• Positioning the insufflation needle and the primary cannula are best accomplished with the patient in an unaltered horizontal position.

• Proper patient selection is critical for laparoscopic management of ovarian cysts because of concerns about an adverse effect on prognosis with malignant tumors.

• Laparoscopic myomectomy often requires laparoscopic suturing; thus, more technical skills are needed than with many other endoscopic procedures.

• Laparoscopic hysterectomy comprises any removal of the uterus where at least part of the dissection is accomplished laparoscopically while the remainder, if any, is finished vaginally.

• Dehiscence and hernia risk appear to significantly increase when the fascial incision is larger than 10 mm in diameter.

• The incidence of unintended electrosurgical activation injuries can be reduced if the surgeon always remains in direct control of electrode activation and if all electrosurgical hand instruments are removed from the peritoneal cavity when not in use.

• Patients recovering from laparoscopic surgery usually experience daily improvement. Pain diminishes, gastrointestinal function returns rapidly, and fever is extremely unusual. Therefore, if a patient’s condition is not improving, possible complications of anesthesia or surgery should be considered.

Endoscopy is a procedure that uses a narrow telescope to view the interior of a viscus or preformed space. Although the first medical endoscopic procedures were performed more than 100 years ago, the potential of this method was realized only recently. Endoscopes are used to perform a variety of operations. In gynecology, endoscopes are used most often to diagnose conditions by direct visualization of the peritoneal cavity (laparoscopy) or the inside of the uterus (hysteroscopy).

When used appropriately, endoscopic surgery offers the benefits of reduced pain, improved cosmesis, lower cost, and faster recovery. The indications for endoscopic surgery are outlined here and described in more detail in the appropriate chapters. The technology, potential uses, and complications of laparoscopy and hysteroscopy are summarized here.

Laparoscopy

The past four decades have witnessed rapid progress and technologic advances in gynecologic laparoscopy. Operative laparoscopy was developed in the 1970s, and in the early 1980s, laparoscopy was first used to direct the application of electrical or laser energy for the treatment of advanced stages of endometriosis. The use of high-resolution, and, more recently, high-definition video cameras in operative laparoscopy made it easier to view the pelvis during the performance of complex procedures (1,2). Most procedures that previously were performed using traditional techniques are feasible with the laparoscope, including adnexal procedures such as ectopic pregnancy and ovarian cystectomy; uterine surgery, such as myomectomy and hysterectomy; and reconstruction of the pelvic floor, such as retropubic urethropexy and sacral colposuspension. The endoscopic approach may have drawbacks in some patients. Although many laparoscopic procedures appear to reduce the cost and morbidity associated with surgery, others were replaced by even less invasive procedures, and a few were not effective replacements for more traditional operations. The use of microprocessor-assisted laparoscopy allows the surgeon to operate remotely from the operative field, in a sitting position, with the “robot” allowing translation of natural hand manipulations to the peritoneal cavity with the specially designed instruments. The value of this and other techniques and indications for operative endoscopy are still under investigation and constantly in a state of evolution.

Diagnostic Laparoscopy

The lens of a laparoscope can be positioned to allow wide-angle or magnified views of the peritoneal cavity. The clarity and illumination of the optics allow a better appreciation of fine detail than is possible with the naked eye. Laparoscopy is the standard method for the diagnosis of endometriosis and adhesions because no other imaging technique provides the same degree of sensitivity and specificity.

There are limitations to laparoscopy. The view of the operative field may be restricted, and if tissue or fluid becomes attached to the lens, vision may be obscured. Soft tissues, intramural myomas, or the inside of a hollow viscus cannot be palpated. For assessment of these tissues, an imaging modality, such as ultrasonography, computed tomography (CT), or magnetic resonance imaging (MRI), is superior. Because of its ability to view soft tissue, ultrasonography is more accurate than laparoscopy for the evaluation of the inside of adnexal masses. The intraluminal contour of the uterus
instances with sutures, clips, or linear cutting and stapling devices. The ureter should be identified and should be clear of the pedicle to be transected.

The technique for performing laparoscopy for oophorectomy and cystectomy is similar to that used for laparotomy and any frank malignancy should be managed expeditiously by laparotomy and imaging technology, laparoscopy more often is used to confirm a clinical impression than for initial diagnosis.

Laparoscopy may disclose abnormalities that are not necessarily related to the patient’s problem. Although endometriosis, adhesions, leiomyomas, and small cysts in the ovaries are common, they are frequently asymptomatic. Thus, diagnostic laparoscopy must be performed prudently, interpreting findings in the context of the clinical problem and other diagnoses.

Therapeutic (Operative) Laparoscopy

The role of laparoscopy in the operative management of gynecologic conditions is evolving. Many procedures previously performed as traditional abdominal and vaginal operations are feasible or even readily performed under laparoscopic direction. Operative laparoscopy has the benefit of shorter hospital stays, less postoperative pain, and faster return to normal activity. These general features of laparoscopic procedures contribute to a reduction in the “indirect costs” of surgical care, including less time away from work and a diminished need for postdischarge supportive care in the home. In addition to the other benefits of endoscopic procedures, adhesions are less likely to form with laparoscopic surgery than with laparotomy. Because sponges are not used, the amount of direct peritoneal trauma is reduced substantially, and contamination of the peritoneal cavity is minimized. The reduced exposure to the drying effect of room air allows the peritoneal surface to remain more moist and, therefore, less susceptible to injury and adhesion formation.

Despite these advantages, there are potential limitations: exposure of the operative field can be reduced; instruments are small and can be used only through fixed ports; and the ability to manipulate the pelvic viscera is limited. In some cases, the cost of hospitalization increases, despite a shortened stay, because of prolonged operating room time and the use of more expensive surgical equipment and supplies. Efficacy may be reduced if a surgeon cannot adequately replicate the abdominal operation. In some patients, there is an increased risk of complications, which can be attributed to the innate limitations of laparoscopy, the level of surgical expertise, or both. With an adequate combination of ability, training, and experience, however, operative time is comparable to those of traditional abdominal surgery and complications may be reduced.

Tubal Surgery

Sterilization

Laparoscopic sterilization has been used extensively since the late 1960s, and while it can be performed with local anesthetics, it is usually accomplished under general anesthesia. The fallopian tubes can be occluded by suture, clips, silastic rings, or with radiofrequency electrocoagulation, most commonly with a bipolar electrocoagulation instrument (see Chapter 10). When an “operative laparoscope” is used, only one incision is required because the sheath in such a system contains an instrument channel. Otherwise, a second port is needed for the introduction of the occluding instrument. Patients generally remain in the hospital only for a few hours; even when general anesthesia is used. Postoperative pain is usually minor and related to gas that remains in the peritoneal cavity (shoulder pain, dyspnea), and in the case of occlusive devices, pain at the surgical site. These effects normally disappear within a few days. The failure rate is about 5.4 per 1,000 woman-years. The use of laparoscopic tubal sterilization was impacted by the availability of office vasectomy, effective intruterine contraception, and the development of office-based hysteroscopic sterilization techniques, discussed later in this chapter.

Ectopic Gestation

Medical therapy with methotrexate is considered first-line therapy for tubal pregnancies that meet criteria that may include the following: no cardiac activity, tubal mass smaller than 4 cm as determined by ultrasonography, and β-hCG level less than 10,000 (7,8). When surgical therapy is required, ectopic gestation can usually be managed successfully by using laparoscopic salpingotomy, salpingectomy, or segmental resection of a portion of the oviduct (see Chapter 20) (9,10). Salpingotomy is performed with scissors, a laser, or an electrosurgical electrode after carefully injecting the mesosalpinx with a dilute vasopressin-containing solution (20 U in 100 mL of normal saline). For salpingectomy, the vascular pedicles are usually secured with electrosurgical desiccation or coagulation, but it is possible using ligatures or clips. Tissue is usually removed from the peritoneal cavity through one of the laparoscopic cannulas.

