Complications of laparoscopic surgery

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INTRODUCTIONThe rate of serious complications associated specifically with a laparoscopic approach is overall low. Up to one-half of complications occur at the time of abdominal access for camera or port placement [1]. Complications can also arise from abdominal insufflation, tissue dissection, and hemostasis [2]. Conversion to an open procedure may be needed to manage complications that have been identified intraoperatively, while others may not be recognized until the postoperative period. Severe complications such as vascular injury and bowel perforation can be catastrophic and are the main cause of procedure-specific morbidity and mortality related to laparoscopic surgery.

Much of the literature discussing the complications associated with laparoscopic surgery is drawn from the gynecologic literature, which has provided the most comprehensive study of these injuries [3]. It is presumed that results from these studies can be generalized to other abdominal and retroperitoneal surgeries, but wherever possible, outcomes of laparoscopic surgery in gynecology, general surgery, and urology are distinguished.

Surgical complications unique to a laparoscopic approach are discussed here. Surgical techniques and their specific complications are discussed in individual topic reviews. Other general issues relating to laparoscopic surgery, including abdominal access and instrumentation, are reviewed elsewhere. (See "Abdominal access techniques used in laparoscopic surgery" and "Instruments and devices used in laparoscopic surgery" and "Overview of gynecologic laparoscopic surgery and non-umbilical entry sites" and "Overview of laparoscopy in children and adolescents".)

EPIDEMIOLOGY AND RISK FACTORS The rate of complications associated specifically with a laparoscopic approach is overall low. Complications related to initial abdominal access occur in fewer than 1 percent of patients [4-7]. Once abdominal access is established, complications during the course of the procedure are similarly rare; however, late hernia at port sites can affect up to 6 percent of patients. The incidence of specific complications for specific laparoscopic procedures is discussed more fully in the sections below. The following studies illustrate typical findings:

●One survey reported results of claims arising from abdominal access injuries between 1980 and 1999 and medical device reports to the US Food and Drug Administration (FDA) [8]. The incidence of abdominal access injury was 5 to 30 per 10,000 procedures. Bowel and retroperitoneal vascular injuries comprised 76 percent of all injuries, and almost 50 percent of small and large bowel injuries were unrecognized for at least 24 hours. The type and proportion of organ injury during abdominal access were as follows:

•Small bowel (25 percent)

•Iliac artery (19 percent)

•Colon (12 percent)

•Iliac or other retroperitoneal vein (9 percent)

•Secondary branches of a mesenteric vessel (7 percent)

•Aorta (6 percent)

•Inferior vena cava (4 percent)

•Abdominal wall vessels (4 percent)

•Bladder (3 percent)

•Liver (2 percent)

•Other (less than 2 percent)

●A review of gynecologic procedures performed from 1975 to 2002 reported that access-related bowel injuries occurred in 4.4 per 10,000 procedures and entry-related vascular injuries occurred in 3.1 per 10,000 procedures [9]. An open abdominal access technique (eg, Hasson) was not associated with fewer complications than a closed entry technique.

●An analysis of 629 trocar injuries reported to the FDA included 408 injuries to major blood vessels, 182 other injuries (mainly bowel injuries), and 30 abdominal wall hematomas [10]. Among the 32 deaths, 26 were due to vascular injuries and 6 deaths resulted from bowel injuries. Injury to the aorta and inferior vena cava were the vessels most commonly resulting in death. The diagnosis of gastrointestinal perforation was delayed in 10 percent of cases, and the mortality rate among these patients was 21 percent.

●A prospective study of 403 patients who underwent laparoscopic abdominal surgery found a complication rate of 3 percent after a minimum of three months of follow-up [11]. Consistent with other studies, complications were mostly related to the abdominal access site (75 percent) and included (in order of frequency) abdominal wall hematoma, port-site hernia, and port site infection.

Risk factors — Patients who have had prior surgery for intra-abdominal or pelvic disease (eg, diverticulitis, pelvic inflammatory disease) have a higher risk of complications related to adhesions compared with patients who do not have this past history. Other conditions that increase the risk of complications include extensive bowel distention, very large abdominal or pelvic mass, and diaphragmatic hernia. In addition, patients with poor cardiopulmonary reserve may not be candidates for abdominal insufflation given the physiologic changes related to pneumoperitoneum. For patients with risk factors for complications, the laparoscopic approach and approach to abdominal access need to be carefully planned; an open approach may be preferred.

The frequency of complications may be related to surgeon experience and the number of the specific procedures performed for some, but not all, types of surgical procedures [12,13]. Studies focusing on various laparoscopic surgeries have had mixed conclusions [14-19].

●For the treatment of acute cholecystitis, lower surgeon volume was a predictor of the need for open conversion and prolonged length of hospital stay but did not predict the rate of bile duct injury or mortality in a large review of the Nationwide Inpatient Sample (NIS) [18].

●A survey of 181 urologic surgeons following completion of a supplemental laparoscopy course found that surgeons who did not participate were threefold to fivefold more likely to have at least one complication at 3 and 12 months, respectively, compared with surgeons who participated [14].

●In a comparison of complications of open (n = 512) and laparoscopic (n = 112) bowel resection performed by four study surgeons, surgical volume and training had no relationship to the incidence of complications, which varied from 9 to 47 percent [15]. Rather, an inflammatory indication was a strong predictor of technical complications.

