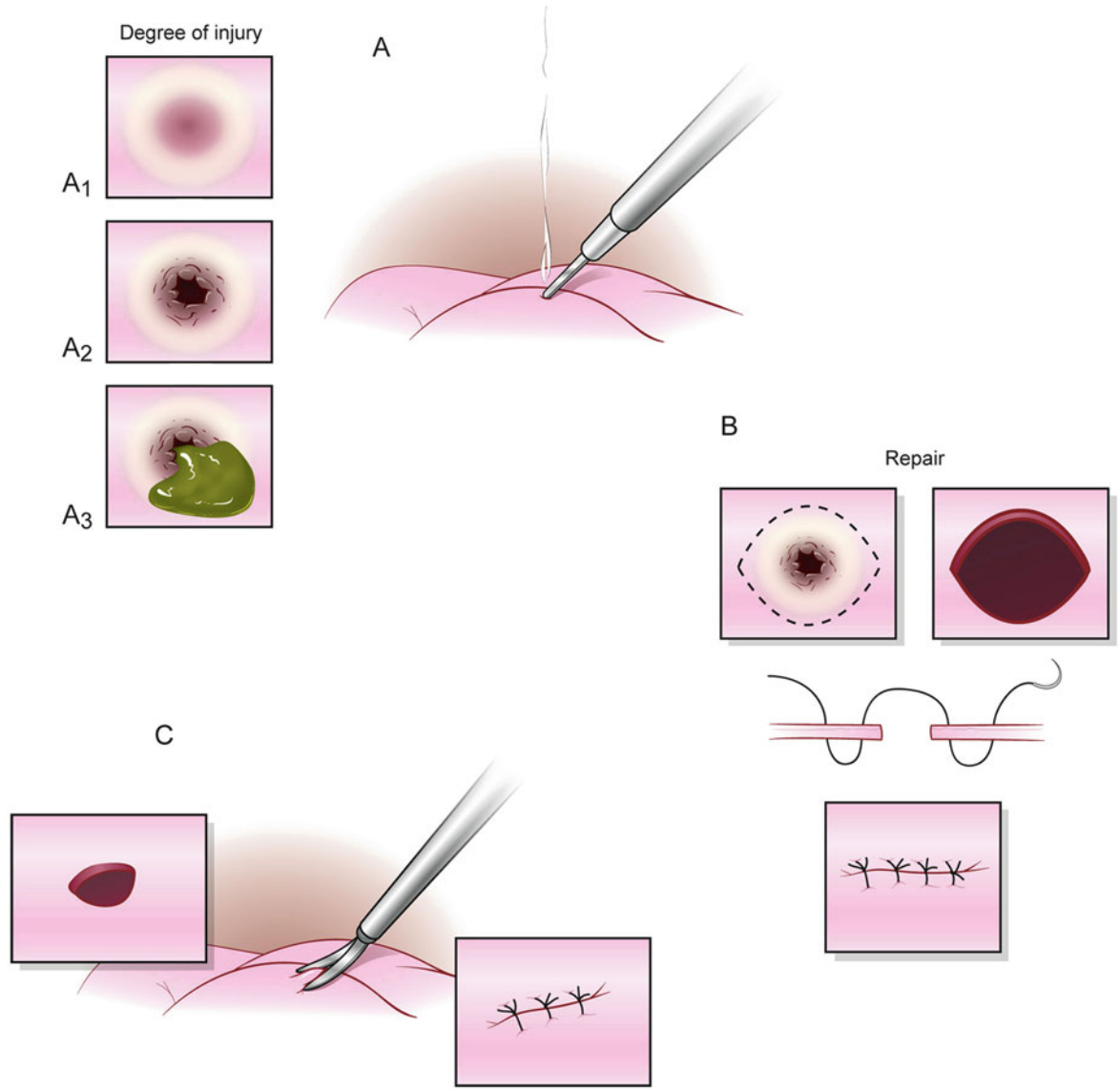

Fig. 1 Thermal and sharp injuries to the bowel during laparoscopic surgery. (**a**) Small thermal injury. The figures reveal the various appearances of thermal injuries. (A_1) The blanching apparent on the first panel may contain tissue that will ultimately undergo coagulation necrosis and sloughing. (A_2) The next panel shows a thermally induced enterotomy without spillage of succus and (A_3) the third panel shows a thermally induced enterotomy with spillage of succus. Repair of these injuries is necessary as shown in (b). (**b**) Repair of small, thermally induced bowel injuries requires excision to viable tissue and primary repair with Lembert suture. (**c**) Sharp enterotomy: This may be closed primarily, in most cases

