32 Complications of Laparoscopy

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Introduction

Since its inception more than a century ago when Dr. Hans Christian Jacobaeus performed the first laparoscopy on a human patient [1], laparoscopy and minimally invasive surgery have transformed medicine in a quest to continuously evolve by improving diagnostic capabilities and offering management of complex ailments in a variety of different specialties. Gynecologists pioneered the specialty of minimally invasive surgery and are credited with its wide acceptance. This movement was fueled by the need to reduce morbidity and mortality related to surgical procedures. For example, in the eighteenth century, hysterectomies had a reported mortality rate of 70%, but with significant advances in aseptic techniques, use of antibiotics and anesthesia, and minimally invasive technique, mortality rates today are less than 0.02% [2].

It is important to be able to classify and define complications in a clear and concise manner. Although there is some variation in the literature, the most commonly accepted definition of complication is "an unintended and undesirable event or condition during or following medical intervention, to such an extended disadvantage to the patient's health condition that adjustment of medical intervention is necessary, and/or irreparable damage has occurred" [3]. Overall complication rates for gynecologic laparoscopy have remained at <1% for several decades [4–7] with an overall mortality rate of 3.33 per 100,000 patients [5].

This chapter is designed to discuss possible complications related to laparoscopic surgery from the time of abdominal access to the postoperative period. Mastery of surgical technique, superior anatomical knowledge, and a continuous quest to improve are essential tools for all surgeons, while prevention remains the most important factor in avoiding complications. Early recognition and management of complications in a timely, safe, and efficient fashion is the key to overcoming the pitfalls of laparoscopy.

Complications from Abdominal Wall Entry and Port Placement

Complications occurring during abdominal wall entry are among the more common causes of surgical injury during laparoscopy. Prospective studies have shown that up to one-third to one-half of complications occur at time of abdominal entry [5, 8, 9], occurring with an incidence of 1.1–5.5 per 1000 cases [6, 10, 11]. Many techniques have been described for abdominal wall

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entry including closed (Veress) entry, open (Hassan) entry, direct entry, direct visualization entry, and radially expanding entry. Retrospective and prospective studies have shown no significant differences in major complication rates between each entry technique; thus there is no clear consensus as to the superior method of laparoscopic entry into the peritoneal cavity [12], and entry technique should be determined by surgeon training and experience. Regardless of entry approach, there are innate risks associated with the surgical requirement for introduction of trocars through the anterior abdominal wall. The most common complications associated with abdominal wall entry include failure to gain abdominal entry, extraperitoneal insufflation, gas embolism, abdominal wall vessel and nerve injury, bowel injury, bladder injury, and major vascular injury [13].

Failure to Gain Entry

Failed entry seems to be most likely in the closed (Veress) entry technique with rates as high as 0.06% [12] and is more common in the setting of previous abdominal surgery with subsequent adhesive disease. A failed entry site should routinely be inspected to assess for injury. If bile, stool, or blood returns at placement of the Veress needle or initial trocar, the device should be left in place, and alternative access gained immediately. If entry fails but there is no complication, access can be reattempted at the same site [14]. Alternative access type (laparoscopic or open laparotomy) should be based on the surgeon's ability to perform corrective procedures and degree of bleeding if a vascular injury is suspected (see section "Major Vascular Injury" below).

Extraperitoneal Insufflation

Extraperitoneal insufflation, or inadvertent creation of an air pocket external to the peritoneal layer, is an uncommonly reported complication of laparoscopy, occurring with a frequency of 0.001–0.59% of laparoscopic cases [13], although it is probably underreported because of its limited clinical significance. It is most likely to occur with a closed abdominal entry technique [15, 16] when entry into the peritoneal cavity is not visually confirmed prior to flow of carbon dioxide (CO_2) for establishment of pneumoperitoneum. It can result in difficult or failed abdominal entry or poor operative visualization after identification and correction because of the distention of subcutaneous tissue the anterior abdominal wall. Mild to severe subcutaneous emphysema is also a known complication, and subcutaneous emphysema can extend into the labia, scrotum, legs, chest, head, and neck when gas tracks along the prefascial planes [17]. It presents as crepitus under the skin or slowly rising CO_2 level intraoperatively and typically resolves within 1–2 days [18]. Severe subcutaneous emphysema, while rare, is associated with serious complications such as pneumothorax, pneumomediastinum, pneumopericardium, and hypercarbia [19, 20]. These outcomes may be a result of direct ascension of extraperitoneal gas or a result of passage of gas through congenital defects of the diaphragm [21]. These complications are more likely in the setting of longer operative time (>200 min), higher maximum measured end-tidal CO(2), greater number of surgical ports (>6), and older patient age (>65 years) [22].

Gas Embolism

Carbon dioxide is the best gas for pneumoperitoneum insufflation as it is nontoxic, nonflammable, colorless, highly soluble, easily buffered in the blood, and rapidly excreted through the lungs [19, 21]. Subclinical carbon dioxide embolism is common, occurring with a frequency of 100% in a recent study using continuous transesophageal echocardiography during total laparoscopic hysterectomy [23]. However, clinically relevant carbon dioxide embolism is an uncommon, often fatal risk of laparoscopic surgery that results from direct entry of the gas into a vein, artery, or solid organ [24]. The incidence of clinically significant carbon dioxide embolism is rare, ranging from 0.001 to 0.59% [25–27] but with a mortality rate of 28.5% [28]. Gas embolism usually occurs during or soon after insufflation and presents as sudden onset of tachycardia or bradycardia, systemic hypotension, cyanosis, arrhythmia, or asystole [24].