●In a review of a nationwide inpatient database, the overall rates for complications related to laparoscopic hysterectomy were similar for low-volume versus for high-volume surgeons (9.8 and 10.4 percent, respectively) [16]. No differences were found for intraoperative complications, surgical site complications, medical complications, transfusion, or reoperation.

RELATED TO ABDOMINAL ACCESS Potential complications arising from initial abdominal access to insufflate the abdomen and place the laparoscopic camera, and the abdominal ports needed to introduce laparoscopic instruments, include vascular injury, gastrointestinal perforation, solid visceral injury, nerve injury, port-site hernia, and surgical site infection. Access-related vascular and gastrointestinal injuries are the leading causes of fatalities following laparoscopic surgery [20].

Most reviews reporting complications related to abdominal access are drawn from the gynecologic literature. In one large review of gynecologic laparoscopy, over 50 percent of these complications occurred during abdominal access [1]. As laparoscopic techniques became more widely adopted, reports of morbidity and mortality related to laparoscopic complications increased related to the increased number of procedures and to the well-defined learning curve associated with the adoption of laparoscopic techniques [3]. For laparoscopic cholecystectomy, complications of abdominal access and abdominal insufflation were also found to be the most frequent cause of morbidity and mortality [21]. A review of 1399 trocar-associated injuries and fatalities reported in the Food and Drug administration (FDA) Manufacturer and User Facility Device Experience (MAUDE) database found a high proportion of reports were associated with laparoscopic cholecystectomy compared with other laparoscopic procedures [20]. This likely reflects the high prevalence of this procedure as the most common laparoscopic procedure performed in the United States. The majority of complications were related to user technique. A device issue or failure contributed in 8 percent of reported complications; however, approximately one-third of devices were not assessed, because they were not returned to the manufacturer or the condition of the device prevented evaluation.

Knowledge of proper access techniques is crucial to avoid these complications. However, no significant differences in overall complication rates have been found for closed compared with open techniques for primary abdominal insufflation when performed by experienced surgeons [9,22,23]. Most severe injuries are due to blind insertion of access devices [24-28]. Although the results of several retrospective reviews can be used to justify the use of blind techniques [29-34], many surgeons prefer a visual entry technique to place primary trocars; secondary trocar/ports should always be placed under direct laparoscopic vision with the abdomen insufflated. Abdominal access techniques are discussed elsewhere. (See "Abdominal access techniques used in laparoscopic surgery", section on 'Choice of technique'.)

Conversion to an open procedure may be required to manage complications of abdominal access. In a systematic review in the early experience with laparoscopic cholecystectomy, 15 percent of conversions (1400/78,747 patients) were due to access-related complications such as bleeding or bowel injury [35].

Vascular injury — The overall reported rate of vascular injury (arterial or venous injury) ranges from 0.1 to 6.4 per 1000 laparoscopies. Most injuries involve minor vessels; however, underreporting is common. Vascular injury most commonly occurs during abdominal access and is second only to anesthesia as a cause of death from laparoscopy [36-45]. In one review, the mortality rate among patients suffering a vascular injury was 15 percent [36].

Vascular injury most commonly occurs while placing a pneumoperitoneum needle (eg, Veress) or primary trocar [40,45-47]. Although a Veress needle is often implicated as the cause of distal aortic or iliac vessel injury, vascular injuries can occur with any of the available devices using open or closed techniques, during any laparoscopic procedure, including those in the upper abdomen. In the review of the MAUDE database described above, 4/9 fatal aortic injuries occurred during laparoscopic cholecystectomy [20].

Vascular injuries related to abdominal access can be grouped into major and minor vascular injuries. Major vascular injuries affect major vessels such as the aorta, inferior vena cava, and iliac vessels, while minor vascular injuries affect vessels of the abdominal wall, mesentery, or other organs.

Minor vessels — Vascular complications most commonly result from laceration of minor vessels. Although the injured vessel is considered minor, these injuries are more often a cause for transfusion, conversion to an open procedure, or reoperation. Minor superficial bleeding sites can usually be identified using probing instruments or an irrigator-aspirator. Once identified, the site can be coagulated or clipped. The use of laparoscopic instruments for hemostasis and management of complications of laparoscopic entry are discussed separately. (See 'Management of hemorrhage' below and "Management of hemorrhage in gynecologic surgery".)

During initial abdominal access to establish pneumoperitoneum, the omental and mesenteric vessels are most commonly injured, particularly if there are adhesions [1,48]. The most common vascular injury overall is laceration of the inferior epigastric artery during placement of lateral trocars (usually as secondary trocars) in the lower abdomen [49]. Injury to the inferior epigastric vessels is more common than injury to the superior epigastric vessels, likely because the superior epigastric vessels in the upper abdominal wall often form a plexus of arteries [3].

Cutting trocars with sharp blades are more likely to injure vessels compared with smooth, conical-tip trocars that push the vessel out of the way [50]. Partial lacerations of the inferior epigastric artery vessels may not spontaneously stop bleeding, because the vessel is tethered and cannot retract and spasm. Similar to the inferior epigastric vessels, other abdominal wall vessels can be injured, particularly if the trocar is not placed under direct vision, and if secondary trocars are placed without prior transillumination of the abdominal wall to identify their presence.

