Gynecologic Laparoscopy

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21.1 Introduction

During the last four decades, the discipline of gynecologic surgery has seen significant advancement in the use of minimally invasive surgery. The laparoscopic technique itself was revolutionized by the continuous fine tuning of the traditional instruments and the addition of new ones. The last decade has witnessed the introduction of robotic assistance and the laparoendoscopic single-site surgery (LESS) as new enhancements to the field. In addition, laparoscopy has become one of the most common surgical procedures performed in the USA and worldwide. It became the gold standard for many gynecologic procedures, such as removal of ectopic pregnancies and the treatment of endometriosis.

A recent study looked at a Cohort of 264,758 women who underwent hysterectomy for benign gynecologic disorders at 441 hospitals across the USA from 2007 to 2010. Use of robotically assisted hysterectomy increased from 0.5% in 2007 to 9.5% of all hysterectomies in 2010. During the same time period, laparoscopic hysterectomy rates increased from 24.3 to 30.5% [1].

For other procedures, including laparoscopically assisted hysterectomy and treatment of gynecologic cancers, the relative risks and benefits of the laparoscopic approach are still being determined.

This chapter will give an overview of the history and modern use of laparoscopy. Laparoscopic complications and specific laparoscopic techniques are considered in subsequent chapters.

▪▪ Clinical Case

A 42-year-old G3 P3 presents to her gynecologist's office with long standing history of vaginal bleeding, frequency of micturition, and constipation over the past 3 years. Her gynecologic history is significant for a diagnosis of mutifibroid uterus. She has had bilateral tubal ligation. Her Pap smears have been normal. Her vital signs are stable and her review of systems is noncontributory. Her pelvic exam reveals normal appearing vagina and cervix. Her bimanual examination is difficult because of her obesity, but does reveal 16 week size uterus. Pelvic ultrasound shows a mutifibroid uterus with the dominant fibroid being intramural and measured 7 cm in the maximum diameter with a 12 mm endometrial stripe. Laboratory evaluation includes a negative blood hCG, white blood cell count, hemoglobin of 9.8 g/dL, and platelet count of 350,000 per mcL. After reviewing different treatment options, she elected to go for total laparoscopic hysterectomy. On the day of surgery, peritoneal access was obtained via Palmer's point. Upon inserting the right lower quadrant trocar, the trocar tip wen in the right common iliac vein. Immediate laparotomy was performed and vascular surgery was called for help.

21.1.1 History

Hippocrates described the first example of an endoscope, an early rectal speculum, in Greece between 460 BC and 375 BC. The ruins of Pompeii, Italy (70 AD), provided the next example, a three-bladed vaginal speculum, similar to a modern-day speculum. Next, Philipp Bozzini in Germany (1773–1809) developed a light conductor that he called "Lichtleiter," which directed light into the patient's body and then reflected the image back to the eye of the surgeon. John D. Fisher (1798–1850) described an endoscope to inspect the vagina, and he later modified it to examine the bladder and urethra. In 1853, Antoine Jean Desormeaux pioneered the first functional endoscope, which was mainly used for urologic cases. This instrument had mirrors and a lens with a lamp flame as the light source, which burned a mixture of alcohol and turpentine.

The first experimental laparoscopy ("celioscopy") was performed in Berlin in 1901, by Dr. Georg Kelling, who placed a cystoscope into the abdomen of dogs to evaluate the ability of insufflated air to stop gastrointestinal hemorrhage [2]. Dr. Hans Christian Jacobaeus of Sweden published the first description of "laparothoracoscopy" in 1910 as a technique to evaluate patients with peritoneal tuberculosis. However, laparoscopy made little headway into clinical practice until after World War I. It took until the 1960s for laparoscopy to be accepted in the USA and Europe as a safe and valuable surgical procedure.

For many years, gynecologic laparoscopy was performed almost exclusively for diagnostic purposes and for sterilizations. By the 1970s, the role of laparoscopy had expanded to include lysis of adhesions and treatment of endometriosis [3]. The technology and equipment advanced over the next four decades such that laparoscopy is now used for a wide variety of procedures ranging from treatment of ectopic pregnancies and ovarian cysts to hysterectomy, incontinence procedures, and management of gynecological malignancies.

21.2 General Techniques for Laparoscopy

21.2.1 Primary Trocar Placement

For many years, the standard techniques used for creating a pneumoperitoneum and placing a laparoscopic port into the abdomen were either a closed technique or an open approach. In the last decades, multiple alternative approaches and locations have been reported. The five most common approaches are as follows:

- Standard closed technique (Veress needle insufflation followed by primary trocar insertion)
- Direct trocar insertion (no insufflation prior to trocar insertion)
- Open laparoscopy
- Left upper quadrant (LUQ) insertion technique.

Both reusable and disposable instruments are commonly used. The ultimate safety of many of the newer techniques and instruments has yet to be determined.

21.2.2 Standard Closed Technique: Veress Needle and Primary Trocar Insertion

The standard closed technique was used almost exclusively for decades and continues to be widely used today. Both the Veress needle and primary trocar are blindly placed through a periumbilical incision into the peritoneal cavity. Using this approach with reusable instruments, the combined risk of injuring retroperitoneal vessels, bladder, or bowel has been found to be less than 1 in 1000 cases [4]. This approach has become the "gold standard" against which all other techniques are judged.

For the standard technique, the patient is placed in a horizontal position, and the abdominal wall is elevated by manually grasping the skin and subcutaneous tissue. This is done to maximize the distance between the umbilicus and the retroperitoneal vessels. Alternatively, a penetrating towel clips placed at the base of the umbilicus could be used to elevate the anterior abdominal wall.

In a woman of ideal weight (body mass index [BMI] <25 kg/m^2) or only slightly overweight (BMI 25–30 kg/m^2), the lower anterior abdominal wall is grasped and elevated, and the Veress needle is inserted toward the hollow of the sacrum at a 45° angle (Fig. 21.1) [5]. In the

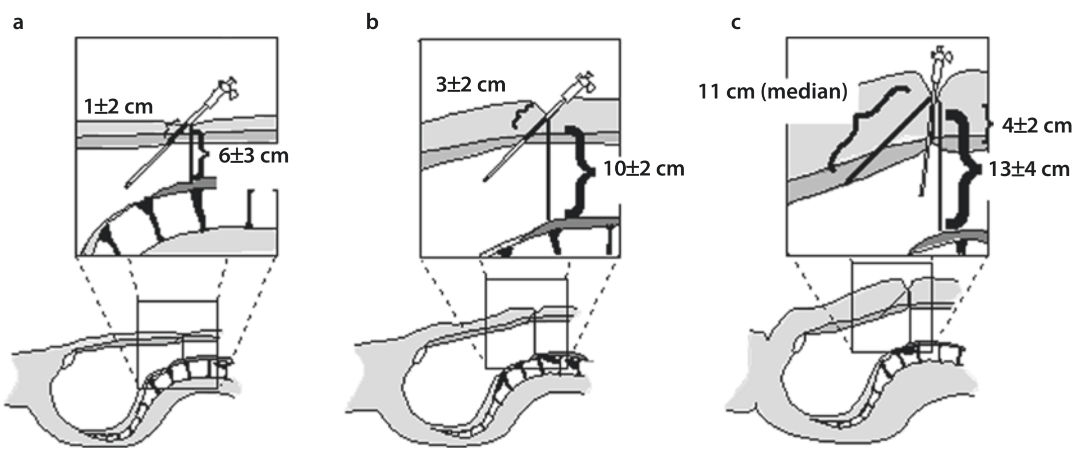


Fig. 21.1 Changes in the anterior abdominal wall anatomy with weight. Diagram of representative sagittal views derived from magnetic resonance and computed tomographic imaging for patients in three groups: (**a**) Ideal weight (body mass index [BMI] <25 kg/m^2). (**b**) Overweight (BMI 25–30 kg/m^2). (**c**) Obese (BMI >30 kg/m^2). An 11.5-cm Veress needle is superimposed on each view for comparison (reproduced with permission from Hurd WW, Duke J, Falcone T. In: Hurd WW, Falcone T, eds. Clinical reproductive medicine and surgery. St. Louis, MO: Mosby/Elsevier; 2007)

thinnest patients in this group, the retroperitoneal vessels are much closer to the abdominal wall and the margin for error is reduced, with as little as 4 cm between the skin and these vessels. In the obese patient (BMI >30 kg/m^2; weight usually >200 lb) a more vertical approach, approximately 70–80°, is required to enter the peritoneal cavity because of the increased thickness of the abdominal wall. It is important to avoid subcutaneous tunneling of the Veress needle and/or the trocars prior to puncturing the fascia of the anterior abdominal wall.

Verification that the Veress needle tip is in the peritoneal cavity is done by a number of methods, including the "hanging drop test," injection and aspiration of fluid through the Veress needle, and close observation of intra-abdominal pressure during carbon dioxide insufflation. After a pneumoperitoneum has been created, the Veress needle is removed and the primary port trocar (most commonly 5 or 10 mm in diameter) is placed at an angle identical to that used for the Veress needle.