When a carbon dioxide embolism is suspected based on timing of cardiovascular collapse, a series of steps must be immediately initiated [24]:

1. The surgeon should discontinue carbon dioxide insufflation.
2. The anesthesiologist should discontinue nitrous oxide and ventilate with 100% oxygen to improve ventilation perfusion mismatch and hypoxemia.
3. The patient should be positioned in steep Trendelenburg and left lateral decubitus position to allow gas to rise to the apex of the right atrium (RA) and prevent entry into the pulmonary vasculature.
4. The surgical team should initiate cardiopulmonary resuscitation with:
   (a) Aggressive volume expansion to increase central venous pressure
   (b) Administration of inotropic agents and vasopressors to maintain cardiac output
   (c) Placement of a central venous or pulmonary artery catheterization for aspiration of gas from the RA or right ventricle (RV)
5. If available, consider cardiopulmonary bypass and/or hyperbaric oxygen therapy.

Abdominal Wall Vascular Injury

Abdominal wall injury occurs with an incidence of 0.52% and most often involves laceration of the deep inferior and superficial epigastric vessels during lateral port placement [9]. Serious complications are rare but can lead to transfusion, hematoma, abscess formation, and reoperation to control bleeding [29]. Lateral port placement should be carefully chosen to avoid these vessels with both direct laparoscopic transperitoneal visualization of the path of the inferior epigastric vessels deep to the muscle and fascia along the abdominal wall, transillumination of the superficial epigastric vessels, and a thorough understanding of the anatomic relationship of these vessels along the anterior abdominal wall. Cadaveric dissection, imaging series, and intraoperative mapping studies have shown that the inferior epigastric vessels branch from the external iliac lateral to the medial umbilical ligament and medial to the round ligament and then travel along the anterior abdominal wall 4–8 cm from the midline [30–32]. This distance becomes more lateral, up to 11 cm from the midline, in obese patients and under insufflation [32]. The "safe zone" is generally considered to be >8 cm from the midline at a level superior to the anterior superior iliac spine (ASIS). Choosing appropriate insertion sites based on an understanding of abdominal wall anatomy may minimize the risk of vessel injury; however, because of anatomic variation, strategies for managing abdominal wall vessel injury are required [29].

Abdominal vessel injury may present as oozing or dripping along the shaft of the trocar into the abdominal cavity or may not become apparent until a port is removed because of the tamponading effect of both the trocar and the pneumoperitoneum. If bleeding is identified, electrocautery may be sufficient to control superficial bleeding. However, the injured vessels may retract from the incision, so if bleeding persists, alternative techniques should be immediately employed. A Foley catheter may be inserted through the port site, inflated, and placed on gentle traction for 24 h to tamponade the site. Alternatively, suture ligation of the proximal and distal ends of the vessel may be required. This can be accomplished in several ways: (1) transabdominally, placed 1 cm away from the skin edge with through-and-through sutures (to be removed 12–24 h later); (2) transabdominally with extension of the skin incision, exploration of the incision and deep U-stitches; or (3) laparoscopically with a fascial closure device used within the trocar site [18].

Abdominal Wall Nerve Injury

Abdominal wall nerve injury is an uncommon but recognized complication of laparoscopic surgery. Ilioinguinal and iliohypogastric nerve injury has been reported in up to 3.7% of procedures performed through Pfannenstiel incisions [33] but occurs with low frequency in laparoscopy. This is because the ilioinguinal and iliohypogastric nerves enter the abdominal wall inferior and medial to the ASIS [34], an uncommon location for placement of ports in gynecologic laparoscopy. Thus, abdominal wall surgical sites inferior and medial to the ASIS increase the risk for abdominal wall nerve injury and entrapment [35] and should be avoided.

Intraoperative Complications

Major Vascular Injury (MVI)

A major vascular injury (MVI) is defined as laceration of the aorta, inferior vena cava, or the iliac vessels. Fortunately, the incidence of MVI at the time of laparoscopy is low and ranges from 0.1 to 6.4 per 1000 procedures; however, the mortality rate from these events approaches 12.5% [21]. Most vascular injuries occur at the time of intraperitoneal access and are related to insufflation of the abdomen with a Veress needle (39%) or placement of the primary trocar (37.9%) [36]. MVI can also occur during operative laparoscopy, especially in more complex procedures that require retroperitoneal dissection of vessels and lymph nodes. Most MVIs are arterial in nature involving the aorta or common iliac. Injury to these vessels can lead to severe hemodynamic changes due to voluminous blood loss in a very short period of time. The most commonly affected vein is the inferior vena cava [37].

In a review of nearly 30,000 gynecologic laparoscopic procedures, it was noted that the surgeon's experience was correlated with the overall complication rate but not with the incidence of MVI [5]. This emphasizes the importance of awareness of possible complications regardless of the surgeon's level of expertise. Prevention remains the best recipe: understand the pathology, study the relevant anatomy, review risk factors, and plan the surgical approach carefully prior to entering the operating room.

Immediate recognition of MVI is a key step to improve outcomes. Identification of free blood in the abdominal cavity is appreciated with larger lacerations of one of the major vessels; however, MVIs may not be immediately recognized due to retroperitoneal containment of hemorrhage. In these circumstances, hemodynamic changes may be noted by the anesthesiologist first. A thorough understanding of physiologic/hemodynamic changes that take place during a hemorrhagic event, and clear and immediate communication with all members of the surgical team, is crucial to improve patient outcomes and survival. Identifying a retroperitoneal hematoma, dark venous blood pooling in the abdomen, or bright red pulsatile blood should alert the surgeon that an MVI has occurred (Fig. 32.1), and steps to identify the injury, secure the blood vessel, and control the bleeding should be taken immediately.