Bleeding due to a vascular injury at a port site may not be observed with the port site cannulas in place and the abdomen insufflated due to tamponade. Delayed bleeding can occur after the patient has been transferred from the operating room, typically within one hour [51]. However, delayed abdominal wall hematomas can present two or three days after surgery. Clinical manifestations include abdominal wall pain, abdominal wall or flank ecchymosis, and external bleeding from a trocar site. Patients can also present initially with hemodynamic instability due to significant blood loss from a port site that bleeds internally.

Patients with an abdominal wall hematoma from laparoscopic access who are hemodynamically stable and with no signs of hematoma expansion can be managed conservatively (image 1). The hematoma may drain spontaneously through one or more port sites. Intervention is indicated if the hematoma expands, the patient becomes hemodynamically unstable, or the hematoma becomes infected. For some patients, percutaneous embolization of the bleeding vessel may be an option; however, rapidly expanding hematomas leading to hemodynamic instability or infected hematomas are more effectively managed using an open surgical approach.

Major vessels — Rarely, injury to a major retroperitoneal vessel occurs, with incidences ranging from 0.1 to 1.0 percent [23,24,26,27,39,52]. Injury to major venous structures (eg, inferior vena cava, iliac vein) can also occur, and massive air embolism has also been reported due to unrecognized intravenous placement of a pneumoperitoneum needle and subsequent gas insufflation [27].

Major vascular injuries may occur due to a lack of appreciation for the proximity of important vascular structures to the anterior abdominal wall [3]. The distance from the anterior abdominal wall to the aorta can be as little as 2 cm in thin individuals [53]. The distal aorta, which lies directly beneath the umbilicus, and right common iliac artery, which crosses the midline, are each particularly prone to injury. Techniques for minimizing vascular injuries are discussed in detail elsewhere. (See "Abdominal access techniques used in laparoscopic surgery", section on 'Choice of technique'.)

Injury to the aorta or iliac vessels during abdominal access can lead to rapid exsanguination and death unless prompt vascular control and repair are undertaken [10,54]. Major vascular injuries may be recognized immediately by observing free blood in the abdominal cavity. However, vascular injury may not be appreciated right away, due to bleeding into the mesentery or retroperitoneum rather than into the peritoneal cavity. Managing injury to a major vessel requires subspecialty expertise, and consultation with a surgeon experienced with vascular procedures should be obtained without delay. The anesthesia team should be immediately notified that there is a problem. For patients in lithotomy position (eg, gynecologic, rectal surgery), it is advisable to maintain the extremities in an elevated position to minimize hypotension. For upper abdominal procedures for which the patient has been placed into reverse Trendelenburg position, the bed should be flattened, or placed into Trendelenburg position, as needed. If a vascular or trauma surgeon is not immediately available (community facility, ambulatory surgery center), we advocate a damage control approach as used in trauma surgery [27]. To minimize ongoing blood loss, the abdomen should be rapidly opened with a midline incision, pressure should be applied directly to the bleeding site for initial control, and the abdominal cavity can be packed, if needed. These maneuvers allow for fluid resuscitation while awaiting the vascular or trauma surgeon, or arrangements for immediate transfer if subspecialty expertise is not available. Techniques for packing the abdomen in the setting of acute hemorrhage are discussed elsewhere. (See "Surgical management of splenic injury in the adult trauma patient", section on 'Packing' and "Overview of damage control surgery and resuscitation in patients sustaining severe injury", section on 'Damage control laparotomy'.)

Management of hemorrhage — Prevention of bleeding by meticulous hemostasis during dissection is a fundamental principle of laparoscopic surgery. The identification of significant hemorrhage should prompt the surgeon to immediately notify the anesthesiologist for fluid resuscitation, transfusion, or potential need to convert to an open procedure.

When significant hemorrhage occurs during the course of laparoscopic surgery, it is often due to a technical error, such as inadvertent cautery away from the field of dissection; excessive thermal spread; improper staple length, height, or stapling technique; or failure to recognize a significant vascular structure prior to its division with nonvascular stapling instrument.

Mild-to-moderate bleeding can often be controlled with compressive maneuvers. Local compression allows a surgeon time to consider strategies for definitive hemostasis and may, in itself, be a definitive treatment. Most small to medium-sized vessels will spasm, and bleeding slows and often stops altogether with simple compression. To provide local compression, a gauze sponge can be passed through a 10 mm port to compress the identified area of bleeding. Soaking the sponge with dilute (1:10,000 or 1:100,000) epinephrine has also been described for controlling bleeding during laparoscopic cholecystectomy [55] and laparoscopic Heller myotomy [56]. Under some circumstances, a piece of healthy and mobile omentum can be grasped and used to compress the area. This technique is useful for sudden, significant bleeding from division of the short gastric arteries during laparoscopic fundoplication or laparoscopic splenectomy.

Dry hemostatic agents (eg, Surgicel, Gelfoam) can easily be passed through a laparoscopic port and used in conjunction with mechanical compression. Fibrin glue (with the aid of a special laparoscopic applicator) has also been used to provide hemostasis during liver biopsy [57], splenic surgery for trauma [58], partial nephrectomy [59], and gastric bypass [60,61]. Topical hemostatic agents are discussed in detail elsewhere (table 1). (See "Overview of topical hemostatic agents and tissue adhesives".)