When salpingotomy is performed, regardless of the route, there is about a 5% chance that trophoblastic tissue remains. In such instances, medical treatment with methotrexate is appropriate (see Chapter 20). Consequently, β-hCG levels should be measured weekly until there is confidence that complete excision occurred (11–13).

Ovarian Surgery

Ovarian Masses

Laparoscopic removal of selected ovarian masses is a well-established technique supported by high quality evidence (14–16). Proper patient selection is critical for laparoscopic management of adnexal masses because of the possible adverse effect of laparoscopic approaches on prognosis with malignant tumors (17,18). Preoperative ultrasonography is mandatory. Sonolucent lesions with thin walls and no solid components are at very low risk for malignancy and, therefore, are suitable for laparoscopic removal. For postmenopausal women, the measurement of CA125 levels is useful in identifying candidates for laparoscopic management (19,20). Combining age, menopausal status, an ultrasound score, and the serum CA125 level into a “risk of malignancy index” seems to offer an effective approach to the identification of cysts at high risk for epithelial malignancy (21–23). Lesions with ultrasonographic findings suggestive of mature teratoma (dermoid), endometrioma, or hemorrhagic or other cysts presenting with torsion or other causes of acute pain may be suitable for endoscopic management (24–27). Ovarian tumors should be assessed by frozen histologic section, and any frank malignancy should be managed expeditiously by laparotomy (14,18,20).

The technique for performing laparoscopy for oophorectomy and cystectomy is similar to that used for laparotomy. For cystectomy, scissors are used to incise the ovarian capsule, and blunt dissection or aqua dissection is used to separate the cyst from the ovary. If oophorectomy is performed, the vascular pedicles are occluded and transected, usually with radiofrequency electrosurgical coagulation and cutting systems, but in some instances with sutures, clips, or linear cutting and stapling devices. The ureter should be identified and should be clear of the pedicle to be transected.

Efficacy

When surgical therapy is required, ectopic gestation can usually be managed successfully by using laparoscopic salpingotomy, salpingectomy, or segmental resection of a portion of the oviduct (see Chapter 20) (9,10). Salpingotomy is performed with scissors, a laser, or an electrosurgical electrode after carefully injecting the mesosalpinx with a dilute vasopressin-containing solution (20 U in 100 mL of normal saline). For salpingectomy, the vascular pedicles are usually secured with electrosurgical desiccation or coagulation, but it is possible using ligatures or clips. Tissue is usually removed from the peritoneal cavity through one of the laparoscopic cannulas.
Cysts that appear to be benign may be drained before extraction through a laparoscopic cannula or, less commonly, a posterior culdotomy. If there is concern about the impact of spilled cyst contents, the specimen should be removed in a retrieval bag inserted into the peritoneal cavity through a laparoscopic port. Some authors describe a minilaparotomy technique, or enlarging one port site incision, to exteriorize the mass, drain it externally without intraperitoneal spill, remove the cyst or ovary, and then reintroduce the adnexa into the peritoneal cavity.

Although in the past the ovary routinely was closed after cystectomy, this practice may be unnecessary and could contribute to the formation of adhesions. There is controversy about this point as at least one randomized clinical trial (class 1) suggested that suture-based closure of the ovary is associated with fewer adhesions than using electrodesiccation alone.

Other Ovarian Surgery

Ovarian torsion, previously treated by laparotomy and oophorectomy, often can be managed laparoscopically. Even if there is apparent necrosis, the adnexa can be untwisted, usually with preservation of normal ovarian function. Performing a cystectomy at the same time that the ovary is untwisted greatly reduces the likelihood that ovarian function will be maintained. Rarely is adnexitomy indicated.

Polycystic ovarian syndrome can be treated laparoscopically using electrosurgery or laser vaporization to perform ovarian “drilling.” This procedure reduces the volume of ovarian stromal tissue and may lead to a temporary return of normal ovulation. Although such procedures were successful in a number of randomized trials, postoperative adhesions form in 15% to 20% of patients, which underscores the need for first exhaust medical treatment.

Uterine Surgery

Myomectomy

Laparoscopic myomectomy, although feasible, may be difficult to perform because proper closure of the myometrium requires laparoscopically directed suturing and, thus, requires more technical skills than many other endoscopic procedures. While it is possible that microprocessor-assisted (robotic) laparoscopic myomectomy may allow more surgeons to suture effectively under laparoscopic guidance, even in expert hands there appears to be no benefit to robotic surgery in any measurable perioperative outcome.

There remain some questions regarding the efficacy of laparoscopic myomectomy, especially as it relates to the treatment of infertility and heavy menstrual bleeding, each of which are thought to be secondary to submucosal myomas. Although there are some well-designed studies evaluating infertility outcomes comparing laparoscopic myomectomy to that performed by laparotomy, the sample sizes are still relatively small, and the cases are highly selected, limiting the size and number of the lesions to be removed. In these trials, fertility outcomes were similar between the laparoscopic and the laparotomy approaches. These other trials evaluating perioperative outcomes, such as duration of admission, surgical pain, and operative complications, found the laparoscopic approach to be superior.

Proper patient selection for myomectomy, regardless of route, is extremely important, particularly because, by age 50, the prevalence of leiomyomas may be as high as 70% in whites and 80% in women of African ancestry. It is relatively easy to mistakenly ascribe symptoms to the presence of leiomyomas. Unless the myoma involves the endometrial cavity, it is unlikely to contribute to heavy menstrual bleeding or infertility; the impact of intramural myomas on infertility is not well understood. Leiomyomas that cause pressure are often large and may be located near vital vascular structures that may preclude the laparoscopic approach even in expert hands. Many women will do well with expectant or medical management or with procedural alternatives such as uterine artery embolization. The surgeon should freely select a laparotomic approach, either at the outset or during the procedure, if technical limitations put the patient at risk or otherwise compromise the potential relevant clinical outcomes. Patients who have pelvunculated or subserosal leiomyomas that cause bothersome discomfort or pain in association with torsion are especially good candidates for laparoscopic excision.

Hysterectomy

Laparoscopic hysterectomy encompasses a variety of procedures, including the facilitation of vaginal hysterectomy with variable extents of endoscopic dissection, supracervical hysterectomy by dissection, amputation and mechanical removal of the fundus, and the removal of the entire uterus under laparoscopic direction. In most environments, the procedure is performed with a combination of electrosurgical vessel sealing devices and mechanical cutting systems, often incorporated into a single instrument. In some instances sutures, clips, and linear cutting and stapling devices are employed in the process of dissecting or occluding vascular pedicles.

Compared to vaginal hysterectomy, there is a slightly higher risk of complications with laparoscopic hysterectomy, but this risk is probably lower than for abdominal hysterectomy. As experience is gained with laparoscopic hysterectomy, these outcomes may approach those of vaginal hysterectomy. The procedural costs of laparoscopic hysterectomy are greater than either vaginal or abdominal hysterectomy but can be dramatically reduced when reusable instruments are employed. Most studies show less postoperative pain, shorter hospital stays, and faster postoperative recovery with laparoscopic hysterectomy than with abdominal hysterectomy. There is evidence that pain scores and quality-of-life measures, including sexual activity and physical and mental functioning, were significantly better for women who underwent laparoscopic versus abdominal hysterectomy. These differences were present at 6 weeks following surgery and remained at the 12-month follow-up visit. When the societal benefits of faster return to work or family are considered, the cost of laparoscopic surgery is significantly less.