It is important to remain calm and help your team understand the urgency of the situation. Immediately notify anesthesia and nursing to prepare for resuscitation efforts, emergency laparotomy, and massive transfusion protocols. Vascular and/or trauma consultants should be called to assist as soon as a MVI is identified. Once your team is appropriately briefed on the urgent nature of the event, proceed with a midline laparotomy, and apply direct pressure to the bleeding site with dry sponges. It is also helpful to have your assistant apply manual compression of the aorta at the level of the esophageal hiatus to decrease blood flow to the injury site. If the site of injury is easily identified, maintain direct pressure on the injured vessel until the vascular surgeon arrives. If a vascular surgeon is not available, pack the abdomen tightly with multiple dry laparotomy sponges, and close the abdomen under tension. Initiate emergency transport to a tertiary medical center.

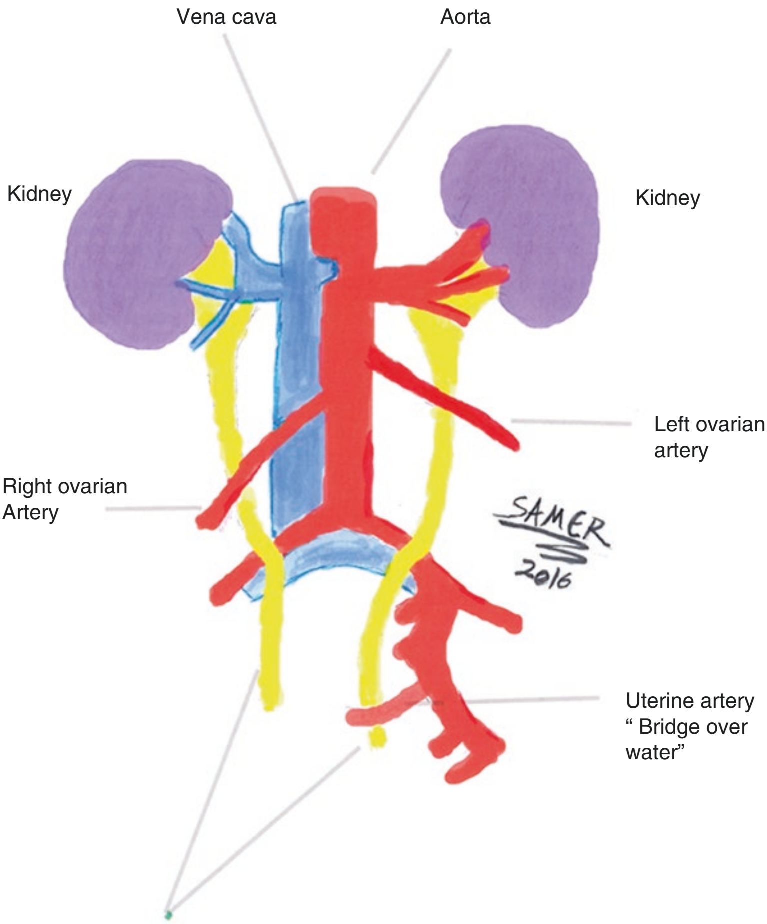

Fig. 32.1 Relationship of the ureter to pelvic vasculature. Note the course of the ureter as it descends over the pelvic brim over the bifurcation of the common iliac. Once it enters the deep pelvis, the ureter travels on the lateral aspect of the uterosacral ligament to then penetrate the base of the broad ligament. It then passes under the uterine artery—"bridge over water"—traveling medially over the anterior vaginal fornix before it enters the trigone

Bowel Injury

Injury to the intestinal tract remains low with an incidence of 0.03–0.18% of all patients undergoing laparoscopic surgery [38], while the incidence in gynecological procedures seems to be higher, ranging from 0.06 to 0.65% [18]. Immediate recognition and management of bowel injury is essential to decrease morbidity and mortality associated with this type of injury. Mortality rates from bowel injury at the time of laparoscopy approach 2.5–5% [21], and in cases of delayed diagnosis, mortality rates approach 28% [18]. Since most bowel injuries are not immediately diagnosed, a worsening postoperative course complicated by pain, fever, leukocytosis, and eventually peritonitis and sepsis should prompt immediate concern and action.

Bowel injury often is a result of a puncture wound with a Veress needle or primary trocar at the time of abdominal wall entry, but it can also take place during adhesiolysis or with the use of electrosurgical instruments. Approximately 50% of all bowel injuries occur at the time of intraperitoneal access, and the vast majority occur in patients who have had prior surgery or adhesive disease.

The key factors in minimizing the likelihood of bowel injury are surgical planning, superior knowledge of surgical anatomy, thorough understanding of the pathology at hand, and respect for the tissue. Intraoperative injury should be immediately recognized and managed. Bowel injury at the time of Veress needle insertion should be suspected when one of the following signs is present: high intra-abdominal pressure (>10 mmHg), aspiration of fecal material, malodorous smell, or asymmetric distention of the abdomen. Routine inspection of the point of entry at time of laparoscopy, a thorough survey of the abdomen and pelvis, as well as the use of intraoperative bowel integrity test, also called a "flat tire" test when sigmoid injury is suspected, are important tools to aid in recognition of bowel injury. The intraoperative bowel integrity test can be easily accomplished by filling the pelvis with water and introducing air into the rectum. The proximal colon can be obstructed with a blunt instrument while introducing air from the distal end. The presence of air bubbles is diagnostic of a sigmoid perforation. Once an intraoperative bowel injury is recognized, repair should take place without delay. The abdomen should be copiously irrigated and intravenous antibiotics initiated. The entire length of the bowel should be inspected to ensure no occult injury exists. The repair will be determined by the type, location, and size of the injury. Injury can be classified as mechanical (needle or trocar) or thermal (electrosurgical) and can be located in the small or large bowel.