Once bleeding has slowed or ceased, the area is inspected to identify the bleeding point, which is isolated and controlled with a clip, suture, cautery, or any of the other methods described above. The field should then be irrigated carefully with saline. Irrigation should be used judiciously to minimize soiling of the tip of the laparoscope with blood and other fluids.

Conversion to an open procedure — The need to convert to an open procedure due to bleeding is determined by the rate of bleeding, the amount of blood loss, the clinical status of the patient (tachycardia, hypotension, sepsis), the presence (or lack) of a clearly defined source, and the comfort of the surgeon with his or her ability to see and control the bleeding quickly using laparoscopic techniques. Patient factors such as advanced age or poor functional status and comorbidities (cardiopulmonary conditions, obesity, cirrhosis, clotting disorders) should be taken into account when determining whether laparoscopic attempts at hemostasis are likely to be successful and deciding how long to persist.

When moderate-to-heavy bleeding occurs, vision can be obscured when blood on the inside of the port repeatedly contacts the tip of the cleaned scope each time it is reinserted. A long cotton-tipped applicator can be used for cleaning the inside of a 5 mm port, but removal or replacement of the port may be needed. If adequate visibility cannot be maintained, conversion to an open procedure will be needed.

The decision to convert for bleeding is justifiable and prudent. An important source of patient morbidity results from the failure to convert to an open procedure in a timely fashion when bleeding is encountered. Laparoscopic hemostasis that is partially effective or ineffective can lead to significant blood loss and its associated clinical consequences.

It is important to be vigilant about the possibility of injury to local anatomic structures when attempting to control bleeding. As an example, during laparoscopic cholecystectomy, efforts to control a bleeding artery without adequate visibility can lead to application of a clip to the common bile duct or right hepatic artery [62]. Extensive monopolar electrocautery in this region can also result in a thermal injury to the bile ducts or duodenum [63]. (See "Complications of laparoscopic cholecystectomy".)

Gastrointestinal puncture — Bowel injury is the third leading cause of death, after anesthesia and major vascular injury, following a laparoscopic procedure [36]. Until a landmark study, most intestinal injuries during laparoscopy were incorrectly attributed to electrosurgery but were in actuality due to pneumoperitoneum needle (eg, Veress) or trocar placement [64]. Injury to the gastrointestinal tract occurs in 0.03 to 0.18 percent of patients undergoing laparoscopic surgery [24,40,41,44,45,65]. Thirty to 50 percent of inadvertent bowel injuries occur during abdominal access [1,25,66-68].

The small bowel is the most commonly injured gastrointestinal structure during abdominal access for laparoscopic surgery, but stomach, liver, and colon injuries have been reported when subcostal access techniques are used [25,34,69]. Decompressing the stomach with an orogastric or nasogastric tube prior to upper abdominal access may minimize the potential for inadvertent stomach injury.

The incidence of bowel injury related to abdominal access is variable depending upon the procedure.

- In one large retrospective review of gynecologic surgeries, approximately one-third of bowel injuries occurred during abdominal access, and the remaining two-thirds resulted from dissection, electrocoagulation, or tissue grasping [47].
- In a retrospective review of 29,966 gynecologic patients, 33 percent of intestinal injuries were sustained during the insertion of a pneumoperitoneum needle, 50 percent during placement of the umbilical trocar, and 17 percent during placement of a secondary trocar [65].
- The incidence of intestinal injury following laparoscopic cholecystectomy is very low, ranging from 0.05 to 0.3 percent [23,37,70].
- Five cases of intestinal perforation from a pneumoperitoneum needle or cannula were identified in a systematic review of 54 studies on laparoscopic hernia; there were no mortalities [71]. The occurrence of gastrointestinal injury with laparoscopic antireflux procedures is similarly low [72].

Many bowel injuries go unrecognized, and, consequently, the patient can present postoperatively with or without peritonitis, often following discharge. The absence of peritoneal signs does not rule out the possibility of bowel perforation and spillage of gastrointestinal contents within the peritoneal cavity. Delayed diagnosis of an access-related gastrointestinal injury is a significant cause of morbidity and mortality and a major reason for legal action in the United States [73]. In a review of 21 studies of bowel injuries sustained during laparoscopic urologic surgery, the incidence of bowel injury among 14,447 cases was 0.65 percent [74]. Nearly one-half of the injuries were not recognized at the time of the surgery. No patient with bowel injury that was recognized intraoperatively sustained a postoperative adverse event, whereas patients with unrecognized injury and presenting in a delayed fashion required multiple procedures to manage the injury. In an analysis over time, the percentage of unrecognized bowel injuries decreased from 70 percent in earlier years to 37 percent [74].

An open technique for laparoscopic abdominal access might be expected to decrease the incidence of bowel injury; however, some have reported a higher incidence of bowel injury with open compared with closed techniques. One large retrospective review reported an incidence of 0.4 percent for Veress techniques and 1.1 percent for the open technique [4]. A possible reason for a higher incidence may be a selection bias as some surgeons reserve open access techniques for patients anticipated to have complicated entry (eg, adhesions). (See "Overview of gynecologic laparoscopic surgery and non-umbilical entry sites", section on 'Choice of access site and techniques'.)