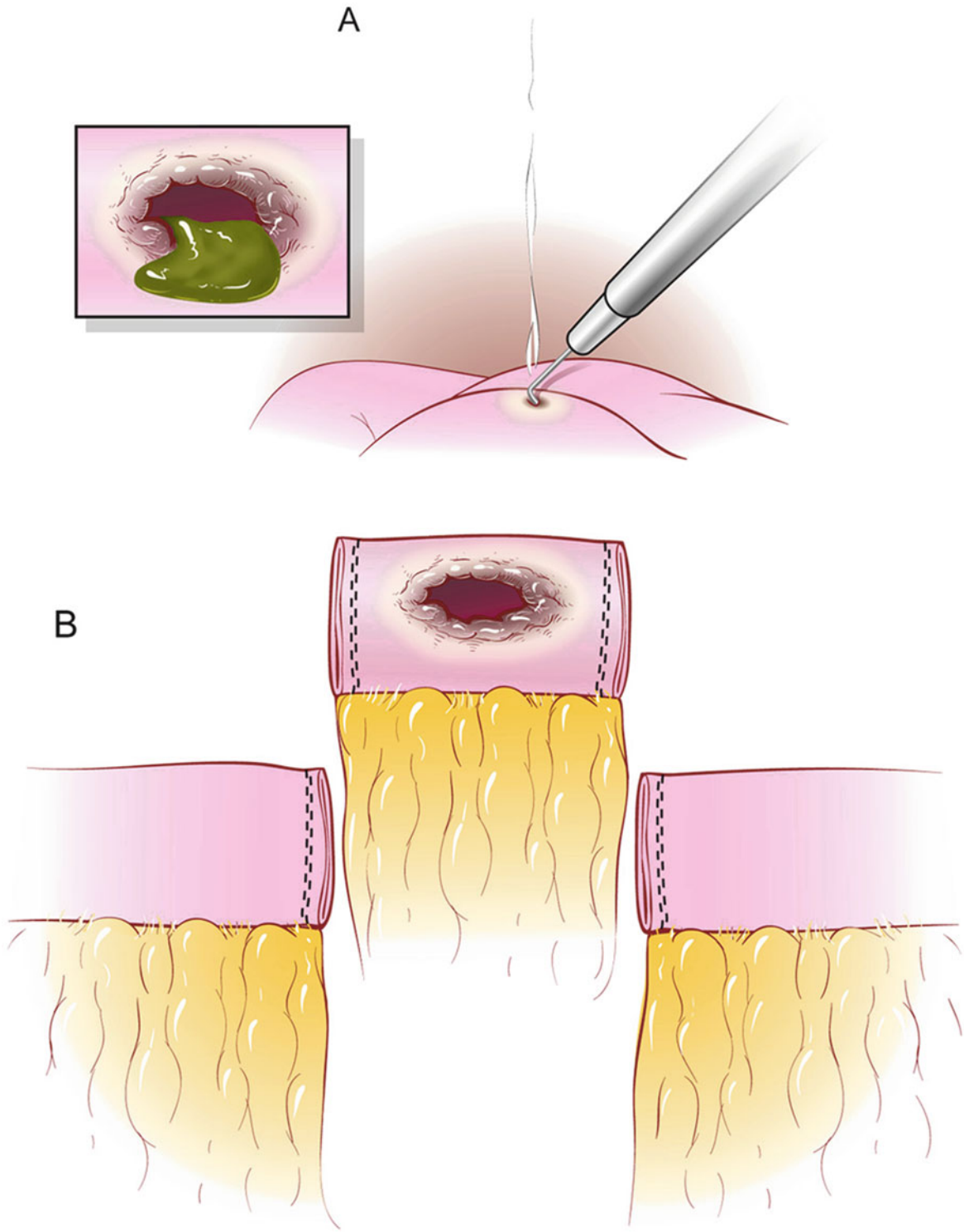

Fig. 2 Large, thermally induced bowel injury (**A**). Larger injuries may require bowel resection (**B**)

primary repair. If the area is blanched, but there is no enterotomy or there appears to be only a superficial serosal injury, the area must be excised until viable tissue is encountered and only then is it oversewn.

The unrecognized bowel injury in laparoscopic and robotic surgery is unique in its presentation (Table 3). The traditional recognition of a bowel injury in the patient who either underwent surgery or is seen in the emergency department includes ileus and exquisite abdominal pain with rigidity. The patient often has fever and leukocytosis and requires aggressive resuscitation. Bishoff and colleagues evaluated a series of laparoscopic surgeries and found the presentation to be quite different from that of a traditional acute abdomen caused by bowel injury. All but one of the patients who had an unrecognized bowel injury had a leukocytosis. Many of the patients had a low-grade fever. Furthermore, ileus is uncommon as is nausea and vomiting. Many times, the patient will have bowel sounds, no peritoneal signs, and diarrhea. There is often exquisite tenderness at the trocar site nearest to the bowel injury. If there is a high index of suspicion, the patient should be taken to the operating room immediately for exploratory laparotomy, washout, and repair. A computed tomography with oral contrast may be obtained if the diagnosis is less clear [3].