21.2.3 Direct Trocar Insertion

Direct trocar insertion is a technique whereby the primary trocar is inserted without having previously inserted the Veress needle and insufflating the abdomen with carbon dioxide [5]. This could be achieved blindly or via the optical-trocar-assisted technique. The direct primary trocar is inserted at an angle similar to that described above for the closed technique. The peritoneal cavity is then insufflated with carbon dioxide through the umbilical port.

The optical trocar insertion allows visualization of the layers that are being penetrated during entry via a laparoscope in the cannula. It is assumed that this approach could reduce the risk of injury since the technique is no longer blind. However, vascular and visceral injuries are reported with this approach. On the other side, seeing the injury as it happens will allow prompt recognition and repair, nullifying the consequences of delayed diagnosis and management.

This technique decreases the risk of extraperitoneal insufflation by allowing the surgeon to confirm intraperitoneal placement of the primary trocar before insufflation. Although small randomized studies have not demonstrated an increased risk of injuries, some series suggest that this technique might increase the risk of bowel injury [5, 6]. A larger randomized study demonstrated no major complications on comparing the two approaches. However, minor complications including preperitoneal insufflation, failed entry or more than three attempts necessary to enter the peritoneal cavity with the trocar were significantly more frequent in the Veress needle technique group [7]. In a recent meta-analysis comparing the Veress needle to direct trocar insertion, pooled analysis showed a borderline significant reduction for major complications based on five events in 2 RCTs (n = 978) and a reduction in minor complications in favor of direct trocar insertion [8].

21.2.4 Open Laparoscopy

Open laparoscopy, first described by Dr. Harrith Hasson in 1971, refers to creating a small incision in the abdomen and placing the port through the incision without using a sharp trocar [6, 9]. The skin and anterior rectus fascia are incised with a scalpel, and the peritoneal cavity is bluntly entered with a Kelly or Crile forceps. A laparoscopic port with a blunt-tipped trocar is then placed into the peritoneal cavity. For the "Hasson" technique, fascial sutures are used to assist subsequent closure and help maintain a pneumoperitoneum [6]. This method almost eliminates the risk of retroperitoneal vessel injury and is preferred by many laparoscopists for this reason. Although open laparoscopy does not entirely avoid the risk of bowel injury, many laparoscopists use this approach in an effort to decrease this risk in patients with previous abdominal surgery suspected of having adhesions.

Randomized controlled trials comparing the Hasson and Veress techniques showed no significant reduction in major complications, but the Hasson technique showed significantly less minor complications and failed entries. CO_2 leakage was far more common when using the Hasson technique [8]. In addition, a recent meta-analysis concluded that there are less minor complications and failed attempts when using the Hasson or direct entry technique when compared to the Veress method, but there is limited evidence regarding major complications [8].

21.2.5 Left Upper Quadrant Technique

This approach was developed for use in patients with previous abdominal surgery with suspected or known periumbilical bowel adhesions, during pregnancy, and with large pelvic masses. It is performed by using a LUQ site to place both the Veress needle and primary laparoscopy port into the abdomen. This point, sometimes referred to as Palmer's point, is in the mid-clavicular line beneath the lower rib margin (Fig. 21.2).

It is important to know the anatomy of the LUQ before using this technique. The most important organs that are closest to this site are the stomach and left lobe of the liver [10]. Although a small series has shown the risk of complications to be small, the relative risk of complications with this technique remains to be demonstrated by a large study [11].

Often times, a supraumbilical entry site is selected over the umbilicus for a variety of indications with large masses [12]. A recent study evaluated distances to vital retroperitoneal vasculature that were encountered with 45- and 90-degree angle entry from the umbilicus and 2 commonly described supraumbilical entry points at 3 and 5 cm cephalad from the umbilicus. According to the theoretic modeling, supraumbilical primary port placement can be implemented safely irrespective of the angle of entry as all the distances are greater than at the level of the umbilicus [13].

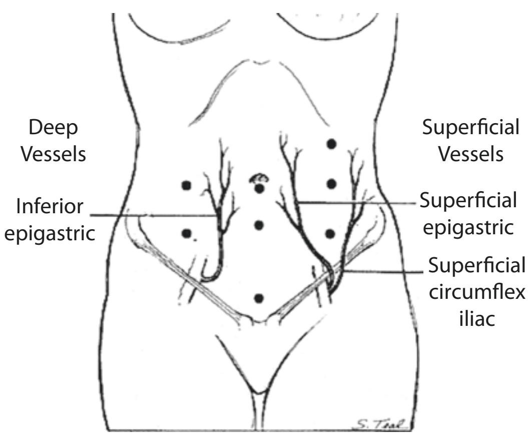


Fig. 21.2 Ideal port sites in relation to the deep and superficial vessels of the anterior abdominal wall (reproduced with permission from Hurd WW, Duke J, Falcone T. In: Hurd WW, Falcone T, eds. Clinical reproductive medicine and surgery. St. Louis, MO: Mosby/Elsevier; 2007)

It is important to understand that all the studies cited above on the angle of insertion are theoretical models based on imaging. In fact due to the alterations of the abdominal wall such as lifting in order to obtain primary access will change the distances and relative anatomy.

21.2.6 Placement of Secondary Ports

Secondary ports are required to perform most gynecologic laparoscopy procedures today. After identifying the epigastric vessels by transillumination and visualizing them intra-abdominally through the laparoscope, 1–4 secondary ports are placed, depending on the procedure [14]. A midline port is often placed 3–4 cm above the pubic symphysis. Lateral ports are placed approximately 8 cm from the midline and 5 cm above the pubic symphysis to avoid the inferior epigastric vessels (see Fig. 21.2) [15]. This lateral site corresponds to McBurney's point in the right lower quadrant and is approximately one-third of the distance from the anterior iliac crest to the pubic symphysis (Fig. 21.3). Additional lateral ports for the principal surgeon are required for most operative laparoscopy cases. The site chosen is typically at the level of the umbilicus lateral to the rectus muscle. This site offers the surgeon a comfortable use of both hands and allows access to most areas of the pelvic or abdominal cavity.

Secondary ports are placed with sharp trocars under direct laparoscopic visualization to avoid injuring intraperitoneal structures. These trocars

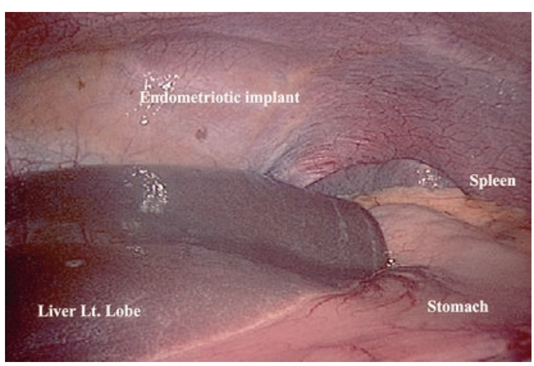


Fig. 21.3 Anatomy of the left upper abdomen (reproduced with permission from Hurd WW, Duke J, Falcone T. In: Hurd WW, Falcone T, eds. Clinical reproductive medicine and surgery. St. Louis, MO: Mosby/Elsevier; 2007)

should be placed directly into the peritoneal cavity without tunneling. After removal, the intra-abdominal gas pressure is reduced to observe for signs of hemorrhage indicative of abdominal wall vessel injury. If the port diameter is ≥10 mm, the fascia and peritoneum should be closed with a full-thickness suture to reduce the risk of subsequent herniation. When comparing bladed to radially expanding trocars, three studies ($n = 408$) showed less minor complications and a trend toward pain reduction when using a radially expanding trocars [8]. Radially expanding trocars reduce minor vascular complications when compared to bladed trocars [8].

21.2.7 Removal of Ports and Port-Site Closure

At the conclusion of the procedure, port removal should be performed in a way to minimize patient risk. Secondary ports should be removed under direct visualization to detect any bleeding that might have been masked by the port or the intra-abdominal pressure. All carbon dioxide used for pneumoperitoneum should be allowed to escape prior to removal of the umbilical port to minimize postoperative shoulder pain and avoid pushing bowel into the incision sites as residual gas escapes.

21.2.8 Multifunctional Laparoscopic Instruments

Traditionally, power instruments were used during laparoscopy because suture ligation, the most common hemostatic method used during laparotomy, is difficult to perform laparoscopically. *Electrocoagulation* was perhaps the first power instrument used during laparoscopy. This instrument is heated by passing electrical current through the tip of a grasping instrument, which is then used to coagulate tissue.