Gastrointestinal injury should be managed when recognized. Iatrogenic small and large bowel injuries are managed as with other traumatic intestinal injuries, based upon the grade of injury (table 2). Injuries due to the pneumoperitoneum needle (eg, Veress) may be able to be managed conservatively. Most other trocar punctures require simple primary closure, reapproximating the bowel wall with simple sutures in one or two layers. For discrete large bowel injuries, colostomy is rarely needed. If the operating surgeon is inexperienced or uncomfortable performing such a repair, we advise consultation with a surgeon experienced with bowel surgery. (See "Traumatic gastrointestinal injury in the adult patient", section on 'Repair by injury grade'.)

Bladder puncture — Bladder injury is a rare but reported injury during abdominal access for laparoscopy. A history of prior pelvic surgery increases the risk of bladder injury [75]. Injury to the bladder is more commonly associated with primary or secondary trocar insertion, rather than related to dissection during the course of the operation.

In general, puncture of the bladder results when a midline, suprapubic trocar is placed in a patient with an overdistended bladder. In a survey of 407 obstetrician-gynecologists in Canada involving 136,997 patients, there were eight bladder injuries [45]. Four occurred with the pneumoperitoneum needle, two with the primary trocar, and two with the secondary trocar.

When anticipating port placement below the level of the umbilicus, a Foley catheter should be placed to decompress the bladder. Although it is commonplace for patients to void immediately before the procedure, it is safer to drain the bladder with a catheter after the induction of anesthesia [3]. The catheter can also provide a means for early recognition of this complication. Clinical signs of bladder injury include gaseous distention of the urinary drainage bag and bloody urine [48,76]. If a bladder injury is suspected, instillation of indigo carmine or methylene blue into the bladder may aid in identifying an injury.

If the bladder is punctured with a pneumoperitoneum needle (eg, Veress), repair is generally not needed. Small 3 to 5 mm punctures in the dome of the bladder generally resolve spontaneously with bladder decompression for 7 to 10 days [75]. Larger or irregular defects will require a suture closure with absorbable sutures using an open or laparoscopic approach [77]. The Foley catheter should be left in place for 4 to 10 days depending on the size and location of the puncture or tear. If the operating surgeon is unsure of bladder management, urology consultation should be obtained.

Nerve injury — The location of port sites should be chosen to avoid abdominal wall nerves (figure 1). (See "Abdominal access techniques used in laparoscopic surgery", section on 'Abdominal wall anatomy' and "Anatomy of the abdominal wall".)

Procedure-specific dissection should keep neighboring nerves in mind to minimize injury. Nerve injury is not likely to be recognized intraoperatively and can result in persistent postoperative pain. (See "Nerve injury associated with pelvic surgery" and "Post-herniorrhaphy groin pain".)

Hernia

Port-site hernia — Port-site hernia following laparoscopic surgery is less common compared with incisional hernia occurring after open surgery [52,78-83]. One study evaluating the risk for late-onset hernia following a variety of open and laparoscopic surgeries reported incidences of incisional hernia at 1.9 and 3.2 percent at two and five years after laparoscopic surgery, respectively [84]. By comparison, the incidence of incisional hernia for open surgery was 8 and 12 percent, respectively.

In a survey of members of the American Association of Gynecologic Laparoscopists, the incidence of port-site hernia was reported at 0.21 percent. Eighteen percent of these hernias occurred in spite of fascial closure [85]. Other reviews in gynecology have reported similar findings [86,87]. In a systematic review of port-site hernia following laparoscopic cholecystectomy, an overall incidence of port-site hernia was 1.7 percent, with incidences ranging from 0.3 to 5.4 percent [88]. Later studies have reported similar results [89,90]. The incidence of port-site hernia for laparoscopic antireflux procedures is more difficult to determine, as reporting it is more sporadic.

Trocar/port diameter and access technique can affect the rate of hernia formation. Port-site hernia appears to be related to more complex procedures that require multiple ancillary ports and larger-diameter ports used for specimen removal, stapling devices, and single-site surgery [91]. A study comparing single-site and multiport laparoscopy found an increased risk for hernia in patients who underwent single-site surgery, which requires a larger port [92]. The use of port devices designed to minimize leakage of insufflated air (eg, fascial screws) also increases the incision size and may damage fascial tissue, increasing the risk for port-site hernia. Other factors include older age and higher body mass index. Increased operative times and excess tissue manipulation may also lead to fascial weakening.

With the use of trocars ≤12 mm, radially dilating trocars, or bladeless trocars, the risk of developing incisional hernia is low [78,86,87,91]. However, although uncommon, hernia has been reported for 5 mm trocar sites. Most authors close fascial defects if a port >12 mm is used, regardless of site or trocar/port type, and some advocate repairing port sites ≥10 mm [78,91,93-96]. However, in spite of primary fascial closure of port sites ≥10 mm, hernia is still reported (see "Abdominal access techniques used in laparoscopic surgery", section on 'Fascial closure'). Most surgeons advocate at a minimum closing trocar sites ≥15 mm or those used for specimen extraction.

When port-site hernia is identified following laparoscopy, the site should be repaired to prevent the development of intestinal complications (ie, obstruction, strangulation) [96]. The management of incisional hernias is discussed in detail elsewhere. (See "Overview of abdominal wall hernias in adults".)