Small needle puncture wounds may be managed expectantly, but larger defects need to be repaired. It is acceptable to perform the repair laparoscopically if the surgeon has the expertise and the procedure is technically feasible [39]. Small injuries can be repaired primarily; large lacerations may require segmental resection. Colostomy should only be used in the presence of gross contamination and/or advanced peritonitis as prophylactic colostomy has been shown to increase morbidity without an improvement in anastomotic leaks. Superficial lacerations involving the serosa or submucosal layers can be oversewn with a delayed absorbable suture in a single layer. Deeper lacerations need to be closed in two layers: close the mucosa, submucosa, and muscularis in one layer using a delayed absorbable suture, and follow with interrupted silk sutures including the submucosa to the serosa. Repairs should always be closed transversely to avoid luminal strictures.

Unrecognized bowel injury offers a tremendous increase in morbidity and mortality for the patient. Immediate evaluation of postoperative complaints of pain, fever, nausea, and vomiting is an essential first step. While an unrecognized bowel laceration will usually present within the first or second postoperative days, an unrecognized bowel thermal injury may not present until 7–10 days postoperatively. While symptoms can vary from very mild and nonspecific to severe pain, fever, and ultimately sepsis, it is crucial to critically evaluate all postoperative complaints with an elevated degree of suspicion. Initial evaluation always includes a thorough history and physical exam, laboratory evaluation, and imaging via computed tomography with oral contrast. If the diagnostic tests are inconclusive but clinical findings are suspicious for bowel injury, a diagnostic laparoscopy should be considered.

Urologic Injuries

Injuries to the urinary bladder and ureter occur at a frequency of 0.02–1.7% of gynecologic laparoscopic procedures [21]. As previously discussed, prevention, recognition, and early management of injury are essential to optimize outcomes and minimize morbidity. Failure to recognize bladder or ureteral injury at the time of surgery will inevitably lead to postoperative complications, peritonitis, fistulas, and impaired renal function.

Injury to the bladder occurs at a much higher frequency than injury to the ureters. Types of injury vary depending on complexity of the procedure and surgical experience. The most common type of bladder injury is perforation of the bladder with a Veress needle or placement of suprapubic trocars. Simple steps to minimize injury to the bladder include bladder decompression with a Foley catheter prior to surgical incisions and placement of accessory ports under direct laparoscopic guidance. Needle punctures and small lacerations can be managed conservatively; however, larger lacerations (>10 mm) should be repaired in two layers using a delayed absorbable suture. Integrity of the repair should

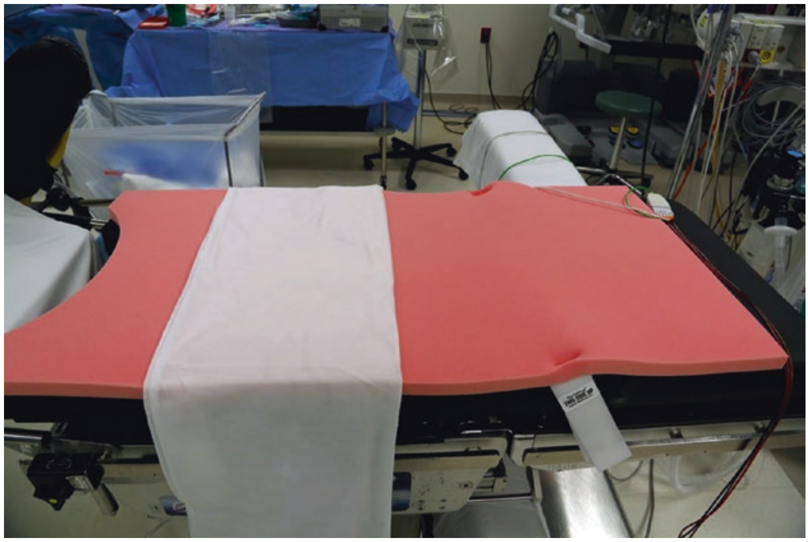

Fig. 32.2 The Pink Pad from Xodus Medical products is placed over the OR table and secured in place with Velcro straps. The drawsheet facilitates tucking of the arms and patient transfer after procedure is completed. The pad is intended for direct contact with patient's skin to eliminate sliding during the procedure

be confirmed by backfilling the bladder and observing for leakage. A Foley catheter should be kept in place for at least 7 days for complex injuries or those located near the bladder trigone. Thermal injury to the bladder can occur when dissecting the bladder from the lower uterine segment. This is more common when dense adhesions are present from prior cesarean sections or in the presence of advanced endometriosis in the anterior cul-de-sac. Meticulous surgical technique that includes releasing the bladder from a lateral to medial approach, utilizing sharp dissection instead of electrocautery, and avoiding blunt dissection techniques will help prevent bladder injury.