Injury to the pancreas, spleen, and liver also occurs in laparoscopic and robotic surgery. Most of these injuries may be managed conservatively. Injury to the pancreas is uncommon but can have significant morbidity. This most often occurs with laparoscopic left adrenalectomy, nephrectomy, and partial nephrectomy. In the urologic literature a rate of 0.2% has been reported [16]. These injuries are most commonly discovered post-operatively. If discovered intraoperatively, a GIA stapler can be used to repair the injury. If the injury is not discovered intraoperatively, there is usually a delay in diagnosis, and because of the rapid recovery of patients who have undergone laparoscopic surgery, the patient is often at home when the symptoms begin. The patient complains of pain out of proportion to the procedure, epigastric pain radiating to the back, nausea, and vomiting. The patient will have leukocytosis and an elevated serum amylase. Intravenous fluid hydration, nasogastric tube, parenteral nutrition, administration of somatostatin, and drainage may be required. If the surgeon has a high index of suspicion, a drain can be placed intraoperatively and the fluid can be sent for amylase if the patient develops symptoms. The drain can be removed when the output is less than 50 cc every 24 h and the patient can then be started on a low-fat diet [17]. A pancreatic fistula may develop and may take as long as 3 weeks to heal [18]. Splenic injuries occur in 0.3% of laparoscopic procedures [4]. Splenic injuries occur most often while mobilizing the splenic flexure to expose the retroperitoneum. There is an increased risk if the patient has adhesions. A splenic injury is most often managed with simple fulguration if minor. If the bleeding is more difficult to control, an argon beam coagulator can be used. Biocompatible liquid polymers have also been used to control splenic bleeding [19]. Splenectomy due to a large injury and excessive bleeding is rare, but has been reported [20]. Hepatic injury does not often occur and is treated much like a splenic injury. It is difficult to estimate the rate of hepatic injury as these are mostly incidental and controlled with electrocautery. Like a splenic injury, an argon beam coagulator may be necessary to control more excessive bleeding from hepatic injuries. Difficult to control bleeding may require placing a figure of eight suture at the site of the injury.

Table 3 Presenting signs and symptoms of unrecognized laparoscopic bowel injuries

	Patient No.				
	1	7	8	9	10
Trocar pain	Yes	Yes	Yes	Yes	Yes
Abdominal distention	Yes	Yes	Yes	Yes	Yes
Leukopenia	Yes	No	Yes	Yes	Yes
Diarrhea	Yes	No	Yes	Yes	Yes
Cardiovascular collapse	No	No	Yes	Yes	Yes
Ileus	No	No	No	No	Yes
Abdominal pain	No	No	No	No	No
Leukocytosis	No	No	No	No	No
Fever greater than 101 F	No	No	No	Yes	No
Nausea	Yes	No	No	Yes	Yes
Vomiting	No	No	No	Yes	Yes

Trocar Site and Incisional Hernias in Laparoscopic and Robotic Surgery

Herniation of bowel through a trocar site is an uncommon occurrence in laparoscopic and robotic surgery (Fig. 3). The first trocar site hernia was reported in