Selection of the route of hysterectomy must be done considering the anatomy, the disorder or disease state, the patient’s wishes, and the training and experience of the surgeon. Laparoscopic hysterectomy offers no advantage for women in whom vaginal hysterectomy is possible because the endoscopic approach is more expensive and probably has a higher risk for perioperative morbidity. The ideal place for laparoscopic hysterectomy is as a replacement for abdominal hysterectomy.

Outside of physician training, there are relatively few remaining indications for abdominal hysterectomy, which should be reserved for the minority of women for whom a laparoscopic or vaginal approach is not appropriate, including (i) patients with medical conditions, such as cardiopulmonary disease, where the risks of either general anesthesia or the increased intraperitoneal pressure associated with laparoscopy are deemed unacceptable; or (ii) where morcellation is known or likely to be required and uterine malignancy is either known or suspected. For both laparoscopic and vaginal hysterectomy the reasons include: (i) hysterectomy is indicated but there is no access to the surgeons or facilities required for vaginal or laparoscopic hysterectomy and
If referral is not feasible; or (ii) circumstances where anatomy is so distorted by uterine disease or adhesions that a vaginal or laparoscopic approach is not deemed safe or reasonable by individuals with recognized expertise in either vaginal or laparoscopic hysterectomy techniques (52,54). For surgeons without the skill and training to perform minimally invasive hysterectomy (either vaginal or laparoscopic), for benign indications, consideration should be given for referral to a gynecologist with such training.

Infertility Operations

When infertility occurs secondary to disruption of the normal anatomy or anatomic relationships by an inflammatory process, laparoscopically directed operations used to restore anatomy include fimbriloplasty, adhesiolysis, and salpingostomy for distal obstruction (55). Fimbrioplasty is distinguished from salpingostomy because it is performed in the absence of preexisting complete distal obstruction. Endometriosis associated with adnexal distorion can be treated by laparoscopic adhesiolysis. Whereas there is no known additional benefit of medical treatment of coexistent active endometriosis, the evidence relating to ablation of minimal and mild endometriosis is mixed, although when subjected to meta-analytic technique, there is a slight fecundity benefit for those undergoing laparoscopic ablation (56–58). Laparoscopy is used for procedures in which gametes (gamete intrafallopian transfer) or zygotes (zygote intrafallopian transfer) are placed into the fallopian tube after oocytes are removed either via ultrasound- or laparoscopically guided technique. Adhesiolysis may be accomplished by blunt or sharp dissection with scissors, ultrasonic shears, or an electrosurgical electrode. There is no evidence that laser-based instruments provide any additional value over less expensive techniques such as electrosurgery (59–61). The dissecting instruments are usually passed through an ancillary port; when laser energy is used, the channel of the operating laparoscope may be used for this purpose. Although there is controversy regarding the most appropriate modality for adhesiolysis, these methods are probably equally effective in appropriately trained hands.

Laparoscopic operations for the treatment of mechanical infertility are probably equally effective to similar procedures performed by laparotomy. In patients with extensive adhesions, successful outcomes are unlikely regardless of the approach. Consequently, assisted reproductive technologies such as in vitro fertilization and embryo transfer are necessary in these situations (see Chapter 32) (13,55).

Endometriosis

The laparoscopic management of endometriomas parallels that of adnexal masses, although the ultrasonographic complexity of endometriomas sometimes makes it difficult to distinguish them preoperatively from a neoplasm (62). The close attachment of the endometrioma to the ovarian cortex and stroma may make it difficult to find surgical dissection planes, and incomplete removal increases the risk of recurrence. In such instances there may be a tendency either to compromise the function of the remaining ovary by attempting complete removal or to risk recurrence by leaving part of the endometrioma in place. A Cochrane review found good evidence that excisional surgery for endometriomas decreases the recurrence of the endometrioma, decreases the recurrence of pain symptoms, and in women who were previously subfertile, increases subsequent spontaneous pregnancy (63). Consequently, where possible the excisional approach should be the goal. Multifocal endometriosis may be treated by mechanical excision or ablation, the latter using coagulation or vaporization with either electrical or laser energy. With proper use, each energy source creates about the same amount of thermal injury (59–61). Endometriosis frequently is deeper than appreciated initially, making excisional techniques valuable in many instances (64,65).

Pelvic Floor Disorders

Laparoscopy can be used to guide procedures to treat pelvic support defects, including culdoplasty, enterocele repair, vaginal vault suspension, paravaginal repair, and retropubic cystourethropexy for urinary stress incontinence. Although these conditions can be treated vaginally, the laparoscopic approach may offer benefits, particularly with retropubic urethropexy. There is some evidence that the laparoscopic approach is effective when compared with the traditional methods, but, in most instances, vaginal or laparoscopic mesh-based techniques seem to be the most frequently used approaches (66,67). Using the same surgical principles applied during traditional pelvic floor repair, laparoscopy promises better access to key anatomical landmarks and potentially more accurate suture placement (68). Whereas apical and anterior compartment defects can be successfully corrected via laparoscopy, posterior and perineal defects are best visualized and repaired using vaginal techniques. The laparoscopic treatment of enterocele and vault prolapse may be useful in patients who require abdominal approaches after failure of a previous vaginal procedure. Because of the anatomical proximity of the pelvic ureter to the uterosacral ligament and anterolateral vagina, bilateral ureteral patency should be confirmed cystoscopically after laparoscopic vaginal vault suspension, enterocele repair, culdoplasty, cystourethropexy, or paravaginal repair.

Gynecologic Malignancies

The role of laparoscopy in the management of gynecologic malignancy is not clearly established (69–71). A study performed by the Gynecology Oncologic Group showed that laparoscopic management of presumed stage I endometrial cancer was feasible (72). Larger-scale studies suggest that women treated with a laparoscopic approach do not fare worse than those treated via laparotomy (73,74). The potential for laparoscopic lymphadenectomy fostered a resurgence of interest in vaginal radical hysterectomy for stage I carcinoma of the cervix. Laparoscopy is being investigated for the staging of early ovarian malignancy and for second-look surgery (75,76).

Patient Preparation and Communication

The rationale, alternatives, risks, and potential benefits of the selected approach should be explained to the prospective patient. She should be advised concerning the likely outcome of expectant management if the procedure was not performed.

The expectations and risks of diagnostic laparoscopy, and those of any other procedures that may be needed, must be explained. It may be helpful to compare risks and recovery with the same procedure performed via abdominal surgery. The risks of laparoscopy include those associated with anesthesia, infection, bleeding, and injury to the abdominal and pelvic viscera. The possibility of conversion to laparotomy if a complication should occur or if the procedure cannot be completed via laparoscopic surgery should also be discussed. Infection is uncommon with laparoscopic surgery. For procedures involving extensive dissection, there is a higher risk for visceral injury. These risks should be clearly presented in a fashion that includes both the possibilities of immediate and delayed recognition. The patient should be given realistic expectations regarding postoperative disability. Because pain and visceral dysfunction normally continue to improve after uncomplicated laparoscopy, the patient should be instructed to communicate immediately any regression in her recovery. After diagnostic or brief operative procedures, patients can be discharged on the day of surgery and usually require 24 to 72 hours off work or school. If extensive dissection—a major surgical procedure performed laparoscopically—is necessary or if the surgery lasts longer than 4 hours, hospital admission may be necessary, and the period of disability may then be
Preoperative mechanical bowel preparation was perceived as reducing the morbidity of colonic surgery should an injury occur and improving visualization and exposure of the operative field at laparoscopy. There is an abundance of high-quality evidence demonstrating that preoperative mechanical bowel preparation does not reduce the morbidity of colonic surgery (77). There is one high-quality trial that shows that mechanical bowel preparation may not improve visualization at gynecologic laparoscopy (78). It is premature to abandon preoperative bowel preparation to improve visualization, because, in a small subset of patients, it may facilitate surgery. Mechanical bowel preparation should be considered to help improve visualization in selected instances where stool in the colon might compromise visualization of the operative field.