Ureteral injuries are infrequent but are associated with due to tremendous morbidity. The ureter can be inadvertently transected, crushed, devascularized, or burned intraoperatively. Risk factors for ureteral injury during laparoscopy include surgeon inexperience, large fibroids, large adnexal mass, severe adhesive disease, and endometriosis. Most ureteral injuries happen at the level of the cardinal ligament or infundibulopelvic ligament but may also occur at the lateral border of the uterosacral ligament, ovarian fossa, and ureteric canal. Understanding the course of the ureter as it descends over the pelvic brim over the bifurcation of the common iliac is essential to prevent injury (Fig. 32.2) and for intraoperative mapping. Once the ureter enters the deep pelvis, it travels on the lateral aspect of the uterosacral ligament to then penetrate the base of the broad ligament. It then passes under the uterine artery—"bridge (*uterine artery*) over water (*ureter*)"—traveling medially over the anterior vaginal fornix before it enters the bladder. Radiologic studies [40] demonstrated that the ureter can be located as close as 5 mm from the cervix. Careful dissection, gentle handling of tissue, and thorough knowledge of pelvic anatomy will help reduce and prevent ureteral injury. Visualization of the ureter is imperative prior to desiccation and transection of tissue. If the surgeon is unable to visualize the ureter vermiculating transperitoneally, a retroperitoneal dissection should be carried out to expose the ureter. Mobilizing the bladder in a caudad fashion away from the cervicovaginal junction, skeletonizing the uterine arteries, and developing a posterior peritoneal reflection will also protect the ureters and bladder. Cephalic displacement of the uterus allows for lateral deviation of the ureters, effectively increasing the distance between the ureters and the cervicovaginal junction.

If a ureteral injury is suspected, prompt evaluation should be undertaken. The surgeon should inspect the ureter as it courses down the pelvic side wall and enters the bladder. Presence of vermiculation does not rule out injury. If a partial or complete transection is identified, extravasation of urine will confirm the diagnosis. When needed, intravenous indigo carmine can be administered to facilitate visualization of the injured area. Ureteric crush injuries and complete obstruction of the ureter by either suture ligation or sealing devices will be identified more readily at the time of cystoscopy by observing a lack of ureteral efflux on the injured side. Treatment of intraoperatively recognized ureteral injury is determined by the type and severity of the injury and its anatomical location. Most commonly, a urologist is consulted to aid in the repair of the ureter. As a rule, it is always preferable to reimplant the ureter rather than to anastomose it due to a lower risk of complications with this approach. It also always more favorable to mobilize the bladder to reach the ureter than to mobilize the ureter to reach the bladder, since the latter may result in ureteral ischemia. By dividing the peritoneum on both sides of the bladder, the bladder can easily reach the end of a transected ureter at the level of the pelvic brim. Severe thermal and crush injuries to the ureter require resection of the affected area and reanastomosis or reimplantation of the resulting segments.

The great majority of bladder injuries are recognized intraoperatively, but similar to bowel injury, ureteric damage is not always diagnosed at the time of surgery, leading to significant delays in management and increased morbidity to the patient. Postoperative complaints of fever, nausea, vomiting, pain, hematuria, abdominal distention/ascites, voiding dysfunction, and leakage of fluid form the incision sites or vagina should immediately raise a concern for a delayed diagnosis of ureteral or bladder injury. These complications often manifest themselves postoperative day 2–7 but can present as late as 33 days postoperatively [41]. Immediate evaluation should be undertaken to determine if an injury has occurred, where it is located, and what the severity is. A renal ultrasound may be performed to identify the presence of hydronephrosis, ureteral dilation, or urine ascites in the abdomen. A urogram (computed tomography) with contrast and a retrograde pyelogram are also effective imaging modalities. Once the diagnosis is made, establishment of renal drainage is essential either via percutaneous nephrostomy tubes, ureteral stents, Foley catheter, or a combination of these three methods. Supportive treatment should be initiated by evacuation of urinoma/ascites, antibiotics if needed, and surgical repair when patient is stable. Bladder injuries can be accompanied by ureteral injuries, and the latter must be ruled out. The reverse is also true: bladder injuries must be ruled out in the presence of ureteral injuries.

Neuropathic Injury

The incidence of nerve injury after gynecologic surgery is low and approaching 2% [42], but the consequences are high, often leading to minor discomfort and paresthesias, but occasionally, depending on the type and severity of the injury, to loss of motor function and permanent disability. Neuropathic injuries can happen at any time during the operative period, from the time the patient is positioned in preparation for surgery to the moment anesthesia is reversed and the patient is transferred to the recovery room. In an otherwise uncomplicated surgery, when the patient complains of postoperative pain, paresthesias, loss of sensation, or motor weakness, you should be suspicious of a nerve injury. In addition to direct injury, such as transection, entrapment, or thermal injury during the operative portion of the procedure, the surgeon must be cognizant of the possibility of compression or stretching from patient positioning or patient shifting during the procedure.

Most gynecological laparoscopic procedures require positioning the patient in the lithotomy position and some degree of Trendelenburg. Steep Trendelenburg (>30°) is an independent risk factor for brachial plexus injury [21], while prolonged operative time (>4 h), obesity, and frequent patient repositioning during surgery add significant risk for neuropathic injury. Most commonly, the femoral, sciatic, and peroneal nerves are involved when a lower extremity nerve injury is suspected after a procedure in the lithotomy position and the mechanism of injury is often due to compression of the nerve involved.

Clinical presentation will generally allow for identifying which nerve is involved. For example, if a patient presents with weakness without pain of the quadriceps resulting in difficulties with walking and climbing stairs, suspicion of a femoral nerve injury should be considered. A femoral nerve injury is usually due to compression against the inguinal ligament with severe hyperflexion of the leg. This can also happen as the femoral nerve is stretched when the leg is externally rotated and/or abducted at the hip. When the patient presents with posterior leg pain and weakness radiating from buttocks to leg, a sciatic nerve injury is usually the culprit. A sciatic nerve injury can occur with stretch injury with high lithotomy position when the knee is straightened in the stirrups and from direct compression of the nerve during long procedures. When a patient presents with a foot drop and weakness or numbness of the dorsal part of the foot, a peroneal nerve injury is to blame. This is usually a result of compression of the lateral portion of the knee against the stirrup.