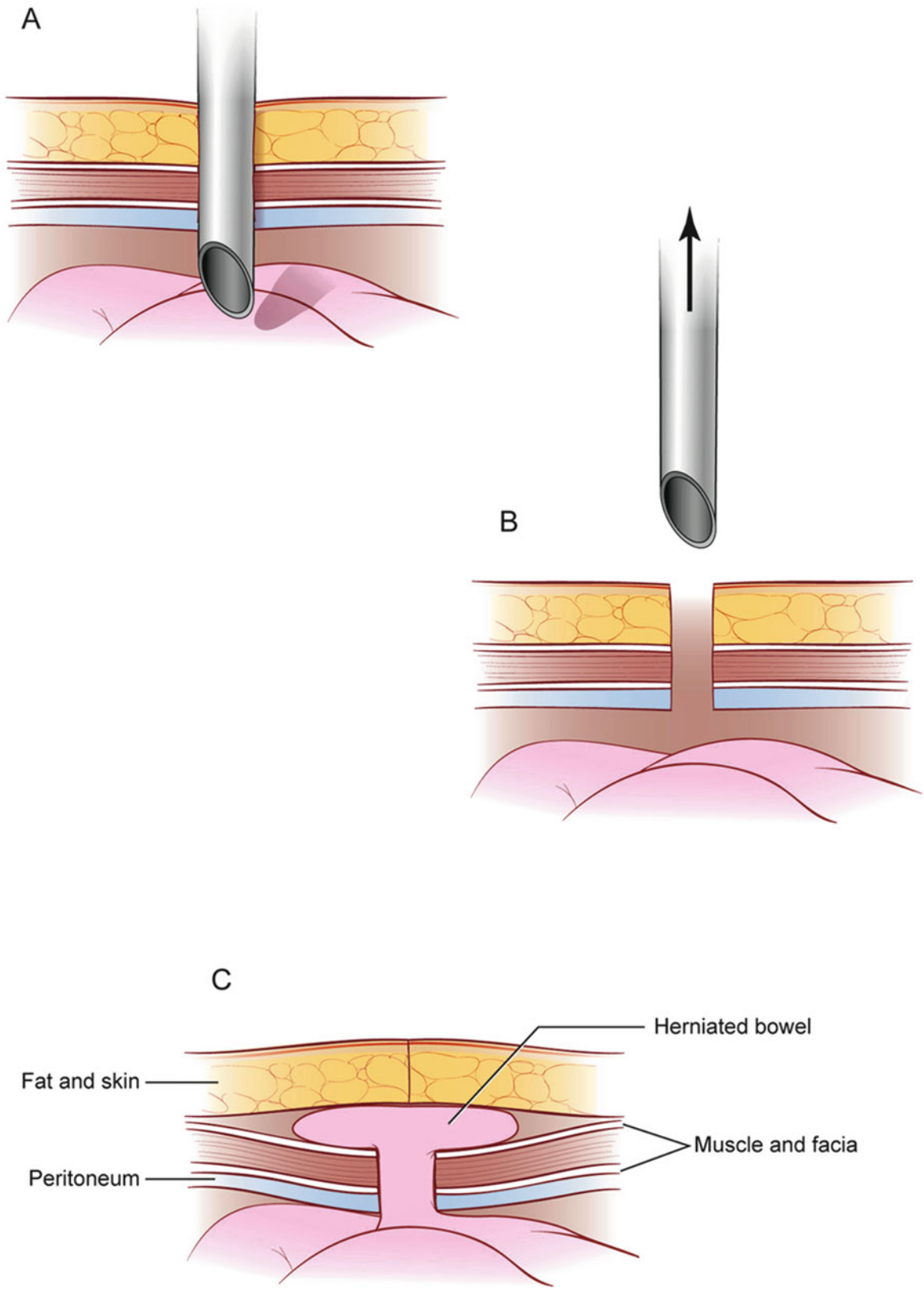

Fig. 3 Evolution of a trocar site hernia: The trocar is placed (**A**). The trocar is then removed after the completion of the laparoscopic portion of the case (**B**). The fascial defect was not closed and the bowel herniates through the fascial defect (**C**)

the gynecologic literature in a large series of diagnostic procedures in 1968 [21]. Since that time, there have been many reports of trocar site hernias. The incidence ranges from 0.65 to 2.8% in the general surgery literature [22, 23]. The true incidence of trocar site hernias may be higher due to underreporting. Larger trocars are predictably more prone to hernia formation, whether the fascial defect is closed or not. In the gynecologic literature, 86.3% of trocar site hernias were found in defects larger than 10 mm, 10.9% in defects at least 8 mm in length, and 2.7% in those 5 mm or less [24]. The overall incidence of trocar site hernias in ports 5 mm or less has been reported to be 0.056% [25, 26].

There is a question of whether to close the fascial defects after the trocar removal and whether trocar sites of a certain size should be closed is a debated subject. It has been reported that the incidence of bowel adhesions and incarcerations that occur after the defect is closed or left open is similar [27]. Many suggest that a trocar site hernia after closure of the fascial defect is a result of partial closure and improper suturing technique. The gynecologic literature has shown that closing the fascial defect of a 12 mm incision significantly reduces development of a trocar site hernia [25]. It has also been noted that closed laparoscopy has a higher trocar site hernia incidence than open (Hasson) laparoscopy and this has been attributed to a higher rate of wound infection in the closed series [28].

The paraumbilical region has been shown in many studies to be the area where most hernias develop and this has been attributed to the inherent weakness of the area and a lack of a posterior fascial covering with intervening muscle between the anterior fascial leaves [29]. Using the umbilical and paraumbilical region as the extraction site, which leads to stretching of the fascia and possibly extending the fascial incision, has also been found to increase the incidence of trocar site hernias [14].

Host factors have been attributed to an increase in trocar site hernia formation and these include obesity, poor nutrition, diabetes mellitus, steroid use, and concomitant wound infection, although these factors did not reach statistical significance when evaluated [28].

There have been recent reports of trocar site herniation of bowel contents after using the 8 mm DaVinci (Intuitive Surgical, Sunnydale, CA) trocar [30]. Although it is generally accepted that these fascial defects do not have to be closed, as these reports gather, they may suggest a benefit to closing 8 mm fascial defects (Fig. 4).

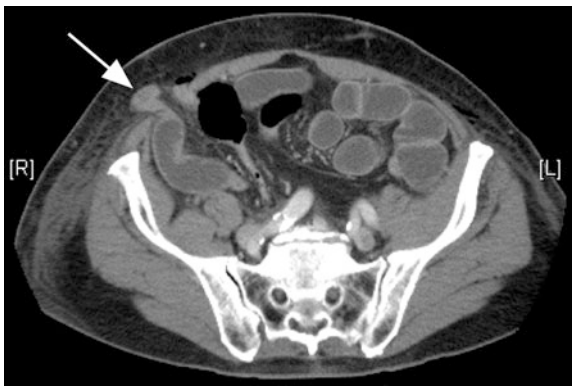

Fig. 4 A trocar site hernia that occurred from an 8 mm robotic trocar

Trocar site hernias usually present as abdominal pain at the trocar site and small bowel obstruction. A portion of patients are asymptomatic. All trocar site hernias must be recognized and repaired immediately to prevent small bowel obstruction or incarceration and bowel necrosis.