In the last four decades, other methodologies have been developed, most notably electrosurgery. *Unipolar electrosurgery* passes current through the patient to cut or coagulate tissue. *Bipolar electrosurgery* was developed in an effort to minimize the risk of inadvertent injury to adjacent tissue, particularly the bowel. Bipolar electrosurgery offers an increased margin of safety because the electrical current is confined to the tip of the instrument, but the cutting ability is reduced. *Lasers* offer a precise, rapid, and accurate method of thermally destroying the tissue; however, hemostatic effects are less and lasers are costly. The *ultrasonic scalpel* is an ultrasonically activated instrument that moves longitudinally at a rate of 55,000 vibrations per second and is able to cut tissue and coagulate small vessels without heat or electrical energy. Tips available for this instrument include grasper/scissors, a hook blade, and a ball tip.

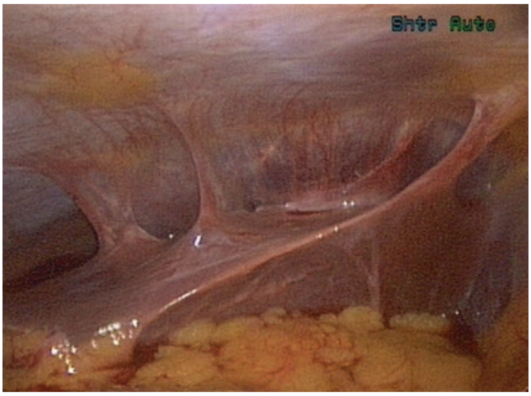
Over the past decade, significant improvements in the design and functionality of these instruments were achieved. The most important refinement was the additional cutting following coagulation. This technology uses the combination of pressure and energy to create the seal by melting the collagen and elastin in the vessel walls and reforming it into a permanent seal. Subsequently, the tissue is then divided using an internal blade. The technology reduces thermal spread to 2 mm. Controlled coagulation and cutting are achieved by a wide variety of commercially available instruments including LigaSure, LigaSure Advance, Gyrus, Harmonic Scalpel, and EnSeal.

21.3 Laparoscopic Procedures

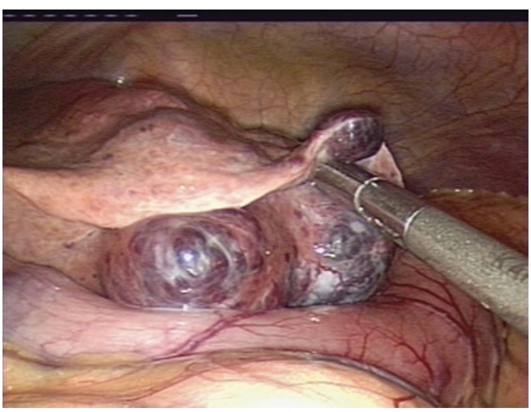
21.3.1 Diagnostic Laparoscopy

Laparoscopy has been used effectively as a valuable diagnostic tool for a wide variety of abdominal and pelvic pathologies. It has been used for the assessment of acute or chronic pain, suspected ectopic pregnancy, endometriosis, adnexal torsion, or other extragenital pelvic pathologies. In most cases, the laparoscope is placed through an infraumbilical port, and a probe is placed through a second suprapubic port to manipulate the pelvic organs, if only a diagnostic laparoscopy is performed. However, for operative laparoscopy other than the simplest procedures, the suprapubic port is not useful and is quite uncomfortable. If operative laparoscopy is performed, the accessory trocars should be placed in the right and left lower quadrants. For advanced laparoscopy, an accessory trocar at the level of the umbilicus lateral to the rectus muscle will allow the principal surgeon to operate comfortably and have access to the pelvis. If tubal patency is a concern, a dilute dye can be injected transcervically, a procedure termed chromopertubation.

Before initiating any surgery, the peritoneal cavity should be thoroughly inspected using a systematic approach. With the surgeon controlling the movement of the laparoscope, each quadrant of the abdomen and then the pelvis should be carefully inspected. Care should be taken to inspect the appendix, omentum, peritoneal surfaces, stomach, surface of the bowel, diaphragms, and liver (▣ Figs. 21.4 and 21.5) [16]. The spleen is usually difficult to see except in thin women (see ▣ Fig. 21.3). If any suspicious lesions are observed, fluid should be obtained for cytology (pelvic washings) prior to biopsying the lesion for frozen section.



▣ **Fig. 21.4** Sub-diaphragmatic adhesions of Fitz-Hugh-Curtis syndrome. These two physicians, Dr. Curtis in 1930 and Dr. Fitz-Hugh in 1934, described the relationship with gonococcal infection (reproduced with permission from Hurd WW, Duke J, Falcone T. In: Hurd WW, Falcone T, eds. Clinical reproductive medicine and surgery. St. Louis, MO: Mosby/Elsevier; 2007)



▣ **Fig. 21.5** Liver hemangioma (reproduced with permission from Hurd WW, Duke J, Falcone T. In: Hurd WW, Falcone T, eds. Clinical reproductive medicine and surgery. St. Louis, MO: Mosby/Elsevier; 2007)

Laparoscopic pelvic assessment is often performed in a non-standardized fashion depending on the surgeon's discretion. Reporting positive or negative findings is random and lesions in atypical locations such as anterior and posterior cul-de-sac, deep inguinal rings, and ovarian fossa may be missed, and patient care would be less than optimal. We proposed a method for systematic pelvic assessment based on anatomical landmarks [17].

In this system, the pelvis was topographically divided into two midline zones (zones I and II) and two paired (right and left) lateral zones (zones III and IV). Zone I is the area between the two round ligaments from their origin at the uterine cornua to their insertion in the deep inguinal rings. Zone II is the area between the two uterosacral ligaments from their origin from the back of the uterus to their insertions in the sacrum posteriorly. Zone III is the area between the uterosacral ligament inferiorly and the entire length of the fallopian tube and the infundibulopelvic ligament superiorly. Zone III contains the tubes and the ovaries. Zone IV is the triangular area lateral to the fallopian tube and the infundibulopelvic ligament and medial to the external iliac vessels up to the round ligament. This system was validated in a retrospective study and prospective evaluation is ongoing [17].

21.3.2 Tubal Sterilization

Tubal sterilization is one of the most commonly used methods of birth control. Laparoscopy is one of the most common techniques used for permanent sterilization in the world. Original laparoscopic techniques used electrocautery or electrosurgery to coagulate the midportion of the tubes. Other techniques, including clips and silastic bands, have gained popularity. The pregnancy rates vary by age of the patient, ranging from 1 to 3% after 10 years [18, 19]. Given the recent discoveries indicating that the Fallopian tube is the site of origin of ovarian cancer, the uptake of salpingectomy increased significantly as a method of sterilization in different parts of the world [20].

21.3.3 Lysis of Adhesion and Tubal Reconstructive Surgery

Adhesions are frequently encountered pelvic pathology. They are usually the result of previous pelvic infections secondary to PID or a ruptured appendix, endometriosis, or previous surgery. These adhesions may contribute to infertility or chronic pelvic pain. Lysis of adhesions is performed bluntly or by sharp dissection using scissors or a power source. Extreme caution should be used if adhesions <1 cm from ureter or bowel are lysed using unipolar electrosurgery because of the unpredictable nature of current arcing. The other power techniques, such as the ultrasonic scalpel, may be a better choice for adhesiolysis near bowel for surgeons that do not have experience with unipolar cautery.

Tubal reconstructive surgery is still performed even in the era of in vitro fertilization (IVF) and is almost exclusively performed laparoscopically. Fertility-enhancing procedures include adhesiolysis, fimbrioplasty, and terminal neosalpingostomy. Prior to and during these procedures, *chromopertubation* is carried out to document proximal tubal patency by injecting dilute indigo carmine dye through the cervix using a cannula. Laparoscopic surgery is performed using the principles of microsurgery to avoid tissue damage, including delicate handling of tissues and minimal use of electrosurgery for hemostasis.

Laproscopic fimbrioplasty or neosalpingostomy has been shown to be effective in young women with hydrosalpinges with no other infertility factors, however, the evidence is fair. On the other side, there is a good evidence to recommend laparoscopic salpingectomy or proximal tubal occlusion in case of r surgically irreparable hydrosalpinges to improve IVF outcome. In addition, there is enough evidence to support the value of microsurgical anastomosis for tubal ligation reversal even in women above the age of 40 years old [21].

Patients with mild tubal disease and preservation of fimbria have excellent pregnancy rates after laparoscopic surgery. Although these patients remain at risk for subsequent ectopic pregnancy, the risk of multiple gestations associated with IVF is avoided for patients who subsequently achieve a viable intrauterine pregnancy.

Unfortunately, adhesions often reform after lysis. Multiple techniques have been used in an effort to decrease reformation. Gentle tissue handling and good hemostasis also appear to be important. Barrier methods have been shown in clinical trials to decrease adhesions but have yet to be proven to improve pain relief or future fertility.

21.3.4 Fulguration of Endometriosis

Laparoscopy is the primary surgical approach used to treat endometriosis. Endometriosis lesions may be resected or ablated, using scissors or any of the power instruments. These treatment approaches have been shown in randomized controlled trials to improve fertility and decrease pelvic pain.