As with any other type of complication, prevention is infinitely better than remediation. The surgical team should take all necessary steps to identify patients at risk for neuropathic injury, especially the morbidly obese, complex procedures that may extend beyond 4 h, patients with arthritic deformities that may preclude from appropriately positioning the extremity, and patients with preexisting neuropathies. A thorough history and detailed physical examination should be documented preoperatively with evaluation of preexisting conditions and, if necessary, have a neurological consultation and assessment prior to surgery. Once in the operating room, the surgeon is ultimately responsible for positioning the patient and ensuring that there are no pressure points or variations of malpositioning that may lead to nerve injury. This responsibility is of paramount importance, and it should not be delegated to another member of the team. Upper extremities can be protected by tucking the arms in the military position. Eliminate the possibility of any pressure points by padding the elbows, wrists, and hands. When possible, avoid prolonged (>4 h) lithotomy position and shoulder braces. If the circumstances allow, consider repositioning of the patient when the operative time is approaching 4 h. This will allow for temporary relief and decompression of affected nerves and an opportunity to better position the patient if shifting or migration on the table has occurred.

Another important step in prevention of injury during surgery is avoidance of steep (30–45°) Trendelenburg. Prior to transferring the patient to the OR table, a foam pad is secured on to the table with Velcro straps, and a drawsheet is placed to allow for tucking of the arms and also for transferring the patient to the transport bed after the procedure is completed (Fig. 32.2). The pad is intended for direct contact with patient's skin to eliminate sliding during the procedure effectively eliminating the need for beanbags and shoulder braces.

When nerve injury is recognized, supportive treatment should be initiated with physical therapy and medications targeted to decrease neuropathic pain such as tricyclic antidepressants and anticonvulsants. Nerve tissue recovers at a slow pace, and it takes approximately 3–4 months to regenerate. Patience and reassurance will go a long way. Referral to a neurologist should be considered if symptoms are severe and refractory to conservative therapy.

Morcellation-Related Injury

With the advancement of minimally invasive surgery, industry innovation, and the introduction of efficient mechanical morcellation devices, the number of complex procedures that could be completed in a minimally invasive manner increased tremendously. The evolution from utilizing scalpels laparoscopically to manual morcellation devices to electric mechanical power tools facilitated tissue extraction but introduced a new dimension of surgical risk. Reports of visceral and vascular injury [43] in addition to the potential risk of seeding of benign or malignant cellular tissue during open power morcellation have led to a reevaluation of the use of these devices. Disclosure of possible risks and written informed consent are essential when considering any tissue morcellation in the peritoneal cavity as small fragments left behind during the process can lead to significant morbidity in the form of pain, infection, parasitic leiomyomatosis, and the potential for seeding malignant tissue. When faced with the challenge of selecting a minimally invasive approach for a patient with a large mass, ruling out the possibility of malignant disease is imperative. Every effort needs to be made to not increase morbidity and mortality to favor a minimally invasive approach. For example, recent literature from Japan [44] suggests that using multiple predictors for the preoperative identification of patients at risk for leiomyosarcoma are important tools in the formulation of a preoperative sarcoma score and include imaging studies (TVUS and MRI), endometrial biopsy, and serum LDH levels. In addition, when performing a laparoscopic hysterectomy, every effort should be made to remove the specimen intact through the vagina or a minilaparotomy site. When morcellation is an option for extraction of large specimens in a minimally invasive approach, containment of tissue throughout the procedure is recommended. Many techniques and tools have been described and utilized for tissue extraction. Recently, the US Food and Drug Administration (FDA) approved the first tissue containment system for use with certain laparoscopic power morcellators to isolate uterine tissue that is not suspected to contain cancer. Regardless of the tools or techniques used for tissue extraction, appropriate documentation of informed consent and a detailed description of the procedure must be included in the operative report.

Postoperative Complications

Port Site Infection

Port site infection is a type of surgical site infection (SSI) subsequent to a laparoscopic surgery and that presents within 1 month of the operative procedure [45]. Wound infections after laparoscopic surgery are uncommon in the setting of preoperative antibiotics, sterile technique, and hemostasis but are more likely to occur in patients with history of nicotine use, diabetes, steroid administration, obesity, cancer, or malnutrition. When infections develop, they present in the typical manner with localized erythema, induration, warmth, and drainage over the laparoscopic port site. Some patients may have systemic evidence including fever and leukocytosis. Necrotizing fasciitis is characterized by copious drainage and devitalized subcutaneous tissue and fascia. Port site infections are most common in the umbilical port, correlated with larger trocar sites and specimen extraction. Superficial infections, typically presenting as erythema and warmth, can easily be treated with local wound care and antibiotics. Deep infections, typically presenting as fluctuance or purulent discharge, require exploration, irrigation, packing, and, if indicated, mechanical debridement.

Port Site Herniation

Post-laparoscopy port site herniation occurs with an incidence of 0.21–5.4% [46–48]. These hernias are most likely to occur when large ports (≥10 mm) are used, such as for single-site procedures [49]. The most important risk factors for development of hernia include older age, higher body mass index, preexisting hernia, bladed trocar design, trocar diameter ≥ 10 mm, increased duration of surgery, multiple ancillary ports and extension of the port site for specimen extraction, stapling, or single-site surgery. Hernia development has been reported for 5 and 7 mm port sites as well as ≥10 mm port sites that underwent primary fascial closure.