Communication with the family or other designated individuals should be arranged prior to the procedure. The patient should arrange for a friend or family member to be present to discuss the results of the procedure with the physician and to drive her home if she is discharged the same day.

Equipment and Technique

To facilitate the discussion of laparoscopic equipment, supplies, and techniques, it is useful to divide procedures into “core competencies,” which are as follows:

1. Patient positioning
2. Operating room organization
3. Peritoneal access
4. Visualization
5. Manipulation of tissue and fluid
6. Cutting, hemostasis, and tissue fastening
7. Tissue extraction
8. Incision management

Patient Positioning

Proper positioning of the patient is essential for patient safety, comfort of the operator, and optimal visualization of the pelvic organs. There may be advantages to positioning the patient while awake to reduce the frequency of positioning-related complications. Laparoscopy is performed on an operating table that can be tipped to create a steep, head-down (Trendelenburg) position that allows the bowel to move out of the pelvis to facilitate visualization after the cannulas is placed. The footrest can be dropped to allow access to the perineum. The patient is placed in the low lithotomy position, with the legs appropriately supported in stirrups and the buttocks protruding slightly from the lower edge of the table (Fig. 23.1). The thighs are usually kept in the neutral position to preserve the sacroiliac angle, reducing the tendency of bowel to slide into the peritoneal cavity. The feet should rest flat, and the lateral aspect of the knee should be protected with padding or a special stirrup to avoid peroneal nerve injury. The knees should be kept in at least slight flexion to minimize stretching of the sciatic nerve and to provide more stability in the Trendelenburg position. The arms are positioned at the patient’s side by adduction and pronation to allow freedom of movement for the surgeon and to lower the risk for brachial plexus injury (Fig. 23.2). Care must be exercised to protect the patient’s fingers and hands from injury when the foot of the table is raised or lowered. After the patient is properly positioned, the bladder should be emptied with a catheter and a uterine manipulator positioned in the endometrial cavity and secured either by an intracavitary balloon or attached to the cervix as appropriate.

Figure 23.1 Patient positioning: the low lithotomy position. The patient’s buttocks are positioned so that the perineum is at the edge of the table. The legs are well supported with stirrups, with the thighs in slight flexion. Too much flexion may impede the manipulation of laparoscopic instruments while in the Trendelenburg (head-down) position.

Figure 23.2 Operating room organization. The patient’s arms are at the sides. The right-handed surgeon stands on the patient’s left. Instruments and equipment are distributed around the patient within view of the surgeon. For pelvic surgery, the monitor should be located between the patient’s legs.
Insufflation of the insufflation needle and primary cannula is aided by an understanding of the normal underlying anatomy, especially the location of the larger retroperitoneal vessels (Fig. 23.3). A “safety zone” exists inferior to the sacral promontory in the area bounded cephalad by the bifurcation of the aorta, posteriorly by the sacrum, and laterally by the iliac vessels (79). In women placed in the Trendelenburg position, the great vessels are oriented more cephalad and anterior, making them more vulnerable to injury unless appropriate adjustments are made in the angle of insertion (Fig. 23.4) (80). Therefore, positioning of the insufflation needle and the primary cannula is best accomplished with the patient in an unaltered supine (horizontal) position. This approach facilitates the evaluation of the upper abdomen, which is limited if the intraperitoneal contents are shifted cephalad by the head-down (Trendelenburg) position.

Figure 23.3 Vascular anatomy of the anterior abdominal wall relative to the sites of port insertion. The location of the vessels that can be traumatized when inserting trocars into the anterior abdominal wall is indicated. The lateral trocars should be placed lateral to the inferior epigastric vessels that course medially to lie under the rectus muscle anterior to the posterior rectus sheath. The relative anatomy of the left upper quadrant port site is shown: the closest structure is the stomach (A) (approximately 4 cm away) and the left lobe of the liver (B) approximately (4 cm away). The spleen (C) is approximately 12 cm away.

Figure 23.4 Vascular anatomy. Location of the great vessels and their changing relationship to the umbilicus with increasing patient weight (from left to right).

Insufflation Needles

Virtually all insufflation needles are modifications of the hollow needle designed by Verres (Fig. 23.5). In cases uncomplicated by previous pelvic surgery, the preferred site for insertion is the base of the umbilicus, where the abdominal wall is the thinnest and usually avascular.

Figure 23.5 Insufflation needle. When pressed against tissue such as fascia or peritoneum, the spring-loaded blunt obturator (inset) is pushed back into the hollow needle, revealing its sharpened end. When the needle enters the peritoneal cavity, the obturator springs back into position, protecting the intraabdominal contents from injury. The handle of the hollow needle allows the attachment of a syringe or tubing for insufflation of the distention gas.

1. A midline infraumbilical incision adequate for the needle is made at the base of the umbilicus with a small scalpel, and the abdominal wall is maximally lifted, either manually or with instruments. Elevation is accomplished manually after affixing towel clips to the abdominal wall on either side lateral to the umbilicus or opposite one another within the edge of the umbilical incision itself (81).

Safe insertion of the insufflation needle mandates that the instrument be maintained in a midline, sagittal plane while the operator directs the tip between the iliac vessels, anterior to the sacrum but inferior to the bifurcation of the aorta and the proximal aspect of the vena cava. Because the sacral promontory is commonly covered in part by the left common iliac vein, vascular injury may occur in the midline below the bifurcation (82).

To reduce the risk of retroperitoneal vascular injury while minimizing the chance of inadvertent preperitoneal insufflation, in women of average weight, the insufflation needle is directed to the patient’s spine at a 45-degree angle. In heavy to obese individuals, this angle may be increased incrementally to nearly 90 degrees, accounting for the increasing thickness of the abdominal wall and the tendency of the umbilicus to gravidate caudad with increasing abdominal girth (79,83). The needle’s shaft is held by the tips of the fingers and steadily but purposefully guided into position only far enough to allow the tip’s entry into the peritoneal cavity. The tactile and visual feedback created when the needle passes through the facial and peritoneal layers of the abdominal wall may provide guidance and help prevent overaggressive insertion attempts. This proprioceptive feedback is less apparent with disposable needles than with the classic Verres needle. With the former, the surgeon must listen to the “clicks” as the needle obturator retracts when it passes through fascia or peritoneum. The spring-loaded obturator is pushed into the needle, revealing its sharpened end. When the needle enters the peritoneal cavity, the obturator springs back into position, protecting the intraabdominal contents from injury. The handle of the hollow needle allows the attachment of a syringe or tubing for insufflation of the distention gas.

2. In instances where known or suspected intra-abdominal adhesions surround the umbilicus, alternative sites should be used for insufflation needle insertion. These sites include the left upper quadrant, most often at the left costal margin, the pouch of Douglas, and the fundus of the uterus (Fig. 23.6). The left upper quadrant is preferred if hepatosplenomegaly is not present and the patient has not previously had surgery in this area. In such patients, the stomach must be decompressed with a nasogastric or orogastric tube before the needle is inserted (84). While at this location the distance between the skin and the posterior peritoneum is generally more than 11 cm, in thin individuals, it may be as little as 7 cm, so the angle of insertion should take this into account. The needle should be directed medially, about 10 to 15 degrees to avoid the kidney and renal artery; in women of relatively high body mass index it can be placed at a 90-degree angle to the skin, and in thin women, this angle should be reduced to about 45 degrees (84,85).