21.3.5 Ectopic Pregnancy Treatment

Laparoscopy has become the surgical approach of choice for most ectopic pregnancies [22]. The embryo and gestational sac are removed either through a longitudinal incision (linear salpingotomy) or by removing the tube (salpingectomy). Both were compared in a recent RCT. The cumulative ongoing pregnancy rate was similar after salpingotomy (60.7%) compared to 56.2% after salpingectomy. However, persistent trophoblast occurred more frequently following salpingotomy compared to salpingectomy. Recurrent ectopic pregnancy rate was 8% following salpingotomy and 5% following salpingectomy [23]. Even a ruptured tubal pregnancy can be treated laparoscopically, as long as the patient is hemodynamically stable.

21.3.6 Ovarian Cystectomy and Oophorectomy

Ovarian pathological conditions, including cysts, commonly result in gynecologic complaint such as pain. The underlying pathology ranges from physiologic and self-limiting functional cysts to ovarian torsion and other benign conditions, to ovarian malignancy. Ovarian cysts are usually characterized ultrasonographically and treated when necessary by laparoscopy or laparotomy, depending upon the size of the cyst and the level of suspicion for malignancy [24]. The most important concept in adnexal surgery is to avoid spilling the cyst content whenever possible.

21.3.7 Myomectomy

Many women with symptomatic fibroid uterus prefer a myomectomy over hysterectomy to preserve fertility or the uterus [25]. In some cases, myomectomy can be performed laparoscopically. The challenges in the case of intramural myomas are related to hemostasis, effective closure of the resulting myometrial defect, and removal of the specimen from the abdomen. Vasopressin can be injected into the uterus to help maintain hemostasis. The excised fibroid can be removed by morcellation or colpotomy. Power morcellators are available to expedite the process. Barrier techniques may be used to decrease subsequent adhesion formation. Some early case series have reported increased risk of subsequent uterine rupture during pregnancy after laparoscopic myomectomy compared to those performed by laparotomy [26]. However, several randomized clinical trials have shown no increased risk in expert hands [26]. A totally laparoscopic approach should be attempted only by gynecologists skilled in laparoscopic suturing. Recently, the uptake of the laparoscopic approach for laparoscopic myomectomy and laparoscopic hysterectomy was challenged by the FDA recommendation against power morcellation [27].

21.3.8 Laparoscopic Management of Pelvic Pain

Many women have severe dysmenorrhea that is unresolved despite medical management but wish to maintain future childbearing potential. In these patients, two laparoscopic approaches have been attempted with some success. Laparoscopic uterosacral nerve ablation (LUNA) is performed by stretching and dividing each uterosacral ligament using electrosurgery or laser alone or in combination with scissors. Care must be taken to avoid injuring the ureters. This procedure has been shown to have some temporary success, but a Cochrane review has questioned the validity of this procedure [28].

Laparoscopic presacral neurectomy (LPSN) is a second approach for central pain. This technically challenging procedure is performed by careful retroperitoneal dissection between the common iliac artery on the right and the inferior mesenteric artery where it crosses over both left common iliac artery and vein on the left. The superior hypogastric plexus, which includes the presacral nerves, is dissected from the left common iliac vein and periosteum of sacral promontory and a 2–3-cm segment is resected. Surgical risks include vascular complications, and long-term risks, such as constipation, are more common than with LUNA. Although both LUNA and LPSN appear to give some patients at least temporary relief from central pain, many clinicians believe that there is insufficient evidence to recommend the use of nerve interruption in the management of dysmenorrhea, regardless of the cause [28].

21.3.9 Hysterectomy

Laparoscopy hysterectomy, first described by Dr. Harry Reich in 1992, is commonly performed today [29]. The three basic laparoscopic approaches for hysterectomy are laparoscopic-assisted vaginal hysterectomy (LAVH), laparoscopic hysterectomy, and laparoscopic supracervical hysterectomy (LSH). Although the basic techniques for each of these approaches are fairly standardized, controversy exists over the risks, benefits, and most appropriate indication of each.

21.3.10 Laparoscopic-Assisted Vaginal Hysterectomy

LAVH is the most commonly employed and technically straightforward of the three. Using 3–4 ports, the peritoneal cavity is surveyed and lysis of adhesions is performed if necessary. Then the infundibulopelvic or utero-ovarian ligaments are occluded and divided, depending on whether the ovaries will be removed. The round ligament is divided, the utero-vesicle peritoneum is incised, and the bladder dissected from the anterior uterus. This step results in an increased risk of bladder injury compared to either abdominal or vaginal hysterectomy. At this point, the uterine arteries laparoscopically are sometimes occluded and divided, although this is associated with an increased risk of ureter injury compared to either abdominal or vaginal hysterectomy. Finally, the posterior cul-de-sac is incised.

The surgeon proceeds vaginally for the remainder of the case, dissecting the vesicovaginal septum anteriorly to enter the anterior cul-de-sac, ligating the uterine vessels if not previously done, removing the uterus and ovaries if appropriate, and closing the vaginal cuff.

21.3.11 Laparoscopic Hysterectomy

Laparoscopic hysterectomy (LH), the common second approach, is performed initially like the LAVH, except that the entire hysterectomy is performed laparoscopically. This approach is often used when there is little or no uterine descent, which makes the vaginal approach unfeasible.

After the infundibulopelvic (or utero-ovarian) and round ligaments are occluded and divided, the bladder is dissected away from the anterior uterus. The ureters are identified, and the uterine vessels and uterosacral ligaments are occluded and divided. The posterior cul-de-sac is incised, the vagina is circumferentially separated from the cervix, and the specimen is removed vaginally. The cuff is closed laparoscopically or vaginally.

21.3.12 Supracervical Hysterectomy

The LSH is a third common laparoscopic approach to hysterectomy for benign indications [30]. The technique begins in a manner identical to LAVH and LH. However, prior to reaching the level of the uterine arteries, the fundus is transected at the uterocervical junction. In order to minimize residual cyclic vaginal bleeding and decrease the risk of developing cervical dysplasia or cancer, the glandular tissue endocervix is cored out or cauterized. The uterine specimen is removed through a 12-mm port abdominal using a power morcellator. The recent debate about tissue extraction following the laparoscopic approach for myomectomy and hysterectomy is yet to be settled [27].

This approach eliminates both the vaginal and abdominal incision, thus decreasing the risk of infection. The risk of ureteral injury is also decreased, since the procedure stops above the level of the uterine artery. However, a risk of subsequently developing cervical dysplasia or cancer remains due to the presence of the cervical stump. For this reason, routine Pap smears are required, and some patient will require additional surgery related to cervical abnormalities. Furthermore, at least two randomized clinical trials have failed to show superior results in bladder function or sexual function [31, 32]. These studies did show a higher reoperation rate for bleeding and prolapse.

Although small trials have tried to assess the value of laparoscopic hysterectomy, a large multicenter, randomized trial that compared laparoscopic with abdominal hysterectomy and laparoscopic with vaginal hysterectomy has provided insight into the role of this procedure [33]. The study confirmed that the laparoscopic approach offers no advantage over the vaginal approach. It also confirmed that the laparoscopic approach is associated with less postoperative pain, shorter hospital stay, and faster convalescence compared with the abdominal approach. It demonstrated that the laparoscopic approach was associated with a slightly higher risk of urinary tract injury. The shorter length of hospitalization with laparoscopic hysterectomy offsets some of the additional costs incurred by longer operating room times and the expense of disposable instruments [34].

21.3.13 Power Morcellation Following Laparoscopic Surgery

Morcellation is used to allow removal of large specimens that cannot be retrieved otherwise. It enabled the laparoscopic option to treat patients with large uteri or uterine myoma. One of the major limitations of this technology is the possible spread of undiagnosed cancer. This concern led the FDA to issue a warning against the use of such technology [27]. That led to many gynaecologists to refrain and many institutions to recommend against the use of the minimally invasive for women where tissue morcellation is required. In the USA, there was a significant decrease in the proportion of minimally invasive hysterectomies and myomectomies performed during the 8 months after the FDA warning statement on the use of power morcellation [35].

Overall, uterine sarcomas are difficult to diagnose preoperatively. The risk of an unexpected uterine sarcoma following surgery for a presumed benign indication is approximately 1 in 350, and the rate of leiomyosarcoma is 1 in 500 [36]. If undiagnosed sarcoma is morcellated that will indeed worsen the prognosis and negatively affect the overall survival. It is imperative that preoperative endometrial biopsy and cervical assessment to avoid morcellation of potentially detectable malignant and premalignant conditions is strongly recommended [37]. Morcellation is contraindicated for patients with hereditary cancer syndromes, and in women with established or suspected cancer where a gynaecologic oncology consultation is mandatory. Irrespective of the current local hospital policy about power morcellation, each patient should be counselled about the possible risks associated with the use of morcellation, including the risks associated with underlying malignancy. Modified morcellation techniques including the use of bags for containment are currently being tested for safety and efficacy. Despite the fact that the FDA has approved the first tissue containment system for use with certain laparoscopic power morcellators to isolate uterine tissue that isn't suspected to be cancerous, there is no clear evidence to support that their use would nullify or prevent the dissemination of undiagnosed uterine sarcomas [38].