Incisional or extraction site hernias can occur in laparoscopic and robot-assisted laparoscopic surgery (Fig. 5). There is generally a loss of fascial integrity that occurs during or after healing. In general, the incidence of incisional hernia formation after surgery is 5–15% [31]. Risk factors associated with formation of incisional hernia include previous abdominal surgery, obesity, renal insufficiency, renal failure, postoperative respiratory tract infection, diabetes, age older

Fig. 5 Extraction site hernia after laparoscopic radical nephrectomy

than 50 years, metastatic disease, and impaired nutrition [32]. Most of the literature looking at extraction site hernias evaluates hand-assisted and pure laparoscopic radical nephrectomy or nephroureterectomy. Hand-assisted laparoscopic radical nephrectomy has been reported in a series to have an incisional hernia rate of 6% when the extraction site was either the midline or a muscle-splitting right lower quadrant incision [32]. Midline extraction site versus Pfannenstiel extraction site was compared to evaluate pain in one study; however, it was noted that there was a 2.9% incisional hernia rate from the midline site and no hernias developed after extraction from the Pfannenstiel site [33]. Another study compared midline with paramedian extraction sites and the midline extraction site to have a higher rate of hernia formation than the paramedian extraction site [34]. This has also been noted in the general surgery literature for laparoscopic colectomy [35]. Bird et al. performed an excellent study evaluating the location of the extraction site specifically as a primary end point and found a paramedian incision in someone with a high BMI to be the highest risk factor for incisional hernia formation [36].

Bowel Complications in Specific Procedures

Complications of Laparoscopic and Robot-Assisted Adrenalectomy

Laparoscopic adrenalectomy is a relatively uncommon procedure and makes up only 2% of the procedures in an academic laparoscopic program [7]. The largest series to date evaluating the complications of laparoscopic adrenalectomy reports a complication rate of 7.5% [37]. The complications included hematoma formation (the most common), splenic injury, pancreatic injury, intraoperative bleeding, pneumothorax, and deep venous thrombosis. Open conversion was required in 5% of the cases. There were no bowel complications reported in these larger series.

There is a paucity of data regarding robot-assisted laparoscopic adrenalectomy. Two studies have compared the two procedures and shown them to be equivalent in complication rate. The only significant differences between the two procedures are a longer operative time and more expense for the robot-assisted laparoscopic adrenalectomy [38, 39] (Tables 4 and 5).

Complications of Laparoscopic and Robot-Assisted Nephrectomy

Laparoscopic renal surgery has been growing in its use and indications since Clayman performed the first laparoscopic nephrectomy in 1990 [40]. The laparoscopic nephrectomy has been one of the most commonly performed laparoscopic cases in urology. Recently, a meta-analysis was performed to evaluate the complications of the laparoscopic renal surgery and the hand-assisted laparoscopic renal surgery (HALRN) [41]. LRN and HALRN have a major and minor complication rate of 13%. The major complication rate of LRN and HALRN is 3% and the minor complication rate is 10%. LRN had a small bowel complication rate of 0.6% and colonic injury incidence of 1.5%. The meta-analysis of HALRN revealed a small intestinal injury of 0.5% and an incisional hernia rate of 0.5%. It should be noted that the meta-analysis of LRN reported no incidents of incisional hernia.

The robotic radical nephrectomy has been evaluated at several centers for safety, efficacy, and feasibility [42]. A series of 43 patients show the robotic radical nephrectomy to be a safe procedure that is not significantly different than LRN or HALRN. There were no major complications and one minor complication (2.6%) which was a morbidly obese patient who developed a wound dehiscence. No bowel injuries have been reported in robot-assisted laparoscopic nephrectomies. Select academic centers studying robotic technology need to develop a larger series in order to evaluate the nature and incidence of complications of robot-assisted laparoscopic nephrectomy before a true comparison with LRN and HALRN can be made.

The transperitoneal and retroperitoneal approaches have been evaluated by Gill and colleagues [43]. The transperitoneal approach provides a larger working space and familiar anatomic landmarks whereas the retroperitoneal approach has a theoretic advantage of a faster return to full bowel function by avoiding the peritoneal cavity. Another advantage of retroperitoneoscopic surgery may be avoiding the peritoneal cavity in patients with multiple prior

Table 4 Laparoscopic bowel complications

Procedure	Overall incidence of bowel complications	Ileus	Small bowel injury	Large bowel injury	Rectal injury	Port-site hernia	Incisional/extraction site hernia	Small bowel obstruction
Adrenalectomy	None reported	–	–	–	–	–	–	–
Nephrectomy	2.1%		0.6%	1.5%	–	–	–	–
HALRN	1%		0.5%	–	–	–	0.5%	–
Partial nephrectomy	None reported	–	–	–	–	–	–	–
HALPN	None reported	–	–	–	–	–	–	–
Nephroureterectomy	3.9%	–	2.3%	0.8%	–	–	0.8%	–
Pyeloplasty	0.6%	–	–	0.6%	–	–	–	–
RPLND	0.65%	–	0.65%	–	–	–	–	–
Cystectomy	7%	6%	–	–	0.5%	–	0.5%	–
Prostatectomy		5.3%	–	0.3%	1.5–2.5%	–	–	–