Figure 23.6 Insufflation needle and cannula insertion sites. In most instances, both the insufflation needle, if used, and the primary cannula are inserted through the umbilicus. When subumbilical adhesions are known or suspected, the insufflation needle may be placed through the pouch of Douglas or in the left upper quadrant after evacuation of the gastric contents with an orogastric tube.
3. Before insufflation, the operator should try to detect whether the insufflation needle was malpositioned in the omentum, mesentery, blood vessels, or hollow organs such as the stomach or bowel. The most direct approach is to use a specially designed insufflation needle that has an integrated cannula through which a small diameter (2 mm) laparoscope can be passed to visualize the point of entry. Otherwise, indirect methods are necessary. Using a syringe attached to the insufflation needle, blood or gastrointestinal contents may be aspirated. To facilitate this examination, a small amount of saline may be injected into the syringe. If the needle is appropriately positioned, negative intra-abdominal pressure is created by lifting the abdominal wall. This negative pressure may be demonstrated by aspiration of a drop of saline placed over the open, proximal end of the needle or, preferably, by using the digital pressure gauge on the insufflator.

4. Additional signs of proper placement may be sought after starting insufflation. The intra-abdominal pressure reading should be low, reflecting only systemic resistance to the flow of CO₂. Consequently, there should be little deviation from a baseline measurement, generally less than 10 mm Hg. The pressure varies with respiration and is slightly higher in obese patients. The earliest reassuring sign is the loss of liver “dullness” over the lateral aspect of the right costal margin. This sign may be absent if there are dense adhesions in the area, usually the result of previous surgery. Symmetric distention is unlikely to occur when the needle is positioned extraperitoneally. Proper positioning can be shown by lightly compressing the xiphoid process, which increases the pressure measured by the insufflator.

5. The amount of gas transmitted into the peritoneal cavity should depend on the measured intraperitoneal pressure, not the volume of gas inflated. Intrapерitoneal volume capacity varies significantly between individuals. Many surgeons prefer to insufflate to 25 to 30 mm Hg for positioning the cannulas, and a body of evidence exists supporting this approach (86). This level usually provides extra volume and enough counter pressure against the peritoneum, facilitating introduction of the cannula and potentially reducing the chance of bowel or posterior abdominal wall and vessel trauma. After placement of the cannulas, the pressure should be dropped to 10 to 15 mm Hg, which reduces the risk of subcutaneous insufflation leading to crepitus and essentially eliminates hypercarbia or decreased venous return of blood to the heart (84, 86, 87).

Primary Access Cannulas

Laparoscopic cannulas (or ports) allow the insertion of laparoscopic instruments into the peritoneal cavity while maintaining the pressure created by the distending gas (Fig. 23.7 and 23.8). Cannulas are hollow tubes with a valve or sealing mechanism at or near the proximal end. The cannula may be fitted with a Luer-type port that allows attachment to tubing connected with the CO₂ insufflator. Larger-diameter cannulas (8 to 15 mm) may be fitted with adapters or specialized valves that allow the insertion of smaller-diameter instruments without loss of intraperitoneal pressure.

Figure 23.7 Disposable access systems. These instruments are designed for single use. A 12-mm internal diameter blunt access system is shown in (A). The next device (B) has a 12 mm internal diameter, but has a deployable blade that is used to cut through the abdominal wall. A smaller diameter blunt conical device is shown in (C) while a sharp conical access system is presented in (D). Both (C) and (D) have a 5-mm inside diameter. A narrow, 2.7-mm diameter cannula is shown in (E). The trocar for this system is a long insufflation needle with a spring deployable obturator.

Figure 23.8 Reusable access systems. A: A sharp conical device, while (B) represents a pyramidal-tipped design. C and D (and inset): Images of the so-called EndoTip device that can be positioned in the abdominal wall by simply twisting or screwing it in without the requirement of a trocar.

The obturator is a longer instrument of slightly smaller diameter that is passed through the cannula, exposing its tip. Most obturators are called trocars because their tip is designed to penetrate the abdominal wall after the creation of an appropriately sized skin incision. Many disposable trocar-cannula systems are designed with a safety mechanism—usually a pressure-sensitive spring that either retracts the trocar or deploys a protective sheath around its tip after passage through the abdominal wall. None of these protective devices makes insertion safer, and they all increase the cost of the equipment.

In the “closed” laparoscopic access technique, cannulas can be inserted either after the successful creation of a pneumoperitoneum or without previously instilling intraperitoneal gas, also referred to as direct insertion. With open laparoscopy, there is less risk of injury to the major blood vessels such as the aorta, inferior vena cava, and common iliacs. Open laparoscopy cannot prevent all insertion accidents because intestine can be entered inadvertently no matter how small the incision. There is little evidence that a pneumoperitoneum is necessary, at least in the absence of preexisting abdominal wall adhesions. In women with no previous surgery, the primary puncture can be performed with a trocar-cannula system, which reduces operating time. The first, or primary, cannula must be of sufficient caliber to permit passage of the laparoscope and usually is inserted in or at the lower border of the umbilicus. The incision should be extended only enough to allow insertion of the cannula; otherwise, leakage of gas may occur around the sheath. The patient should be in an unaltered supine position during placement of the primary cannula. For the primary puncture, either the surgeon or the assistant should elevate the abdominal wall as described previously. Both hands can be positioned on the device, using one to provide counter pressure and control to prevent “overshoot” and resultant injury to bowel or vessels. The angle of insertion is the same as for the insufflation needle; adjustments are made according to the patient’s weight and body habitus (78). The laparoscope should be inserted to confirm proper intraperitoneal placement before the insufflation gas is allowed to flow. Previous abdominal surgery increases the incidence of adhesions of the bowel to the anterior abdominal wall, frequently near the umbilicus and in the path of the primary trocar-cannula system (88, 89). In such patients, another primary insertion site, such as the left upper quadrant, should be selected, even if it is used solely for conveying a narrow “scout” laparoscope, some types of which can be inserted through a trocar cannula system with a design similar to that of an insufflation needle (Fig. 23.9). Using such a laparoscope, the presence of adhesions under the incision can be identified and the umbilical cannula can be inserted under direct vision. If adhesions are noted under the incision, appropriate placement of secondary cannulas may be used to introduce instruments for adhesiolysis. Alternate insertion sites for primary cannulas are shown in Figure 23.6.

Figure 23.9 “Scout” laparoscope. The 2-mm laparoscope from Figure 23.8 and the 2.7-mm access system from Figure 23.7 are shown here.
Ancillary Cannulas

Ancillary cannulas are necessary to perform most diagnostic and operative laparoscopic procedures. Most currently available disposable ancillary cannulas are identical to those designed for insertion of the primary cannula; however, simple cannulas without the so-called safety mechanisms and insufflation ports are generally sufficient (Figs. 23.7D and 23.8D). Some investigators are evaluating the value of systems that allow the insertion of multiple cannulas through a single port, an approach that has the potential to improve surgical cosmesis by reducing the number of incisions created (90–92).

Proper positioning of these ancillary cannulas depends on a sound knowledge of the abdominal wall vascular anatomy. For the secondary puncture, the patient may be tipped head down (Trendelenburg), allowing the abdominal contents to shift from beneath the incision sites, and thus making it unnecessary to lift the abdominal wall during secondary cannula insertion. Alternatively, the intraperitoneal pressure may be maintained at 25 to 30 mm Hg to allow insertion of the secondary cannulas prior to placing the patient in the Trendelenburg position.