21.3.14 Oncologic Procedures

Laparoscopy originally was used in gynecologic oncology for second-look procedures after surgical and chemical treatment of the malignancy. More recently, laparoscopy has been used for the initial staging of gynecologic cancer, including hysterectomy, peritoneal washes with biopsy, partial omentectomy, and pelvic and periaortic lymphadenectomy. Techniques have also been developed for laparoscopically assisted radical vaginal hysterectomy.

The laparoscopic approach to gynecologic cancer remains controversial. There is some concern that laparoscopy might increase the risk of intraperitoneal spread of ovarian cancer. Until the risk, benefits, and the effect on long-term prognosis have been shown to be equal to laparotomy, the laparoscopic approach will remain under close scrutiny.

21.3.15 Robotically Assisted Laparoscopic Surgery

Robotic technology has attempted to address the limitations of conventional laparoscopic surgery. The use of a remotely controlled robot has the potential to facilitate these procedures by allowing the surgeon to be seated comfortably while providing the surgeon a three-dimensional view with improved dexterity and access.

The most commonly used robotic system is the "da Vinci system" (Intuitive Surgical, Mountain View, CA, USA). The FDA approved it for use in abdominal surgeries in 2000. There are three main components: the surgeon console, the surgical cart, and the vision cart. The surgeon sits at a console separate from the surgical field. Movement of handles at the console results in movement of surgical instruments at the operative field. In this system, the surgeon looks into a console that has a dual lens system within the 12-mm laparoscope. The system provides true binocular 3D vision that is similar to looking into a microscope that enables the surgeon to see fine structures up to a tenfold magnification. Movement of the laparoscope is accomplished through the movement of the handles at the console.

The most impressive part of the system is the intra-abdominal articulation of the microinstruments 2 cm from the tip. This articulation serves the same function as a human wrist, mimicking the movements of a hand. This articulating wrist has 7 degrees of freedom of the instruments, providing an opportunity for better suturing, dissection, and reconstructing tissue by allowing the surgeon access to deep pelvic structures. The movement of the instrument tip is intuitive and requires minimal training.

The cart contains the instrument arms and camera arm. The vision cart allows all members of the surgical team to visualize the procedure. Not only does this system provide visual advantages for more precise surgery, improved dexterity, surgeon comfort with less hand fatigue, and improved instrument articulation but also it eliminates unintentional hand tremors.

There are some limitations with the use of robotic technology. One is the initial system cost, maintenance costs, and expense of disposable instruments. Another is the lack of tactile feedback during the procedure, requiring the use of visual cues to properly carry out surgical tasks. For appropriate docking of the robot, it is imperative that a dedicated staff specifically trained on the device is available during all procedures.

Another limitation of the robotic system is its bulky size. Increased surgical operation time is a main limitation of the robotic system. This is attributed to the time required for robot preparation and docking as well as console time. Sait reported an operative time of 92.4 min for a laparoscopic hysterectomy, compared to 119.4 min for a hysterectomy with robotic assistance. However, they also showed a significant learning curve, shortening the length of operation times with increasing robotic experience [39]. Similar results were independently corroborated in a randomized controlled trial [40].

Cost is an important limitation that should be considered. Robotic surgical systems are very costly, adding approximately $3500 per procedure and approximately $2.5 billion nationally per year. This is a huge expense considering little evidence of improved outcomes over standard laparoscopy. Added to these costs, Medicare and most US private insurers do not pay additional fees for use of robotics. To overcome this, hospitals most likely will increase charges for procedures or diagnoses for which robots are used [41, 42]. The reality is that robotics overall is more costly than laparoscopy, but if it allows more surgeons to perform MIS, then maybe in the end it will end up being less costly. Wherever and whenever feasible, robotic-assisted laparoscopic surgery should not replace conventional laparoscopic or vaginal procedures for women undergoing benign gynecologic diseases. This was supported by the findings of a 2012 Cochrane Review [43]. The advantages and the disadvantages of the robotic systems are summarized in ◘ Table 21.1.

◘ Table 21.1 Advantages and disadvantages of the da Vinci robotic system

Advantages	Disadvantages
3D visualization	Initial system cost
Improved ergonomics	No tactile feedback
Improved dexterity	Lack of research on efficiency
7 Degrees of freedom	Insufficient cases to train residents
Elimination of fulcrum effect	Large size of systems
Motion scaling	
Improved suture capabilities and knot tying	

21.3.16 Robotic Gynecologic Surgery

Robotic systems have the potential to convert surgical procedures that we presently perform by laparotomy to laparoscopy and are currently utilized in the fields of reproductive endocrinology and fertility, gynecologic oncology, and female pelvic medicine/reconstructive surgery (◘ Table 21.2). It has been used in robotically assisted tubal anastomosis.

21.3.17 Robotically Assisted Tubal Reanastomosis

For a variety of reasons, sterilization reversal is an alternative to IVF, particularly for patients younger than the age of 35. The immediate and the long-term postoperative outcomes were compared with laparoscopic tubal anastomosis without robotic assistance [44]. The operative times were longer with the use of the robot. The tubal patency rates and clinical pregnancy rates were not significantly different. The major difficulty with laparoscopic tubal anastomosis, with or without robotic assistance, is the limited needle angles to the tubes due to operating through fixed ports. It has been reported that robotic technology is successful in facilitating laparoscopic tubal anastomosis using the da Vinci system. All of the tubal anastomoses were performed with the use of three or four robotic arms, three or four robotic instruments, and one assistant trocar. While the use of robotics prolonged surgical and anesthesia times as well as increased cost, there was no significant difference in pregnancy outcomes compared to a laparotomy technique. Additionally, patients were able to return to normal activities faster than after a laparotomy [45, 46].

Table 21.2 Current uses of robotics in reproductive surgery, gynecologic oncology, and reconstructive pelvic surgery

Reproductive surgery
Simple hysterectomy
Myomectomy
USO, BSO
Tubal reanastomosis
Resection of endometriosis
Ovariopexy
Gynecologic oncology
Radical hysterectomy
Pelvic and para-aortic lymphadenectomy
Appendectomy
LAVH
USO, BSO
Sentinel lymph node biopsy
Omentectomy
LARVH
Ovarian cystectomy
Radical parametrectomy
Radical vaginal trachelectomy
Radical cystectomy
Reconstructive pelvic surgery
Bladder repair
Hysterectomy
Vesicovaginal fistula repair
Sacrocolpopexy

21.3.18 Robotically Assisted Myomectomy

Myomectomy remains the best choice of treatment of symptomatic fibroids in patients desiring to preserve their fertility, even with the new modalities such as uterine artery embolization [26, 47]. Open myomectomy used to be the treatment modality until the emergence on minimally invasive technique. Laparoscopy yielded better cosmesis and shorter postoperative pain and hospital stay. However, this procedure was very challenging. A limitation included needing to precisely dissect the fibroid without unnecessary breaching of the endometrial cavity. Since laparoscopic suturing is a difficult skill to master, it is complicated to suture the fibroid beds in layers with precise approximation of edges, which is needed to prevent uterine rupture during labor. These challenges limited the enthusiasm and acceptance of this technique.

Many studies demonstrated the feasibility of robotically assisted myomectomy [26, 48]. Most recently, the operative and immediate postoperative surgical outcomes of robotically assisted laparoscopic myomectomy, standard laparoscopic myomectomy, and open myomectomy were compared. Blood loss, operative time, and hospital stay were lower for the robot-assisted group. These results showed an association of robotic-assisted myomectomy with decreased blood loss and length of hospital stay compared with traditional laparoscopy and to open myomectomy [49].

21.3.19 Robotically Assisted Resection of Endometriosis

Nezhat et al. compared robotic treatment of stage I or II endometriosis to conventional laparoscopy in a retrospective cohort controlled study in 2010. Forty patients were treated for endometriosis by robot-assisted laparoscopy, and 38 patients were treated by standard laparoscopy. There were no significant differences between these groups in blood loss, hospitalization, or complications, but the mean operative time with the robot was 191 min (135–295) compared with 159 min (85–320) during standard laparoscopy. Since both treatments have excellent outcomes and the robotic technique required a longer operative time, it was concluded that the robot has no added value for the treatment of early stage endometriosis [50].

Most recently, we reported on the safety and feasibility of robotic surgical treatment of advanced pelvic endometriosis. Fifty women underwent a robotic procedure for advanced endometriosis. Twenty-one (42%) had stage III and 29 (58%) had stage IV endometriosis. The median total operative time was 209 (range: 97–368) min, including patient positioning, robot docking, performing surgery, and closure of the port sites. Median actual operative time was 154 (range: 67–325) min, and both total OR time and actual operative time were comparable between the two groups. There was no difference between the two groups regarding estimated blood loss and uterine weight. Pathological evaluation confirmed the endometriosis diagnosis in all patients [51]. In a more recent series, operating time was identified as the only risk factor for the length of the hospital stay and the postoperative complications in patients with stage 3 and stage 4 disease [52].