Table 5 Bowel complications of robot-assisted laparoscopic surgery

Procedure	Overall incidence of bowel complications	Ileus	Small bowel injury	Large bowel injury	Rectal injury	Port-site hernia	Incisional/extraction site hernia	Small bowel obstruction
Adrenalectomy	None reported	–	–	–	–	–	–	–
Nephrectomy	2.6%	–	–	–	–	–	2.6%	–
Partial nephrectomy	Yes	Yes	–	–	–	–	–	–
Nephroureterectomy	None reported	–	–	–	–	–	–	–
Pyeloplasty	None reported	–	–	–	–	–	–	–
RPLND	None reported							
Cystectomy	8.2%	5.7%	1% (enterocutaneous fistula)	–	1%	1% (parastomal)	–	–
Prostatectomy	0.85%	0.2%	0.14%	-	0.1%	0.14%	0.2%	0.06%

surgeries. In Gill's study there were no statistically significant differences in the incidences of complications. In the transperitoneal group, there was an overall complication rate of 10% with one minor bowel injury. The retroperitoneal group had an overall complication rate of 7.7% with no bowel injuries. Although one bowel injury occurred in the transperitoneal group, the difference between the groups is not statistically significant (Tables 4 and 5).

Laparoscopic and Robot-Assisted Laparoscopic Partial Nephrectomy

The laparoscopic partial nephrectomy is one of the most challenging commonly performed cases in urology. There are several steps in the procedure that make it quite difficult. The renal hilum must be dissected meticulously to allow placement of vascular clamps for bleeding control. The position of the mass may make it very difficult to excise the mass and close the defect. Unfortunately, this must be done as quickly as possible to save the nephrons of the kidney. A meta-analysis of laparoscopic partial nephrectomy (LPN) and hand-assisted laparoscopic partial nephrectomy (HALPN) showed a significantly higher rate of major complications in the LPN group (21 versus 3.3%). However, it must be noted that the size of the groups was not equal in this retrospective comparison. The common major complications of LPN are blood transfusion (4.4%), urinoma (3.9%), and arterial bleeding (1.7%). The most common complication of HALPN is urinoma (3.3%). Notably, there was no report of bowel injuries in this meta-analysis.

The robot-assisted laparoscopic partial nephrectomy is seen as being well suited to the robotic procedure as compared to the RALRN mainly because of the surgeon's ability to control the kidney with the fourth arm and the greater degrees of freedom of the robotic instruments that allow a theoretically faster reconstruction of the renal defect and therefore a shorter ischemic time. A multi-institutional analysis of the RALPN evaluated 143 patients [44]. The complication rate was 6.1% and included a hematoma requiring drainage, ileus, pulmonary embolus, urinoma, and rhabdomyolysis. Two procedures were converted to an open procedure. One patient was morbidly obese and the other had a prior open ureterolithotomy. There were no bowel injuries reported in this series (Tables 4 and 5).

Laparoscopic and Robot-Assisted Laparoscopic Nephroureterectomy

Laparoscopic nephroureterectomy (LNU) and hand-assisted laparoscopic nephroureterectomy (HALNU) are a standard minimally invasive procedure for the treatment of transitional cell carcinoma of the upper urinary tract. It is accepted that complete excision of the ureter is a necessary part of the operation [45]. In the traditional operation, either a long midline incision or two separate incisions were made to accomplish this task. Laparoscopy allows the surgeon to make at the most a small Gibson or partial Pfannenstiel incision to complete the excision of the distal ureters and many complete this by using endoscopic methods [46]. LNU has a 19% major and 2% minor complication rate. The most common complication of LNU is hernia at the extraction site. This may be a result of using a paramedian incision in order to address the distal ureter through the extraction site. Wolf and colleagues have reported their complication rate with HALNU. There is an overall 37% complication rate [47]. Major complications represent 19% and minor complications represent 39%. The most common major complication was development of an incisional hernia at the hand port site. Blood transfusion was required in 17% of patients.

The robot-assisted laparoscopic nephroureterectomy is a new procedure that has scant data reporting complications. The largest series has been reported by Nanigian and colleagues [15]. They reported no significant complications in this small group of patients (Tables 4 and 5).

Laparoscopic and Robot-Assisted Laparoscopic Pyeloplasty

Laparoscopic pyeloplasty has become the gold standard for excision and reconstruction of the ureteropelvic junction. It has been proven to have similar functional outcomes as compared to the open procedure [48]. Rassweiler and colleagues took their experience of 189 laparoscopic pyeloplasties and created a meta-analysis of several other large series to develop a group of 601 patients that had undergone laparoscopic pyeloplasties at high-volume institutions and subjected this cohort to the Clavien classification for

complications. Intraoperative complications occurred in 2.3% of the cases and these complications were variable. Conversion to an open operation occurred in 0.5–5.5% of cases as the result of an inability to access the UPJ or finish the anastomosis. Post-operative complications ranged from 5.4 to 15% and represented urine leak, hematoma, bowel injury, and stone formation. Out of the 601 patients, 4 had colonic injuries. Recurrent UPJ obstruction occurred in 3.5–4.8% of cases. It should be noted that the majority of these complications took place during the learning curve.