Ancillary cannulas should always be inserted under direct vision because injury to bowel or major vessels can occur. Before insertion, the bladder should be drained with a urethral catheter. The insertion sites depend on the procedure, the disease, the patient’s body habitus, and the surgeon’s preference. For diagnostic laparoscopy, the most useful and cosmetically acceptable site for insertion of an ancillary cannula is in the midline of the lower abdomen, about 2 to 4 cm above the symphysis. The ancillary cannula should not be inserted too close to the symphysis because it limits the mobility of the ancillary instruments and access to the cul-de-sac. Laparoscopic cannulas can become dislodged and slip out of the incision during a procedure. There are a variety of cannula designs designed to reduce slippage, which include those with threaded exteriors and anchoring systems with balloon tips.

Lateral placement of lower-quadrant cannulas is useful for operative laparoscopy, but the superficial and inferior epigastric vessels must be located to avoid injury (Fig. 23.3). Transillumination of the abdominal wall from within permits the identification of the superficial inferior epigastric vessels in most thin women. The deep inferior epigastric vessels cannot be identified by this mechanism because of their location deep to the rectus sheath. The most consistent landmarks are the medial umbilical ligaments (obliterated umbilical arteries) and the exit point of the round ligament into the inguinal canal. At the pubic crest, the deep inferior epigastric vessels can often be visualized between the medially located umbilical ligament and the laterally positioned exit point of the round ligament. The cannula should be inserted medial or lateral to the vessels if they are visualized. If the vessels cannot be seen and it is necessary to position the cannula laterally, the device should be placed 3 to 4 cm lateral to the umbilical ligament or lateral to the lateral margin of the rectus abdominis muscle. If the incision is placed too far laterally, it will endanger the deep circumflex epigastric artery. The risk of injury can be minimized by placing a 22-gauge spinal needle through the skin at the desired location, in order to directly observe the entry through the laparoscope. This provides reassurance that a safe location is identified and allows visualization of the peritoneal needle hole, which provides a precise target for inserting the cannula.

Even after a properly positioned incision, the abdominal wall vessels can be injured if a trocar slides medially during placement. Large-diameter devices are more likely to cause injury; therefore, the smallest cannulas necessary to perform the procedure should be used. Ancillary cannulas should not be placed too close together because this results in hindrance of the hand instruments, which compromises access and maneuverability.

The incision made must be of adequate length to allow easy insertion of the device through the skin—a 1-cm long incision is inadequate to allow passage of a 1-cm diameter device. It is important to know that the outside diameter of a cannula is larger than the inside diameter, to allow for the thickness of the material used to create the port. In some instances, this can add two or more millimeters to the device diameter, and, therefore, increase the length of the required incision.

Endoscopy

During endoscopy, the image must be transferred through an optical system. Although direct optical viewing is feasible and often used for diagnostic purposes, virtually all operative laparoscopy is performed using video guidance.

Laparoscopes are more than simple telescopes; they serve a dual purpose—transmission of light into a dark and closed cavity and provision of an image of the operative field. The light is generally transmitted from a cold light source via a fiberoptic cable to an attachment on the endoscope that passes the light to the distal end of the telescope via a peripherally arranged array of fiberoptic bundles. The image is obtained by a distally positioned lens and transmitted to the eyepiece via a series of rod shaped lenses. The eyepiece can be used to view the peritoneal contents directly or can serve as a point of attachment for a digital video camera. Some endoscopes transmit the image through a collection of densely packed fiberoptic bundles—an approach that diminishes resolution, but allows flexibility of the endoscope, and that is of great value for small-caliber telescopes or when the device is designed to be steerable with an articulated distal end. Another option is to position a digital chip on the end of the system, which then functions as a camera, obviating the need to have any lenses or fibers to transmit the image, a design that is colloquially called chip-on-a-stick.

A laparoscope with an integrated straight channel, parallel to the optical axis, is called an operating laparoscope because the channel allows for the introduction of operating instruments. This offers an additional port for the insertion of instruments and the application of laser energy. Operative endoscopes are of relatively larger caliber than standard laparoscopes, may have smaller fields of view and may present increased risks associated with the use of monopolar electrosurgical instruments. Standard, viewing only laparoscopes permit better visualization at a given diameter.

In general, the wider the diameter of the laparoscope, the brighter the image, resulting from either more light or wider lenses, which improve the viewing experience for the surgeon. Narrow-diameter laparoscopes generally allow reduced transfer of light both into and out of the peritoneal cavity; therefore, they require a more sensitive camera or a more powerful light source for adequate illumination. In the past, ideal illumination was provided by 10-mm diagnostic laparoscopes, but improvements in optics allowed the 5-mm diameter laparoscope to become the standard in many operating rooms (Fig. 23.10).

Figure 23.10 Laparoscopes. Three 0-degree laparoscopes are shown. From top to bottom, 2-mm, 5-mm and 10-mm diameter.
the peritoneum or the edge of an ovary for the removal of an ovarian cyst. Instruments designed to be minimally traumatic, like Babcock clamps, are not as strong, precise, or quality as nondisposable forceps. The forceps used during laparoscopy should, to the extent possible, replicate those used in open surgery.

Grasping Forceps

The reusable Pelosi manipulator. The ring handle allows the surgeon to antevert the uterus. Articulation of the instrument permits acute anteversion or retroversion, both of which are extremely useful procedural maneuvers. If the uterus is large, longer and wider obturators can be used for more effective control. Two types of uterine manipulators are shown in Figure 23.12.

If electrosurgery is to be performed, small volumes of a nonelectrolyte-containing solution such as glycine or sorbitol can be used for hemostasis and irrigation. Heparin (1,000 to 5,000 U/L) can be added to irrigating solution to prevent blood from clotting and facilitate fluid removal.

Creation of a Working Space

The peritoneal cavity is only a potential space, so it is necessary to fill it with a gas, typically CO$_2$, to create a working environment. Other approaches are being explored that use mechanical lifting systems that allow room air into the peritoneal cavity. Carbon dioxide is injected into the peritoneal cavity under pressure by a machine called an insufflator. The insufflator delivers the CO$_2$ from a gas cylinder to the patient through tubing connected to a Luer adaptor on one of the laparoscopic cannulas. Most insufflators can be set to maintain a predetermined intra-abdominal pressure. High flow rates (9 to 20 L per minute) are especially useful for maintaining exposure when suction of smoke or fluid depletes the volume of intraperitoneal gas.

Intraperitoneal retractors attached to a pneumatic or mechanical lifting system can be used to create an intraperitoneal space much like a tent (93). This gastless or isobaric technique may have some advantages over pneumoperitoneum, particularly in patients with cardiopulmonary disease. Airtight cannulas are not necessary, and instruments do not need to have a uniform, narrow, cylindrical shape. Consequently, some conventional instruments may be used directly through the incisions.

Fluid Management

Fluid may be disseminated into the peritoneal cavity through wide-caliber arthroscopy or cystoscopy tubing using gravity pressure and an infusion cuff or a high-pressure mechanical pump. The pumps deliver fluid faster than the other techniques, and the highly pressurized stream of fluid may facilitate blunt dissection (hydro- or aqua dissection). Small volumes of fluid can be removed with a syringe attached to a cannula; for large volumes, it is necessary to use suction generated by a machine or a wall source.

The type of cannulas used for suction and irrigation depends on the irrigation fluid used and the fluid being removed. For ruptured ectopic gestations or other procedures in which there is a large amount of blood and clots, large-diameter cannulas (7 to 10 mm) are preferred. Cannulas with narrow tips are more effective in generating the high pressure needed for hydrodissection.