21.3.20 Clinical Applications in Gynecologic Oncology

The traditional approach to gynecologic oncology surgeries involves a total hysterectomy, bilateral salpingo-oophorectomy, and dissection of both pelvic and para-aortic lymph nodes. These surgeries and others are now being conducted with the use of robotic surgical systems in select patients.

The specific advantages of robotic-assisted endoscopic procedures in gynecologic oncology arise from the da Vinci's enlarged operative field without the need for large fascial incisions. This allows for more easily identifiable pelvic anatomy while patients experience decreased postoperative morbidity and faster recovery to permit rapid initiation of adjuvant radiotherapy or chemotherapy. The safety profile of the da Vinci utilized for gynecologic oncology applications appears reassuring, with less blood loss and a low complication rate in managing ovarian, endometrial, and cervical cancers, respectively [53–55].

In a recent survey of the Society of Gynecologic Oncology (SGO) members to evaluate the current patterns of use of minimally invasive surgical procedures, including traditional, robotic-assisted, and single-port laparoscopy, and to compare the results to prior 2004 and 2007 surveys, there a significant increase in the uptake of the MIS approach. Overall, three indications for laparoscopy have expanded beyond endometrial cancer staging to include surgical management of early stage cervical and ovarian cancers, but the use of single-port laparoscopy remains limited. There was an increase in the overall use and indications for robotic surgery. This significant rise included radical hysterectomy or trachelectomy and pelvic lymphadenectomy for cervical cancer and total hysterectomy and staging for endometrial cancer. These procedures were found to be significantly more appropriate for the robotic platform in comparison to conventional laparoscopy [56].

21.3.21 Clinical Applications in Female Pelvic Medicine and Reconstructive Surgery

In the literature, robotics have been utilized in the repair of both vesicovaginal fistulas and in the treatment of post-hysterectomy vaginal vault prolapse with sacrocolpopexy [57]. It has been shown that the involvement of obstetrics and gynecology and urology residents has no effect on the surgical outcome of robotic-assisted sacrocolpopexy (RASCP) [58]. The question remains that although the use of robotics combines the outcomes of an open procedure, the benefits of minimally invasive surgery and easy adoptability, does it outweigh the increased cost and time [59]? Like in other disciplines, it has been shown that the robotic approach is longer and more costly than the conventional approach in urogynecologic disorders [60].

21.3.22 Single-Port Laparoscopy

The concept of natural orifice surgery has been recently revisited. Advancements in surgical instruments, optics, and ports have allowed the development of single-port laparoscopy or LESS. LESS can be used for salpingostomy or salpingectomy to treat tubal ectopic pregnancy [61].

Recent studies indicate that the procedure has low rate of complications and similar surgical outcomes compared to conventional laparoscopy. LESS has also been found to be associated with a reduction of gas leakage. The use of LESS has the advantages of reduced postoperative pain, earlier return to daily activities, reduced incidence of port-site hernias and hemorrhage, and improved cosmesis and patient satisfaction. However, data on long-term effectiveness are lacking [62].

LESS is now being used to treat benign and malignant adnexal disease and for hysterectomy. For adnexal disease, LESS can be used to remove ovarian cysts, for salpingo-oophorectomy, to remove endometriosis, and to remove malignant masses. Single-port access total hysterectomy is more commonly used now, with various advancements in place to overcome the limited free movement and technical difficulty. Combining LESS with the da Vinci robot system allows further benefits, including better cosmesis, reduced morbidity from injury during trocar placement, a reduced incidence of postoperative wound infections and hernia formation, and improved dexterity [62].

In a review of 6 RCTs and 15 observational studies including a total of 2085 patients (899 single-incision laparoscopies and 1186 conventional laparoscopies), the surgical outcomes were evaluated. In the pooled analysis, there was no difference in the risk of complications between single-incision laparoscopy and conventional laparoscopy in gynecologic surgery. However, some studies suggest that single-incision laparoscopy may have longer operative time for adnexal surgery, but not for hysterectomy [63]. It remains uncertain if such a new technology is cost-effective with comparable long-term surgical outcomes.

21.3.23 Laparoscopic Complications

Overall, laparoscopy has a relatively favorable complication profile compared to the same procedure performed via laparotomy. In addition to the procedure-related complications, laparoscopy is associated with uncommon but significant complications related to trocar insertion. These injuries involve primarily blood vessels, bowel, and bladder. Given its mostly blind nature, insertion of the Veress needle and primary trocar for initial entry by trocar insertion remains the most hazardous part of laparoscopy, accounting for 40% of all laparoscopic complications and the majority of the fatalities. Despite decades of research and development to find safer methods for initial laparoscopic entry, major vessel injuries have been reported using virtually all types of trocar insertion methods [64]. The following is a brief discussion of avoidance and manage of these complications.

21.3.24 Retroperitoneal Vessel Injury

Techniques used to place primary and secondary laparoscopic ports into the peritoneal cavity are often accompanied by a small but unavoidable risk of injury to blood vessels located in the anterior abdominal wall and the major blood vessels located in the retroperitoneal space. Injury of major abdominal blood vessels is a rare but treatable life-threatening complication of laparoscopy, which occurs in approximately 3 per 10,000 laparoscopies [65]. These injuries most commonly occur during insertion of the Veress needle or primary trocar.

21.3.25 Prevention

The majority of retroperitoneal vessel injuries during laparoscopy occur during blind placement of the Veress needle or primary trocar through a periumbilical incision [66]. To minimize this risk, surgeons need to be aware of anatomic considerations so that they can determine the most appropriate direction and angle of insertion for each patient, as discussed above. The different approaches for primary prevention of vessel injuries are discussed in the following sections.

21.3.26 Awareness of the Patient's Position

For greatest safety, the surgeon should make sure they are aware of the patient's position in relation to horizontal prior to laparoscopic instrument placement. Most laparoscopic surgery is performed in the Trendelenburg position to keep bowel away from the operative field in the pelvis. If the patient is placed in Trendelenburg position with the feet elevated 30° relative to the head prior to instrument insertion, instruments inserted at 45° from horizontal will actually be placed at 75° from the horizontal plane of the patient's spine, which is likely to increase the risk of major vessel injury, particularly in slender patients [67].

21.3.27 High-Pressure Entry

Another technique used in conjunction with closed laparoscopy in an effort to decrease the risk of major vessel injury is "high-pressure entry." Rather than inserting the primary umbilical trocar after obtaining intra-abdominal pressure of 18–20 mmHg, many surgeons increase the pressure to 25–30 mmHg. The rationale is to make the anterior abdominal wall stiffer such that the downward pressure exerted by trocar insertion does not decrease the distance of the umbilicus to the retroperitoneal vessels [68]. Although no controlled studies large enough to demonstrate an advantage have been published, large series including more than 8000 cases suggest that the risk of major vessel injury using this technique is approximately 1 in 10,000 cases (0.01%), compared to a risk of 4 in 10,000 cases (0.04%) reported using standard pressures [69].

21.3.28 Verify Veress Needle Location

Use of the Veress needle used to insufflate the peritoneal cavity is associated with a small risk of intravascular insufflation and venous gas embolism, reported to occur in approximately 1 in 100,000 laparoscopic procedures [70].

Several methods have been used to demonstrate the intraperitoneal location of the Veress needle tip. First, the Veress needle should be placed with the valve open, so that entering a high-pressure arterial blood vessel will immediately result in extrusion of blood through the needle. Second, after needle placement, a syringe should be used to aspirate the Veress needle, to verify that a low-pressure venous blood vessel has not been entered. This is often followed by the "hanging drop test," wherein a drop of saline is placed at the open end of the Veress needle hub. When the abdominal wall is elevated, the drop often disappears into the shaft if the tip is located in the relatively low-pressure peritoneal cavity but will usually not disappear if the tip is preperitoneal or embedded in some other structure.

The "Waggle test" is another maneuver used by some to verify that the needle has not entered the retroperitoneal space. After the needle is placed in the proper position, the hub is moved from side to side using gentle lateral pressure. Lack of lateral mobility suggests that the tip is anchored in the immovable retroperitoneal space, and the needle should be slowly withdrawn until lateral movement is possible. This technique is difficult to interpret in obese patients because the abdominal wall itself can limit lateral movement of the Veress needle, even if it is placed through the base of the umbilicus at the proper angle.

It is recommended that at least one of these methods be used when placing a Veress needle into the abdomen [71]. However, none of these methods absolutely verify intraperitoneal placement of the needle tip. Once insufflation is begun, the strongest predictor of intraperitoneal placement appears to be an initial filling pressure of <10 mmHg.