Port site herniation typically presents with the presence of an intermittent or continuous incisional bulge at the site of a previous laparoscopy port. This may be a cosmetic concern or may cause varying degrees of pain but is typically worsened by exertion or Valsalva. Patients can also present with clinical signs of bowel obstruction or infarction such as nausea, vomiting, abdominal distention, persistent pain, fever, tachycardia, and electrolyte imbalance. This can occur several years after a laparoscopic surgery and may have higher incidence the more remote the patient is from the incident surgery [48]. When port site hernia is identified following laparoscopy, the site should be repaired. Often a laparoscopic, simple suture repair is sufficient for port site hernias, but surgical repair should be individualized based on clinical status, size, and location of defect.

Postoperative Shoulder Pain

Postoperative shoulder is commonly attributed to irritation along the peritoneal undersurface of the diaphragm resulting in a referred pain phenomenon commonly seen in postoperative surgical patients. This occurs because the diaphragm is innervated by left and right phrenic nerves which carry sensory and motor neurons from spinal cord levels C3–C5. When the sensory component of the phrenic nerve is activated by retained insufflation gas, blood, or irrigation fluid or by stretching of the nerve from pneumoperitoneum or pressure from abdominal organs in Trendelenburg position, the nerve sends afferent signals that are processed in the dorsal horn of cervical segments 3–5. Sensory axons from the shoulder converge in the same dorsal horns, and the body misinterprets the afferent signals arising from the phrenic nerve as arriving from the shoulder. This convergence is thought to be the basis for referred pain [21]. The process is self-limiting and management is reassurance and symptomatic care.

References

1. Hatzinger M, Häcker A, Langbein S, Kwon S, Hoang-Böhm J, Alken P. Hans-Christian Jacobaeus (1879-1937): the inventor of human laparoscopy and thoracoscopy. Urologe A. 2006;45(9):1184–6.
2. Sutton C. Past, present, and future of hysterectomy. J Minim Invasive Gynecol. 2010;17(4):421–35.
3. Jansen FW. Complications. In: Istre O, editor. Minimally invasive gynecological surgery. 1st ed. Berlin: Springer; 2015. p. 177–90.
4. Miranda CS, Carvajal AR. Complications of operative gynecological laparoscopy. JSLS. 2003;7:53–8.
5. Chapron C, Queleu D, Bruhat MA, et al. Surgical complications of diagnostic and operative gynaecological laparoscopy: a series of 29,966 cases. Hum Reprod. 1998;13:867–72.
6. Jansen FW, Kapiteyn K, Trimbos-Kemper T, et al. Complications of laparoscopy: a prospective multicentre observational study. Br J Obstet Gynaecol. 1997;104:595–600.
7. Johnston K, Rosen D, Cario G, et al. Major complications arising from 1265 operative laparoscopic cases: a prospective review from a single center. J Minim Invasive Gynecol. 2007;14:339–44.
8. Mac Cordick C, Lécuru F, Rizk E, Robin F, Boucaya V, Taurelle R. Morbidity in laparoscopic gynecological surgery: results of a prospective single-center study. Surg Endosc. 1999;13(1):57–61.
9. Hashizume M, Sugimachi K. Needle and trocar injury during laparoscopic surgery in Japan. Surg Endosc. 1997;11:1198–201.
10. Molloy D, Kaloo PD, Cooper M, et al. Laparoscopic entry: a literature review and analysis of techniques and complications of primary port entry. Aust N Z J Obstet Gynaecol. 2002;42:246–54.
11. Garry R. Towards evidence-based laparoscopic entry techniques: clinical problems and dilemmas. Gynaecol Endosc. 1999;8:315–26.
12. Ahmad G, Gent D, Henderson D, O'Flynn H, Phillips K, Watson A. Laparoscopic entry techniques. Cochrane Database Syst Rev. 2015;8:CD006583. https://doi.org/10.1002/14651858.CD006583.pub4.
13. Cuss A, Bhatt M, Abbott J. Coming to terms with the fact that the evidence for laparoscopic entry is as good as it gets. J Minim Invasive Gynecol. 2015;22(3):332–41.
14. Pryor A, Gracia G. Abdominal access techniques used in laparoscopic surgery. UpToDate. 2015.
15. Angioli R, Terranova C, De Cicco Nardone C, et al. A comparison of three different entry techniques in gynecological laparoscopic surgery: a randomized prospective trial. Eur J Obstet Gynecol Reprod Biol. 2013;171:339–42.
16. Byron JW, Markenson G, Miyazawa K. A randomized comparison of Verres needle and direct trocar insertion for laparoscopy. Surg Gynecol Obstet. 1993;177:259–62.
17. Celik H, Cremins A, Jones KA, Harmanli O. Massive subcutaneous emphysema in robotic sacrocolpopexy. JSLS. 2013;17(2):245–8.
18. Makai G, Isaacson K. Complications of gynecologic laparoscopy. Clin Obstet Gynecol. 2009;52(3):401–11.
19. Ott DE. Subcutaneous emphysema—beyond the pneumoperitoneum. JSLS. 2014;18(1):1–7.
20. Kalhan SB, Reaney JA, Collins RL. Pneumomediastinum and subcutaneous emphysema during laparoscopy. Cleve Clin J Med. 1990;57:639–42.
21. Magrina J. Complications of laparoscopic surgery. Clin Obstet Gynecol. 2002;45:469–80.