If large volumes of fluid are required, isotonic fluids should be used to avoid fluid overload and electrolyte imbalance. If electrosurgery is to be performed, small volumes of a nonelectrolyte-containing solution such as glycine or sorbitol can be used for hemostasis and irrigation. Heparin (1,000 to 5,000 U/L) can be added to irrigating solution to prevent blood from clotting and facilitate fluid removal.

Manipulation of Tissue and Fluid

Uterine Manipulators

Uterine manipulation is an important component of the strategy to maximize visualization for most pelvic procedures, especially for myomectomy and hysterectomy. A properly designed uterine manipulator should have an intrauterine component, or obturator, and a method for attaching the device to the uterus. Articulation of the instrument permits acute antversion or retroversion, both of which are extremely useful procedural maneuvers. If the uterus is large, longer and wider obturators can be used for more effective control. Two types of uterine manipulators are shown in Figure 23.12.

Figure 23.12 Uterine manipulators. Top: The disposable “V-Care” device. At the tip is a balloon inflated to maintain the device in the endometrial cavity. Next to the tip is a cervical collar that serves to facilitate identification of the vaginal fornices and cutting of the vagina in laparoscopic total hysterectomy. The blue truncated cone maintains a seal so that gas will not leak out when culdotomy is performed. Bottom: The reusable Pelosi manipulator. The ring handle allows the surgeon to antevert the uterus.

Grasping Forceps

The forceps used during laparoscopy should, to the extent possible, replicate those used in open surgery. Disposable instruments generally do not have the quality, strength, or precision of nondisposable forceps. Instruments with teeth (toothed forceps) are necessary to securely grasp the peritoneum or the edge of an ovary for the removal of an ovarian cyst. Instruments designed to be minimally traumatic, like Babcock clamps, are
needed to retract the fallopian tube safely. Tenaculum-like instruments are desirable to retract leiomyomas or the uterus. A ratchet is useful for holding tissue without arduous hand pressure. Graspers should be insulated if unipolar radiofrequency instruments are being used to attain hemostasis.

Figure 23.13 Laparoscopic instruments for grasping and manipulating tissue. A: (top and inset) are 5-mm diameter graspers with a curved tip, often called “Maryland” graspers. Other reusable tips (B) and (C) may be positioned in the same handle as is shown for (A). D: A 10-mm claw grasper, while (E) and (F) are 5- and 2-mm manipulating probes respectively. G: A 2-mm grapping forceps.

Cutting, Hemostasis, and Tissue Fixation

Cutting can be achieved by mechanical means or by using laser, radiofrequency electrical, or ultrasonic energy. The methods for maintaining or securing hemostasis include sutures, clips, linear staplers, energy sources, and topical or injectable substances. Secure apposition or tissue fixation may be accomplished with sutures, clips, or staples. With appropriate training, a skilled surgeon can obtain good results with any combination of these techniques for cutting, hemostasis, and tissue fixation. Studies in animals have not demonstrated any difference in injury characteristics when cutting is performed with either laser or radiofrequency energy and randomized controlled studies have shown no differences in fertility outcomes (59–61,94). Therefore, differences in results are likely to be caused by other factors, such as patient selection, extent of disease, and degree of surgical expertise.

Cutting

The most useful cutting instruments are scissors (Fig. 23.14, bottom). Because it is difficult to sharpen laparoscopic scissors, most surgeons prefer disposable instruments that can be used until dull and then discarded. Another mechanical cutting tool is the linear stapler–cutter that can simultaneously cut and hemostatically staple the edges of the incision. The cost and large dimensions of the instruments limit their practical use to only a few highly selected situations, such as separation of the uterus from the ovary and fallopian tube during laparoscopic hysterectomy. Devices that coagulate tissue and mechanically transect it are designed to be narrow enough to be practical and effective enough to become the dominant devices for laparoscopic cutting, when concomitant sealing of vessels is a requirement.

Figure 23.14 Radiofrequency electrosurgical generator. Displayed is the Force FX generator with unipolar laparoscopic electrodes. The device is capable of outputting high-voltage (“coagulation”) and low-voltage (“cut”) waveforms for unipolar instruments and a low-voltage bipolar circuit for bipolar instruments.

Laser and electrical sources of energy manifest their effect by conversion of electromagnetic energy (Fig. 23.14) to mechanical energy, which is then transferred into thermal energy. Highly focused radiofrequency electrical current (high-power or current density), generated by a specially designed electrosurgical generator produces vaporization or cutting by raising the intracellular temperature above 100°C, which rapidly converts water to steam with a massive increase in intracellular volume. This expansion ruptures the already damaged cell membrane, resulting in cellular and tissue vaporization into a cloud of steam, ions, and protein particles. If the instrument used to focus this energy is moved in a linear fashion, tissue transection or cutting will result. Less focused radiofrequency energy (moderate current density) elevates intracellular temperature, causing desiccation, rupture of hydrogen bonds, and tissue coagulation, but vaporization does not occur.

Monopolar electrosurgical instruments that are narrow or pointed are capable of generating the high-power densities necessary to vaporize or cut tissue. Continuous or modulated and relatively low voltage outputs tend to be the most effective. For optimal results, the instrument should be used in a noncontact fashion, following (not leading) the energy through the tissue. Specially designed bipolar cutting probes that contain both the active and dispersive electrode are available. The active electrode is shaped as a needle, or even a blade, while the other larger-surface-area electrodes are designed to be dispersive (Fig. 23.15, top). Laparoscopic scissors are generally of unipolar design and are intended to cut mechanically; energy may be applied simultaneously for desiccation and hemostasis when cutting tissue that contains small blood vessels (Fig. 23.15, bottom).

Figure 23.15 Laparoscopic cutting devices. Top and inset left is a bipolar electrosurgical spatula. Middle and center inset is a harmonic scalpel. This device oscillates at 55,000 Hz to cut tissue. Bottom and inset right are laparoscopic scissors. They may be connected to an electrosurgical generator to act as a unipolar electrode.

Laser energy can be focused to vaporize and cut tissue. The most efficient laser-based cutting instrument is the CO₂ laser, which has the drawback of requiring linear transmission because light cannot be conducted effectively along bendable fibers. The potassium-titanyl-phosphate (KTP) and neodymium:yttrium, aluminum, garnet (Nd:YAG) lasers are effective cutting tools. They are capable of propagating energy along bendable quartz fibers but have a slightly greater degree of collateral thermal injury than radiofrequency electrical or CO₂ laser energy. These limitations and their additional expense constrict the value of these lasers.

Ultrasonic cutting is accomplished mechanically using a blade that oscillates back and forth in a linear fashion (Fig. 23.15, center). The oscillation is achieved using an element located in a handle that vibrates the blade, hook, or one arm of the clamp 55,000 times per second (55 kHz). The distance of the oscillation can be varied and determines the efficiency of the cutting process. The tip of the device cuts mechanically, but there is a degree of collateral thermal tissue coagulation injury that can be used for hemostasis. In low-density tissue, the process of mechanical cutting is augmented by the process of cavitation, in which reduction of local atmospheric pressure allows vaporization of intracellular water at body temperature.

Hemostasis

Because of the visual, tactile, and mechanical limitations of laparoscopy, prevention of bleeding is important for efficient, effective, and safe procedures. Radiofrequency electricity is the least expensive and most versatile method for achieving hemostasis during laparoscopy and can be applied with either monopolar or bipolar instruments. Regardless of the type of system, the process of electrical desiccation and coagulation is best achieved by contacting the tissue with the activated electrode using continuous low-voltage or “cutting” current. With adequate power, typically 20 to 30 watts (depending, in part, on the surface area of the electrodes), tissue will be heated, desiccated, and coagulated. Blood vessels should be
Control of superficial bleeding can be achieved with fulguration, the near-contact spraying of tissue with unipolar, modulated, high-voltage radiofrequency waveforms from the “coagulation” side of the electrosurgical generator. Care must be taken to safely perform laparoscopic fulguration, ensuring that the entire shaft of the laparoscopic instrument is well away from the bowel.