21.3.29 Other Laparoscopic Entry Methods

Multiple insertion methods and instruments have been developed in an effort to decrease the risk of trocar complications. Although each method has theoretical advantages compared to the traditional closed techniques, none has completely eliminated the risk of major vessel injury.

21.3.30 Open Laparoscopy

Open laparoscopy is a widely used alternative technique for placement of the primary laparoscopic port. The Hasson technique is fundamentally a minilaparotomy incision followed by placement of the primary port directly into the peritoneal cavity [72]. Open laparoscopy almost completely prevents the risk of major vessel injury, decreasing the rate to 0.01%, compared to a rate of 0.04% associated with closed techniques using a Veress needle [69].

21.3.31 Direct Trocar Insertion

Direct trocar insertion is a laparoscopic entry technique wherein the primary trocar is placed without prior insufflation, with or without elevation of the anterior abdominal wall manually or with towel clips. This approach is slightly faster than standard closed laparoscopy and avoids the risks of Veress needle placement. Unfortunately, this technique might increase this risk of major vessel injury. Large series (>10,000 cases) report a major vessel injury risk of 0.06–0.09% compared to 0.04% using a standard closed technique [71]. This risk of major vessel injury might be one reason why direct trocar insertion is one of the least frequently used techniques by gynecologists.

21.3.32 Left Upper Quadrant

LUQ insertion of the Veress needle and primary trocar through a site in the LUQ is recommended by some surgeons to decrease the risk of complications associated with bowel adhesions in women with prior abdominal surgeries. The LUQ insertion site (Palmer's point) is located 3 cm below the middle of the left costal margin, and instruments are routinely inserted perpendicular to the patients' skin.

Major vessel injuries have not been reported using this technique. Anatomic studies indicate that the abdominal wall is uniformly thin in this location and the distance from the skin to the retroperitoneal structures is >11 cm in most patients [17]. However, because this distance can be <7 cm in many slender patients, it is recommended that, in slender patients, instruments placed through Palmer's point be directed 45° caudally relative to the patient's spine [73].

21.3.33 Alternative Primary Trocar Design

Alternative primary trocars have been developed, including shielded disposable trocars, optical trocars, and radially expanding trocars [71]. Unfortunately, their use does not prevent major blood vessel injuries. Currently, there is no evidence of benefit of one technique or instrument over another in terms of preventing major vascular injury. When comparing bladed to radially expanding trocars, studies showed less minor complications and a trend toward pain reduction when using a radially expanding trocars [8].

21.3.34 Treatment

Major vessel injuries are a rare but unavoidable laparoscopic complication associated with the closed entry techniques. Every laparoscopic surgeon that uses a closed technique should develop a plan of action for major vessel injury. The surgeon should also become familiar with the availability of laparotomy instruments, blood products, vascular clamps, and surgical consultants. This is especially important when these procedures are performed in a free-standing outpatient surgical facility.

When a major vascular injury is suspected, the following steps should be taken without delay. The nursing personnel should prepare for emergency laparotomy, and anesthesia personnel should consider placing additional intravenous lines and calling for blood products and additional assistance. The surgeon should immediately perform a laparotomy via a midline incision, and blood loss should be minimized using direct pressure over the injury site. When the injury occurs in a medical center, a trauma surgeon or vascular surgeon should be called in to identify and repair the vascular injuries.

The treatment approach is different when a major vessel injury occurs in a facility where vascular surgery personnel and equipment are not available. In these instances, a laparoscopic surgeon without experience in vascular surgery should not attempt to open the retroperitoneal area to repair the vessel [71]. This approach can further injure the vessels, and resultant lack of circulation to the lower extremities can have catastrophic results. Rather, the abdomen should be packed tightly with dry laparotomy pads, and the abdomen quickly closed with either running full-thickness sutures or towel clips [74]. The patient should then be transported by the most expedient method to the nearest fully equipped trauma center.

21.3.35 Abdominal Wall Vessels Injury

Anterior abdominal wall vessels at risk for injury can be divided into two groups: superficial and deep [15]. The superficial vessels consist of the superficial epigastric and circumflex iliac arteries, which are located in the subcutaneous tissue. The deep vessel at risk is the deep inferior epigastric artery, which is located beneath the rectus abdominus muscles immediately above the peritoneum.

Damage to the superficial vessels is often asymptomatic at the time of surgery, whereas damage to a deep vessel usually leads to immediate and rapid blood loss. If unrecognized, damage to either type of vessels can result in postoperative hemorrhage or hematoma.

21.3.36 Prevention

The primary method for avoiding injury to any of these vessels is to visualize the vessels via transillumination and direct laparoscopic visualization prior to lateral trocar insertion. Transillumination of the anterior abdominal wall with the laparoscopic light source is an effective way to visualize the superficial vessels in almost 90% of patients

[14]. The inferior epigastric vessels cannot be seen by transillumination since they lie beneath the rectus abdominus muscle and fascia but can be directly visualized laparoscopically immediately beneath the peritoneum in the majority of patients where they lie between the insertion of the round ligament at the inguinal canal and the medial umbilical fold. Since both the deep and superficial vessels are located an average 5.5 cm from the midline, risk of vessel injury can be minimized by placing secondary trocars 8 cm lateral to the midline and 8 cm above the pubic symphysis [15].

21.3.37 Treatment

When a superficial vessel is found to be bleeding after the port is removed, the most effective approach is to grasp the vessel with a Crile "hemostat" forceps, followed by cautery or ligation. In cases where the injured vessel cannot be grasped, a pressure dressing is often sufficient.

When an inferior epigastric vessel is injured, the result is immediate and brisk bleeding from the port site into the peritoneal cavity. Anesthesiology personnel should be alerted because additional intravenous lines and blood products might be required if the patient becomes hemodynamically unstable. If another port is available, an attempt should be made to occlude the injured vessel with a laparoscopic bipolar electrosurgery instrument above and below the injury. If another port has not yet been placed or electrosurgery is not effective, the bleeding can be temporarily slowed by placing a Foley catheter through the port site into the peritoneal cavity. After the bulb is inflated with saline, the catheter is retracted to hold the bulb tightly against the peritoneal surface and a Kelly forceps used to cross-clamp the catheter on the skin side to maintain traction.

If bipolar electrosurgery is unsuccessful, precisely positioned sutures can be placed above and below the injury using port-site closure instruments. These sutures should be tied deep to the skin above the fascia.

If hemostasis cannot otherwise be achieved, the incision should be widened and the injured vessels individually ligated. The port-site incision should be enlarged transversely to at least 4–6 cm, the fascia of the anterior rectus sheath incised, and the lateral edge of the rectus abdominus muscle retracted medially. The bleeding vessels can be grasped with hemostatic forceps and selectively ligated above and below the injury.

Delayed bleeding can occur when the abdominal pressure decreases after removal of the carbon dioxide, especially if the method used to occlude an injured vessel becomes loose as the patient awakes from anesthesia and is moved [75]. Signs of hemodynamic instability in the recovery room necessitate a return to surgery because uncontrolled bleeding from a lacerated inferior epigastric artery can be life-threatening.

21.3.38 Gastrointestinal Injury

Despite the continued development of both laparoscopic instruments and techniques, gastrointestinal injury continues to be a common, yet potentially avoidable complication of laparoscopy. In the last four decades, the risk of this complication appears to have increased from approximately 3 per 10,000 procedures to as high as 13 per 10,000 procedures [65, 76]. Most bowel injuries occur during placement of the Veress needle or primary trocar and usually when bowel is adherent to the anterior abdominal wall from previous surgery [77]. Other gastrointestinal injuries result from operative procedures including adhesiolysis, tissue dissection, devascularization injury, and thermal injury.

It is essential to minimize morbidity related to gastrointestinal injuries both by prevention and early recognition. Despite an increasing awareness of these risks, gastrointestinal injuries continue to be the most lethal type of injuries associated with laparoscopy, with a mortality rate reported as high as 3.6% [76].

21.3.39 Preventive Measures

No method has yet to be discovered that completely prevents gastrointestinal injuries during laparoscopic port placement [78]. However, it is well established that patients with previous abdominal surgery are at increased risk of gastrointestinal injury during laparoscopy since adhesions to the anterior abdominal wall occur in approximately 25% of these patients. For this reason, certain measures have been used in an effort to decrease the risk of gastrointestinal injuries in these patients.

Two commonly used techniques for high-risk patients are open laparoscopy, as first described by Hasson, and a LUQ closed technique utilizing Palmer's point [78, 79]. Unfortunately, neither of these techniques has been shown in prospective comparison studies to decrease the risk of intestinal injury relative to the open technique [78, 80, 81].

Another alternative approach is the use of an optical-access trocar. These devices are designed to increase safety by visualizing each layer of the abdominal wall during port placement. Unfortunately, these devices have not been shown to decrease the risk of gastrointestinal injuries [82].