Robot-assisted laparoscopic pyeloplasty has gained popularity due to its extra degrees of freedom which aid during reconstruction of the UPJ. Mufarrij and associates in a multi-institutional analysis report a 7.1% major and a 2.9% minor complication rate [49]. The most common major complication was stent migration requiring repositioning or replacement. Other major complications included gluteal compartment syndrome, splenic injury, and pyelonephritis requiring stent exchange. Minor complications included urinary tract infection and prolonged urine leak. No bowel injuries were reported in this series. Recurrent ureteropelvic junction obstruction occurred in 4.3% of patients, which is similar to Rassweiler's meta-analysis of laparoscopic pyeloplasty (Tables 4 and 5).

Laparoscopic and Robot-Assisted Retroperitoneal Lymph Node Dissection

Laparoscopic retroperitoneal lymph node dissection (LRPLND) has been making inroads in recent years for the treatment of stage I non-seminomatous germ cell tumors, although it remains controversial. Steiner and associates reviewed the long-term results of LRPLND [50]. The major complication rate of 1.1% included a recognized colon injury and injury to the renal artery. Minor complications included lymphocele (8.5%) and chylous ascites (4.8%). Transfusion was required in 1.3% of patients, and 2.6% of procedures were converted to an open procedure for bleeding. The complication rate for a post-chemotherapy LPRLND is higher and has been estimated to be almost 50% in some series [51]. Most of those complications are intraoperative and are a result of bleeding. There have been several case reports and some small series evaluating the safety and efficacy of RALRPLND. RALRPLND is safe and there have been no major complications in these reports, but further study is needed (Tables 4 and 5).

Laparoscopic and Robotic Radical Cystectomy

The first laparoscopic cystectomy was performed in 1992 followed by only sporadic attempts at this technically difficult procedure with limited instrumentation [52]. Since that time, with increased experience in laparoscopic techniques and improved instrumentation, laparoscopic, and now robot-assisted laparoscopic, radical cystectomy has become an accepted procedure with the potential benefits of lower blood loss, less pain, and quicker time to recovery. However, open radical cystectomy remains the gold standard for the treatment of muscle invasive transitional cell carcinoma of the bladder. Several larger series of laparoscopic radical cystectomy have evaluated their complications [53–57]. Although various techniques were used, such as extracorporeal suturing in some and different diversions in other series, the results have been pooled to look at the bowel complications. These series evaluate a total of 211 patients that underwent laparoscopic radical cystectomy. The most common bowel complication is ileus, which occurred in 6% of patients. Rectal injury and bowel herniation were encountered in less than 1% of cases. There are a growing number of series that have evaluated robot-assisted laparoscopic radical cystectomy [53, 58–61]. A pooled analysis of these series produces 175 patients undergoing robot-assisted laparoscopic radical cystectomy. The most common complication was formation of an ileus, which occurred in 5.7% of cases. Other bowel complications include rectal injury, which had an incidence of about 1%, as well as parastomal hernia, which also had an incidence of about 1%; enterocutaneous fistula occurred in less than 1% of cases. These analyses serve only to estimate the complication rate. A large-scale study needs to be performed in order to compare these outcomes to those of open radical cystectomy, although there is a suggestion that the bowel complication rate is comparable or even lower than those in the open series [62] (Tables 4 and 5).