Clinical manifestations of port-site dehiscence/hernia include gross disruption of the wound with drainage, presence of a bulge with exertion or Valsalva, or painful continuous bulge if bowel or omentum is incarcerated. The patient can also present with clinical signs of bowel obstruction or infarction. (See "Etiologies, clinical manifestations, and diagnosis of mechanical small bowel obstruction in adults".)

Extraction-site hernia — In complex laparoscopic gastrointestinal or gynecologic surgery, one or more surgical specimens may require an extended incision for specimen extraction. Incisional hernias could develop at the specimen extraction site, the risk of which is correlated with their location.

In a single-center retrospective study of 2148 patients undergoing laparoscopic colorectal resection, a variety of extraction sites were used at the surgeon's discretion, including infraumbilical midline (24 percent), stoma site in the left or right lower quadrant (15 percent), periumbilical midline (23 percent), Pfannenstiel (30 percent), and midline converted (9 percent). At a follow-up of 5.9±3.0 years, the overall extraction-site incisional hernia rate was 7.2 percent. Extraction-site hernias were most common at periumbilical midline (13 percent) and midline converted (12 percent) locations and least common at the Pfannenstiel location (0.9 percent). Besides location of the extraction site, other risk factors include obesity (hazard ratio [HR] 1.23), concurrent port-site hernia (HR 3.66), and postoperative surgical site infection (HR 2.11). Thus, whenever feasible, an extraction site that is off the midline, such as Pfannenstiel, should be selected to minimize the risk of extraction-site hernia.

Surgical site infection — Wound infection is less common following laparoscopic compared with open procedures; nonetheless, it can produce significant morbidity [97]. The presence of significant peri-incisional erythema, wound drainage, and fever may indicate the development of a necrotizing fascial infection [98-100]. The diagnosis and management of necrotizing fasciitis is discussed in detail elsewhere. (See "Necrotizing soft tissue infections".)

Although the umbilicus is more commonly associated with surgical site infection than other trocar sites, this finding correlates with the use of the umbilicus as a specimen extraction site [101]. The incidence of wound infections can be minimized by appropriate administration of prophylactic antibiotics, sterile technique, and use of bags during specimen extraction. Once established, surgical site infection is treated with drainage, packing, and appropriate antibiotics. (See "Antimicrobial prophylaxis for prevention of surgical site infection in adults" and "Complications of abdominal surgical incisions".)

RELATED TO PNEUMOPERITONEUM Complications related to insufflation of gas needed to create pneumoperitoneum include subcutaneous emphysema, mediastinal emphysema, pneumothorax, cardiac arrhythmia, carbon dioxide retention, postoperative pain related to retained intra-abdominal gas, and air embolism due to venous injury. (See 'Vascular injury' above.)

The first two of these (subcutaneous and mediastinal emphysema) are due to insufflation of an improperly positioned pneumoperitoneum needle (eg, Veress) or port. Methods to prevent this complication during initial abdominal access are discussed elsewhere. (See "Abdominal access techniques used in laparoscopic surgery", section on 'Peritoneal access'.)

Other complications (eg, pneumothorax, cardiac arrhythmia, carbon dioxide retention) are related to the physiologic effects of insufflation. Patients who have poor cardiopulmonary reserve are not likely to be offered a laparoscopic procedure, and thus these complications are uncommon. Physiologic effects and related complications of pneumoperitoneum are reviewed in detail separately. (See "Anesthesia for laparoscopic and abdominal robotic surgery in adults", section on 'Physiologic effects of laparoscopy' and "Anesthesia for laparoscopic and abdominal robotic surgery in adults", section on 'Intraoperative complications'.)

Some degree of postoperative abdominal or shoulder pain can be expected after laparoscopic surgery and is related to retained CO_2. It is generally considered a referred pain due to irritation of the diaphragm. Intraoperative measures to minimize pneumoperitoneum-related pain are discussed elsewhere. (See "Abdominal access techniques used in laparoscopic surgery", section on 'Minimizing access-related pain'.)

COVID-19 precautions — Open and minimally invasive surgery can both produce aerosolized particulate. Previous research has shown that laparoscopy can pose a threat to surgeons and other operating room personnel by aerosolization of bloodborne viruses, including HIV (human immunodeficiency virus), hepatitis B virus, and human papillomavirus [102].

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which is causing the COVID-19 pandemic, has been identified in the blood and feces of infected patients [103] but not yet in smoke/aerosol [104]. Although some studies failed to detect the virus in peritoneal fluid [105], abdominal, or adipose tissue samples [106] of patients with active COVID-19 infection, at least one report has detected, by reverse transcriptase–polymerase chain reaction, the SARS-CoV-2 virus in the peritoneal fluid of a patient who underwent emergency abdominal surgery, and the viral load in the peritoneal fluid was higher than that detected in the upper respiratory material from the same patient [107]. (See "COVID-19: Epidemiology, virology, and prevention".)

In communities where SARS-CoV-2 infection is prevalent, the American, European, and Canadian societies for laparoscopic surgeons have suggested that symptomatic patients be tested for SARS-CoV-2 infection, smoke plume generated by electrosurgery be minimized, devices be used to filter released carbon dioxide for aerosolized particles, and personnel attending laparoscopic procedures be protected at minimum by N95 masks and face shields, among other personal protective equipment [108-110]. Additional information on smoke evacuation and filtration systems can be found elsewhere [111,112]. These recommendations are also consistent with those of the Royal College of Obstetricians & Gynecologists [113] and the American College of Surgeons [114].