22. Murdock CM, Wolff AJ, Van Geem T. Risk factors for hypercarbia, subcutaneous emphysema, pneumothorax, and pneumomediastinum during laparoscopy. Obstet Gynecol. 2000;95(5):704–9.
23. Kim CS, Kim JY, Kwon JY, Choi SH, Na S, An J, Kim KJ. Venous air embolism during total laparoscopic hysterectomy: comparison to total abdominal hysterectomy. Anesthesiology. 2009;111(1):50–4.
24. Park EY, Kwon JY, Kim KJ. Carbon dioxide embolism during laparoscopic surgery. Yonsei Med J. 2012;53(3):459–66.
25. Mintz M. Risks and prophylaxis in laparoscopy: a survey of 100,000 cases. J Reprod Med. 1977;18: 269–72.
26. Hynes SR, Marshall RL. Venous gas embolism during gynaecological laparoscopy. Can J Anaesth. 1992;39(7):748–9.
27. Bonjer HJ, Hazebroek EJ, Kazemier G, et al. Open versus closed establishment of pneumoperitoneum in laparoscopic surgery. Br J Surg. 1997;84:599–602.
28. Cottin V, Delafosse B, Viale JP. Gas embolism during laparoscopy: a report of seven cases in patients with previous abdominal surgical history. Surg Endosc. 1996;10(2):166–9.
29. Hurd WW, Pearl ML, DeLancey JO, et al. Laparoscopic injury of abdominal wall blood vessels: a report of three cases. Obstet Gynecol. 1993;82(S):673–6.
30. Hurd WW, Rude RO, DeLancey JO, Newman JS. The location of abdominal wall blood vessels in relationship to abdominal landmarks apparent at laparoscopy. Am J Obstet Gynecol. 1994;174(3):642–6.
31. Saber AA, Meslemani AM, Davis R, Pimentel R. Safety zones for anterior abdominal wall entry during laparoscopy: a CT scan mapping of epigastric vessels. Ann Surg. 2004;239(2):182–5.
32. Burnett TL, Garza-Cavazos A, Groesch K, et al. Location of the deep epigastric vessels in the resting and insufflated abdomen. J Minim Invasive Gynecol. 2016;23(5):798–803.
33. Luijendijk RW, Jeekel J, Storm RK, et al. The low transverse Pfannenstiel incision and the prevalence of incisional hernia and nerve entrapment. Ann Surg. 1997;225:365–9.
34. Rahn DD, Phelan JN, Roshanravan SM, White AB, Corton MM. Anterior abdominal wall nerve and vessel anatomy: clinical implications for gynecologic surgery. Am J Obstet Gynecol. 2010; 202(3):234.
35. Whiteside JL, et al. Anatomy of ilioinguinal and iliohypogastric nerves in relation to trocar placement and low transverse incisions. Am J Obstet Gynecol. 2003;189(6):1574–8.
36. Philips PA, Amaral JF. Abdominal access complications in laparoscopic surgery. J Am Coll Surg. 2001;192:525–36.
37. Sandadi S, Johannigman JA, Wong VL, Blebea J, Altose MD, Hurd WW. Recognition and management of major vessel injury during laparoscopy. J Minim Invasive Gynecol. 2010;17(6):692–702.
38. Pryor A, Mann W, Garcia G. Complications of laparoscopic surgery. UpToDate. 2016.
39. Chapron C, Fauconnier A, Goffinet F, Breart G, Dubuisson JB. Laparoscopic surgery is not inherently dangerous for patients presenting with benign gynaecologic pathology. Hum Reprod. 2002;17:1334–42.
40. Gemer O, Simonovsky A, Huerta M, Kapustian V, Anteby E, Linov L. A radiological study on the anatomical proximity of the ureters and the cervix. Int Urogynecol J Pelvic Floor Dysfunct. 2007;18(9):991–5.
41. Sharp HT, Swenson C. Hollow viscus injury during surgery. Obstet Gynecol Clin N Am. 2010;37:461–7.
42. Cardosi RJ, Cox CS, Hoffman MS. Postoperative neuropathies after major pelvic surgery. Obstet Gynecol. 2002;100:240–4.
43. Milad MP, Sokol E. Laparoscopic morcellator-related injuries. J Am Assoc Gynecol Laparosc. 2003;10:383–5.
44. Nagai T, Yakahori TY, Ishida H, Hanaoka T, et al. Highly improved accuracy of the revised Preoperative Sarcoma Score (PRESS) in the decision of performing surgery for patients presenting with a uterine mass. Springer Plus. 2015;4:520.
45. Sasmal PK, Mishra TS, Rath S, Meher S, Mohapatra D. Port site infection in laparoscopic surgery: a review of its management. World J Clin Cases. 2015;3(10):864–71.
46. Montz FJ, Holschneider CH, Munro MG. Incisional hernia following laparoscopy: a survey of the American Association of Gynecologic Laparoscopists. Obstet Gynecol. 1994;84(5):881.
47. Bunting DM. Port-site hernia following laparoscopic cholecystectomy. JSLS. 2010;14(4):490–7.
48. Bensley RP, Schermerhorn ML, Hurks R, Sachs T, Boyd CA, O'Malley AJ, Cotterill P, Landon BE. Risk of late-onset adhesions and incisional hernia repairs after surgery. J Am Coll Surg. 2013;216(6):1159–67.
49. Marks JM, Phillips MS, Tacchino R, Roberts K, et al. Single-incision laparoscopic cholecystectomy is associated with improved cosmesis scoring at the cost of significantly higher hernia rates: 1-year results of a prospective randomized, multicenter, single-blinded trial of traditional multiport laparoscopic cholecystectomy vs single-incision laparoscopic cholecystectomy. J Am Coll Surg. 2013;216(6):1037.