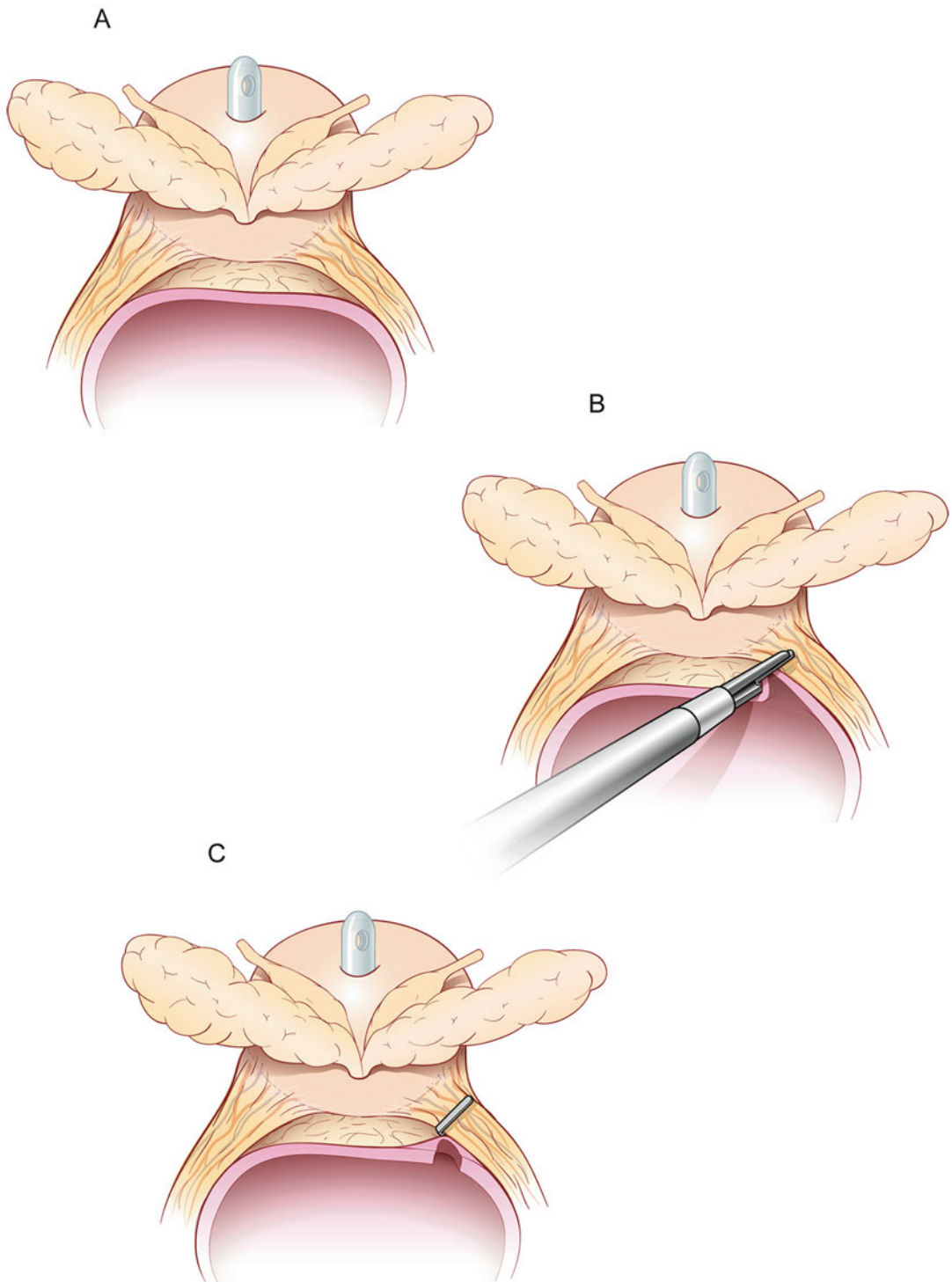

Fig. 6 Rectal injury during laparoscopic radical prostatectomy or robot-assisted laparoscopic radical prostatectomy. (**a**) The bladder neck has been dissected off of the prostate and the rectum has been dissected off of the pedicles of the prostate. (**b**) The rectum is adherent to the right pedicle of the prostate and the right pedicle is about to be transected. (**c**) The rectal injury has occurred and must be repaired in primary fashion, with or without diversion

Laparoscopic and Robot-Assisted Laparoscopic Radical Prostatectomy

The open radical prostatectomy is the gold standard for the treatment of localized adenocarcinoma of the prostate; however, over the last 10 years, minimally invasive approaches to the treatment of prostate cancer have made significant inroads. It is estimated that over 70% of laparoscopic radical prostatectomies were performed with robotic assistance in 2009 [63]. The most common and feared bowel complication related to the open, laparoscopic, and robot-assisted radical prostatectomy is the rectal injury, as it is separated by the two layers of Denonvillier's fascia and the perirectal fat. Risk factors for rectal injuries include previous radiation, scarring from previous surgery or infection, and a large prostate size [64]. Since prostate cancer is the most common non-cutaneous cancer in men in the United States and Europe, there is a significant amount of data available to evaluate the incidence of bowel complications of laparoscopic and robot-assisted laparoscopic radical prostatectomy. Rassweiler and the German Laparoscopic Working Group have evaluated 5,824 patients who have undergone laparoscopic radical prostatectomy [65]. Rectal injury occurred in 1.5–2.5% of these patients. There were no other significant bowel complications in this large number of patients. Hu et al. have evaluated 358 patients undergoing laparoscopic radical prostatectomy [66]. They report a 1.9% incidence in rectal injuries with a resultant 1.9% incidence of rectourethral fistulae. Other bowel complications from this series include a 5.3% incidence of ileus and a 0.3% incidence of colonic injury. Robot-assisted laparoscopic prostatectomy (RALRP) has been rapidly accepted and there are several large series that have well documented their complications. Menon and colleagues have a series of 2,766 RALRPs [67]. In this series there were four bowel injuries and four port-site hernias, for an incidence of 0.1%. It is not specified whether these bowel injuries were rectal injuries. There was one case of prolonged ileus. Patel has reported on 1,500 consecutive RALRPs [68]. Two rectal injuries (0.1%) were encountered and repaired intraoperatively. Three incisional hernias and three cases of ileus were noted (0.2%). There was one port-site hernia and one case of a small bowel obstruction (0.06%). Rectal injuries, when recognized, were repaired primarily in two layers without consequence in all cases reported (see Fig. 6). LRP and RALRP appear to have a low incidence of bowel injuries that compare favorably with the open procedure (Tables 4 and 5).

Conclusion

Bowel injuries are an uncommon occurrence in laparoscopic and robot-assisted laparoscopic surgery. However, these injuries may be life-threatening if not diagnosed and treated rapidly. Laparoscopic bowel injuries have a presentation that is unique compared to bowel injuries encountered during open surgery. It is imperative to understand and recognize this presentation in order to treat the bowel injury in an expeditious manner. The overall incidence, on a procedure per procedure basis, compares favorably with open surgery.

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