As there can be serious consequences of perioperative SARS-CoV-2 infection, the AAGL [108] and Society of American Gastrointestinal and Endoscopic Surgeons (SAGES)/European Association for Endoscopic Surgery (EAES) [109] also recommend that such patients be treated medically and invasive procedures be deferred until the SARS-CoV-2 infection has been fully treated, if possible [115,116].

RELATED TO TISSUE DISSECTION AND HEMOSTASIS Electrosurgical injuries can occur during laparoscopic surgery and are discussed below. The principles of electrosurgery and prevention of electrosurgical complications during surgery, in general, are reviewed separately. (See "Overview of electrosurgery".)

Although vascular injuries are more commonly related to abdominal access, vascular injury related to the dissection phase of laparoscopic surgery can occur. Injuries to the inferior vena cava, the left hepatic vein, abdominal aorta, and inferior phrenic vessels have been reported following laparoscopic antireflux procedures [117,118].

Gastrointestinal injury — Bowel injury is a serious complication because it can be missed at the time of the initial laparoscopy, and a delayed diagnosis increases the risk of bowel necrosis, perforation, and potentially death [119].

Once pneumoperitoneum has been established, injury to the bowel can result from electrosurgical injury or trauma during dissection or manipulation. In one large retrospective review of gynecologic surgeries, approximately one-third of bowel injuries occurred during abdominal access, and the remaining two-thirds resulted from dissection, electrocoagulation, or tissue grasping [47]. Symptoms related to gastrointestinal injury generally manifest within 12 to 36 hours postoperatively, but the presentation can be delayed for up to five or seven days.

If a patient does not gradually improve following laparoscopic surgery and continues to have abdominal pain, especially if associated with tachycardia or fever, bowel injury should be suspected and evaluation undertaken. (See "Overview of gastrointestinal tract perforation".)

Although demonstration of free intra-abdominal air on imaging studies is a sign of gastrointestinal injury, this sign may **not** be helpful after laparoscopic surgery, because approximately 40 percent of patients will have more than 2 cm of free air at 24 hours postlaparoscopy, despite lack of any clinical evidence of bowel perforation [120]. Free intra-abdominal air often may be seen on a radiograph up to one week postoperatively, but the volume should gradually decrease with time. Increasing amounts of intra-abdominal air during a period of observation is concerning, and a finding of increasing free intra-abdominal air suggests ruptured viscus until proven otherwise.

Electrosurgical injuries identified in the operating room should be inverted and oversewn to healthy tissue at the margins, or resected with a 1 to 2 cm margin around the injury site [121-127]. It is important to remember that the visible thermal injury is always less than the actual injury. Resection is a reasonable approach if the electrosurgical injury is a significant size and there is any risk of not getting a healthy tissue margin. (See "Overview of gastrointestinal tract perforation".)

In a systematic review of robotic gynecologic surgery literature, the overall incidence of bowel injury was 1 in 160 [128]. The most common location was in the colon and rectum. Most injuries were managed via a minimally invasive approach.

Urinary tract injury — As a consequence of laparoscopic surgery, the bladder is more typically injured during the insertion of trocars; however, thermal injury to the bladder during dissection (eg, laparoscopic hysterectomy, thermal destruction of endometriosis, low anterior resection) can also occur [75,129-131]. (See 'Bladder puncture' above.)

The incidence of bladder injury varies widely depending upon the type of surgery being performed but in general is less than 0.5 percent [132,133]. This type of injury is most likely to occur during pelvic procedures, such as gynecological and urologic procedures, although it can also happen during inguinal hernia repair, diagnostic laparoscopy, or appendectomy. Bladder injury that appears to have resulted from dissection or electrocoagulation during laparoscopic herniorrhaphy has also been reported [38,52,83,134,135]. The management of the bladder injuries can range from simple catheterization to laparotomy depending upon the severity of the injury.

Ureteral injury occurs in less than 2 percent of pelvic procedures and can result from pelvic dissection during the course of distal colon/rectal, gynecologic, or urologic surgery [136-142], or as a result of thermal injury by excessive use of an energy source adjacent the ureter.

If pelvic dissection is anticipated to be in an inflamed operative field or reoperative field, ureteral stents can be used to help identify the ureters to minimize ureteral injury; however, injury can still occur with a prophylactic stent in place. The best means of preventing inadvertent ureteral injury is identification of the ureter during the procedure using anatomic landmarks and observation of peristalsis [48]. With complex surgeries or where anatomy is unclear, dissection and mobilization of the ureter may be needed. At the conclusion of any laparoscopic procedure in which the operative field is in the vicinity of the ureter(s), the surgeon should confirm and document the integrity of the ureters before closing. (See "Placement and management of indwelling ureteral stents", section on 'Prophylactic' and "Urinary tract injury in gynecologic surgery: Epidemiology and prevention".)

In one meta-analysis of the gynecologic literature, routine cystoscopy increases the intraoperative but not postoperative detection rate of urinary tract injury [143]. The evaluation and management of urinary tract injury is discussed in detail elsewhere. (See "Urinary tract injury in gynecologic surgery: Identification and management" and "Surgical repair of an iatrogenic ureteral injury".)