21.4 Recognition and Treatment

21.4.1 Veress Needle Injuries

The spring-loaded tip of the 14-gauge Veress needle does not prevent perforation of adherent bowel or bowel with limited excursion related to physiologic attachments, such as the transverse colon [83]. Most bowel perforations caused by the Veress needle do not need to be repaired as long as the puncture is not actively bleeding or associate with a tear {Loffer, 1975 #68). Even in the case of colonic puncture, nonoperative management with copious irrigation appears to be sufficient [84].

21.4.2 Stomach Injuries

Injury to the stomach during laparoscopy is relatively uncommon and was reported to occur in less than 3 in 10,000 cases in the earlier days of laparoscopy [85]. Risk factors include a history of upper abdominal surgery and difficult induction of anesthesia, as a gas distended stomach can be below the level of the umbilicus. Routine decompression of the stomach with a nasogastric tube prior to Veress needle or trocar placement has virtually eliminated this risk, even when a LUQ approach is used.

Trocar injury to the stomach requires surgical repair, either via laparotomy or laparoscopy [86]. The defect should be repaired in layers with a delayed absorbable suture by a surgeon experienced in gastric surgery. The abdominal cavity should be irrigated, being careful to remove all food particles as well as gastric juices. Nasogastric suction is maintained postoperatively until normal bowel peristalsis resumes.

21.4.3 Small Intestine Injuries

Intraoperative injuries to the small intestine often go unrecognized during surgery. Injury should be suspected whenever multiple anterior abdominal wall adhesions are present. When the primary trocar and sleeve penetrate completely through both walls of bowel adherent near the umbilicus, the injury will not be visible. Whenever the routine 360° survey of the abdominal cavity reveals bowel adherent near the point of insertion, a 5-mm laparoscope should be placed through a lower quadrant port to view the umbilical port site and search for injury. An injury to nonadherent bowel with the Veress needle or a trocar during initial port placement or during lysis of adhesions may fall out of view into the abdomen. If such an injury is suspected, the bowel should be run with laparoscopic bowel graspers or manually using a laparotomy incision until an injury is satisfactorily excluded.

Postoperatively, unrecognized trocar injuries to the small intestine usually present with symptoms of nausea, vomiting, anorexia, abdominal pain, peritoneal signs, and possibly fever on the second to fourth postoperative day. Although the bacterial load of the small intestine is low, the contents are not sterile, and sepsis is a common result of undiagnosed injuries.

A full-thickness injury to the small intestine of 5 mm or greater should be repaired in two layers, sewing perpendicular to the long axis of the intestine to avoid stricture formation. This can be accomplished with an initial interrupted layer of 3–0 delayed absorbable suture to approximate the mucosa and muscularis. A serosal layer of 3–0 delayed absorbable suture is commonly placed in an interrupted fashion. This is usually performed by laparotomy or by minilaparotomy at the umbilical site, where the injured bowel loop is pulled through to the skin surface and repaired. Laparoscopic repair has also been reported by surgeons with advanced gastrointestinal surgical skills [87]. If the laceration to the small bowel exceeds one-half of the diameter of the bowel lumen, segmental resection is recommended.

21

21.4.4 Large Intestine Injuries

Trocar injuries to the large intestines are reported to occur with frequency of approximately 1 per 1000 cases [88]. Due to the high concentration of coliform bacteria in the large intestine, unrecognized injuries can result in serious intra-abdominal infections that can quickly become life-threatening.

Whenever a large intestine injury is suspected, the area should be carefully inspected using atraumatic bowel graspers. If adhesions or anatomy make laparoscopic inspection difficult, laparotomy is reasonable. An occult injury to the rectosigmoid colon may be detected using the "flat tire test," in which the posterior cul-de-sac is filled with normal saline and air is injected into the rectum using a proctosigmoidoscope or a catheter-tipped bulb syringe [89]. Visible bubbles indicate a large intestine injury.

The management of large intestine injuries depends upon size, site, and time between injury and diagnosis. In general, once the diagnosis of colonic injury is made, broad-spectrum antibiotics should be administered and consultation should be sought with a surgeon experienced with these types of injury. In the case of a small tear with minimal spillage of bowel contents, the defect is closed in two layers with copious irrigation. When a larger injury has occurred or the injury involves the mesentery, a diverting colostomy is sometimes necessary. In the case of delayed (postoperative) diagnosis, tissue inflammation usually makes a diverting colostomy necessary.

21.4.5 Port-Site Hernia

For the first two decades of laparoscopy, ports were placed almost exclusively in the midline, where the anterior and posterior rectus fascia fuses. These midline ports usually consisted of a 10-mm port at the umbilicus and a 5-mm suprapubic port. Port-site hernias at these locations are rare, and those reported are usually limited omental herniation through the umbilical site.

The use of lateral ports for more complex operative laparoscopy has resulted in a dramatic increase in the risk of port-site herniation. In one retrospective review, port-site hernias occurred in 5 of 3500 (0.17%) procedures, with all hernias occurring where ports with diameters ≥10 mm were placed lateral to the midline [90]. Since the rectus fascia splits laterally to form both anterior and posterior sheaths below the arcuate line, bowel herniation can occur between these two fascial layers in what has been called a "Spigelian hernia."

21.4.6 Prevention

To minimize the risk of port-site herniation, both the anterior and posterior fascial sheaths should be closed after removal of all ports 8 mm and larger. This closure is usually performed with the aid of one of a number of commercially available devices or needles that incorporate the peritoneum as well as both fascial layers. Unfortunately, port-site herniation is not completely prevented by careful fascial closure [91].

21.4.7 Recognition and Treatment

Trocar-site hernias usually present as a palpable mass beneath a lateral trocar-site skin incision that manifests during a Valsalva maneuver. Ultrasonography can distinguish herniated bowel from a hematoma. A persistent mass associated with pain indicates an incarcerated hernia and represents a surgical emergency.

Herniated bowel can often be reduced laparoscopically, followed by careful inspection of the affected segments. Although simple repair of the peritoneal and fascial defects is all that is required in most healthy patients, in some cases synthetic mesh may be needed.

21.4.8 Bladder Injuries

Injury to the bladder related to laparoscopic port placement is relatively uncommon and usually related to insertion of the primary trocar in the presence of a distended bladder or insertion of a suprapubic midline trocar in a patient whose bladder dome had extended cephalad secondary to previous surgery [92].

21.4.9 Prevention

The risk of trocar injuries to the bladder can be decreased by draining the bladder with a catheter prior to primary trocar placement. In patients with prior lower abdominal surgery, it seems prudent to place the suprapubic trocar above any previous transverse skin incisions. In all patients, an attempt should be made to visualize the superior bladder margin laparoscopically prior to suprapubic trocar placement [14]. In cases where the superior margin of the bladder cannot be seen, the bladder can be filled with 300 mL to better define its margin. An alternative approach is to use a lateral port site rather than a midline suprapubic site, although the decreased risk of bladder injury may be offset by an increased risk of vessel injury.

21.4.10 Recognition

Laparoscopic bladder injuries are often difficult to recognize intraoperatively. Visible leakage of urine at the time of injury is unlikely in patients with a Foley catheter in place. A common sign of bladder injury is significant bleeding from a suprapubic port site placed in the relatively avascular midline. Frank hematuria suggests a full-thickness injury. An uncommon, but pathognomonic, sign of bladder injury during laparoscopy is insufflation of the Foley catheter bag with carbon dioxide [93].

If bladder injury is suspected during laparoscopy, an indigo carmine solution can be instilled retrograde through a urethral catheter to detect small leaks. Cystoscopy or, less commonly, intentional cystotomy may be used to inspect the bladder mucosa in questionable cases, or to determine the extent of a known injury and to insure that there is no ureteral involvement.

Postoperative recognition of a bladder injury can likewise be difficult. Whenever a patient returns within days of laparoscopy with significant abdominal findings, the possibility of an occult bladder injury should be considered [92]. Bladder injury should be included in the differential diagnosis in the presence of painful urination and microscopic hematuria. Elevation of blood urea nitrogen (BUN) and a serum creatinine suggests intra-abdominal spill of urine with transperitoneal reabsorption. Drainage from a suprapubic incision can be evaluated further by instillation of a dilute indigo carmine solution into the bladder.

21.4.11 Treatment

When a bladder injury is diagnosed in the postoperative period, a retrograde cystogram should be performed to determine the extent of the injury. If surgery is indicated because of peritoneal signs of uncertain etiology, cystoscopy prior to laparotomy may be extremely helpful in determining surgical approach.

Small, uncomplicated, and isolated injuries of superior portion of the bladder can be treated with catheter drainage alone [94]. A retrograde cystogram should be performed after 10 days of continuous drainage and will document spontaneous healing in 85% of patients with small injuries. Primary surgical repair is required for larger injuries and those that involve the dependent portions of the bladder, including the trigone, especially if there is a risk of concomitant injury to the urethra or ureter. Closure should be performed using a water-tight, multilayered repair with absorbable suture. Laparoscopic repair may be performed by those with adequate surgical expertise as long as there is adequate exposure and the ureters and bladder neck are not compromised [95].

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