OTHER COMPLICATIONS

Port site metastasis — Port site metastasis refers to cancer growth at a port incision site after laparoscopic tumor resection [144]. Port site metastasis occurs after 1 to 2 percent of laparoscopic procedures performed in the presence of intraperitoneal malignancy, which is equivalent to the rate of wound metastasis after laparotomy performed under similar conditions [145]. Port site metastasis has been observed in as little as 10 days following laparoscopy.

Purported mechanisms include hematogenous spread or direct contamination by tumor cells, secondary effects from pneumoperitoneum (eg, immune suppression), and surgical technique [145,146]. Although it is not clear whether port site metastases can be prevented, suggested measures to minimize the risk of port site metastases include the use of wound protectors and specimen extraction bags, instillation of agents to prevent tumor growth, and port-site excision.

Vulvar edema — There have been a few case reports of unilateral vulvar edema after operative laparoscopy. The mechanism is unclear, but the condition is self-limited and resolves with conservative management (ice packs, bladder catheterization, analgesia) [147,148]. However, swelling in this setting can also be related to vascular bleeding and may require intervention [149].

SOCIETY GUIDELINE LINKS Links to society and government-sponsored guidelines from selected countries and regions around the world are provided separately. (See "Society guideline links: Laparoscopic surgery".)

SUMMARY AND RECOMMENDATIONS

●Laparoscopic techniques have revolutionized the field of surgery. Before any laparoscopic procedure can begin, the peritoneal cavity needs to be accessed to establish pneumoperitoneum and place ports for the laparoscope and various laparoscopic instruments. Most complications related to laparoscopic surgery occur during abdominal access, but other complications can occur related to abdominal insufflation and tissue dissection. The overall rate of these complications is low. (See 'Introduction' above and 'Epidemiology and risk factors' above.)

●Proper selection of patients, knowledge of surgical anatomy, and attention to proper abdominal access techniques may help to avoid complications. Risk factors for complications include prior surgery/abdominal adhesions, excessive bowel distention, very large abdominal or pelvic masses, and diaphragmatic hernia. Patients with poor cardiopulmonary reserve may not tolerate pneumoperitoneum. For patients with risk factors for laparoscopic complications, an open surgical approach may be preferred. (See 'Risk factors' above.)

●Vascular injury most commonly occurs during abdominal access and is second only to anesthesia as a cause of death from laparoscopy. The most common vascular injury overall is laceration of the inferior epigastric artery, but injuries to major vascular structures can occur and are life-threatening injuries. Vascular injury may not be immediately appreciated during laparoscopy, because bleeding can be retroperitoneal, rather than into the peritoneal cavity, or tamponaded by a port. When minor abdominal wall vessel injury is unrecognized, an abdominal wall hematoma may occur, most of which can be managed conservatively. When major vascular injury is identified, consultation with a surgeon experienced with vascular procedures should be obtained without delay. (See 'Vascular injury' above.)

•Significant hemorrhage during the course of laparoscopic surgery can often be attributed to a technical error such as inadvertent cautery away from the field of dissection; excessive thermal spread of electrocautery; improper staple length, height, or stapling technique; or failure to recognize a significant vascular structure prior to its division with a nonvascular stapling instrument. As in open surgery, mechanical compression and application of topical hemostatic agents are appropriate initial strategies. Moderate bleeding during laparoscopic surgery can be controlled with clips, suture ligation, or electrosurgical methods depending upon the source of bleeding and nature of surrounding tissues. (See 'Management of hemorrhage' above.)

•An important source of patient morbidity results from the failure to convert to an open procedure in a timely fashion when control of bleeding is challenging. Laparoscopic hemostasis that is partially effective or ineffective can lead to significant blood loss and its associated clinical consequences. (See 'Conversion to an open procedure' above.)

●Injury to the bowel can relate to initial abdominal access or during the course of the operation due to electrocautery, or tissue trauma during dissection. The small bowel is the most commonly injured gastrointestinal structure during laparoscopic surgery, but stomach, liver, and colon injury can also occur. The frequency of gastrointestinal injury depends upon the nature of the procedure. Injury to the stomach can be minimized by maintaining stomach decompression with a nasogastric or orogastric tube during the procedure. Any patient who does not gradually improve or who continues to have abdominal pain following laparoscopic surgery should be evaluated for possible gastrointestinal injury. (See 'Gastrointestinal injury' above.)

●Injury to the bladder most commonly occurs during abdominal access rather than during the course of dissection. A history of prior pelvic surgery increases the risk of bladder injury. The risk of bladder injury can be minimized by catheterizing the patient prior to the procedure. (See 'Bladder puncture' above and 'Urinary tract injury' above.)

●Port-site hernia is less common compared with incisional hernia occurring after open surgery. The risk of port-site hernia is increased with larger-diameter ports (≥12 mm), such as those used for specimen removal, stapling devices, and single-site surgery. (See 'Hernia' above.)

●Other complications of laparoscopic surgery include nerve injury, surgical site infection, upper urinary tract injury, and port site metastasis. (See 'Nerve injury' above and 'Surgical site infection' above and 'Urinary tract injury' above and 'Port site metastasis' above.)

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