Ultrasonic instruments can be used for hemostasis as well. Those with a forceps-like end effector disperse the mechanical energy in a way that allows the tissue to be heated and coagulated. These so-called ligating-cutting shears cut when high pressure is exerted in the handle by the surgeon (Fig. 23.16A–C). Hemostatic clips may be applied with specially designed laparoscopic instruments. Nonabsorbable clips made of titanium are useful for relatively narrow vessels, and longer, delayed absorbable, self-retaining clips are generally preferred for larger vessels, 3 or 4 mm or more. Clips may be of particular value when securing relatively large vessels near an important structure such as the ureter.

Laparoscopic suturing is a method for maintaining hemostasis (95–97). Compared with clips or linear staplers, suturing has a relatively low materials cost, although operating time may be longer and more expensive. The two basic methods for securing a ligature around a blood vessel depend on where the knot is tied: ligatures are intracorporeal and extracorporeal. Intracorporeal knots replicate the standard instrument-tied knot and are formed within the peritoneal cavity. Extracorporeal knots are created outside the abdomen under direct vision and then transferred into the peritoneal cavity by knot manipulators (Fig. 23.17). Pretied knotted suture loops attached to long introducers, called Endoloops®, may be used to secure vascular pedicles. Care should be taken to make sure that they are tightly secured and that no other tissue is incorporated in the loop. A number of devices that facilitate the formation and tying of knots are either available or in development.

Figure 23.17 Laparoscopic suturing instruments. The 3-mm and 5-mm diameter laparoscopic needle drivers are displayed in (A) and (C), while a knot manipulator is shown in (B) and inset left. The device is shown transferring a knot into the peritoneal cavity (inset right).

Small areas of low volume bleeding can be treated with topical hemostatic agents. Topical agents such as microfibrillar collagen are available in 5-mm and 10-mm diameter laparoscopic applicators (Fig. 23.13). Fibrin sealants (e.g., Tisseel® and bovine thrombin and gelatin (Floseal®) can also be used. A solution of dilute vasopressin may be injected locally to maintain hemostasis for myomectomy or removal of ectopic pregnancy.

Tissue Extraction

After excising tissue, it is usually necessary to remove it from the peritoneal cavity. Small samples can be pulled through an appropriate-sized cannula with grasping forceps; however, larger specimens may not fit. If the specimen is cystic, it may be drained by a needle or incised, shrinking it to a size suitable for removal through the cannula or one of the small laparoscopic incisions. If there is concern for malignancy, an alternative is to place the specimen in an endoscopic retrieval bag before drainage to prevent spillage (Fig. 23.18). More solid tissue may be morcellated with scissors, ultrasonic equipment, electrosurgery or electromechanical morcellators. If monopolar radiofrequency instruments are used for electrosurgical morcellation, the specimen must remain attached to the patient to preserve the integrity of the electrical circuit. Alternatively, special bipolar needles are available that do not require a dispersive electrode.

Figure 23.18 Specimen removal bag. This 10-mm diameter bag is positioned in the peritoneal cavity. Then the bag is deployed (insets), allowing the surgeon to place specimens for removal.

Larger specimens may be removed by inserting a larger cannula through an incision in the cul-de-sac (posterior culdotomy) or by extending one of the laparoscopic incisions. With the exception of culdotomy (colpotomy), extension of the umbilical incision may be the most cosmetic approach because incisions up to 3 cm in length can be concealed successfully. When the umbilical location is selected, removal of the tissue can be directed from an endoscope positioned in one of the ancillary ports. Electronic morcellators are available to remove large tissue specimens by reducing them to smaller sections (Fig. 23.19). These are especially useful for laparoscopic myomectomy and laparoscopic supravacrubal hysterectomy.

Figure 23.19 Electromechanical morcellator. This device is positioned in the peritoneal cavity and attached to the power generator (inset). The blunt obturator is removed; a grasping instrument inserted through the lumen is used to withdraw the tissue, which is cut by a cylindrical blade. The motor is activated by a foot pedal.
Dehiscence and hernia risk appear to significantly increase when the fascial incision is larger than 10 mm in diameter \(^{98,99}\). Closure of the fascia should take place under direct laparoscopic vision to prevent the accidental incorporation of bowel into the incisions, and the peritoneum should be included to reduce the risk of Richter’s hernia. A small-caliber laparoscope passed through one of the narrow cannulas can be used to direct the fascial closure using curved needles or a ligature carrier especially designed for this purpose.

**Complications**

After laparoscopic surgery patients usually experience a rapid recovery. Pain diminishes, gastrointestinal function improves quickly, and fever is extremely unusual. Therefore, if a patient’s condition is not improving, possible complications of anesthesia or surgery should be considered. Laparoscopic procedures can be complicated by infections, trauma, or hemorrhage, and by problems associated with anesthetic use. The incidence of infection is lower than with procedures performed by laparotomy. Problems associated with visualization in conjunction with the change in anatomic perspective may increase the risk of damage to blood vessels or vital structures such as the bowel, ureter, or bladder.

**Anesthetic and Cardiopulmonary Complications**

A review of laparoscopic tubal sterilization in 9,475 women found no deaths from complications of anesthesia \(^{100,101}\). The potential risks of general anesthesia include hypoventilation, esophageal intubation, gastroesophageal reflux, bronchospasm, hypotension, narcotic overdose, cardiac arrhythmias, and cardiac arrest. These risks can be exacerbated by some of the inherent features of gynecologic laparoscopy. For example, the Trendelenburg position, in combination with the increased intraperitoneal pressure provided by pneumoperitoneum, places greater compression on the diaphragm, increasing the risk of hyperventilation, hypercarbia, and metabolic acidosis. This position, combined with anesthetic agents that relax the esophageal sphincter, promotes regurgitation of gastric content, which in turn can lead to aspiration, bronchospasm, pneumonitis, and pneumonia. Parameters of cardiopulmonary function associated with both CO\(_2\) and N\(_2\)O insufflation include reduced PO\(_2\), O\(_2\) saturation, tidal volume, and minute ventilation and increased respiratory rate. The use of intraperitoneal CO\(_2\) as a distention medium is associated with an increase in PCO\(_2\) and a decrease in pH. Elevation of the diaphragm may be associated with basilar atelectasis, resulting in right-to-left shunt and ventilation–perfusion mismatch \(^{102}\).

**Carbon Dioxide Embolus**

Carbon dioxide is the most widely used peritoneal distention medium, largely because the rapid absorption of CO\(_2\) in blood reduces the significance of gas emboli. If large amounts of CO\(_2\) gain access to the central venous circulation, if peripheral vasoconstriction occurs, or if the splanchic blood flow is decreased by excessively high intraperitoneal pressure, severe cardiorespiratory compromise may result.

The signs of CO\(_2\) embolus include sudden and otherwise unexplained hypotension, cardiac arrhythmia, cyanosis, and heart murmurs. The end-tidal CO\(_2\) level may increase, and findings consistent with pulmonary edema may manifest \(^{103}\). Accelerating pulmonary hypertension may occur, resulting in right-sided heart failure.

Because gas embolism may result from direct intravascular injection through an insufflation needle, the proper placement of the insufflation needle must be ensured. Although the initial intraperitoneal pressure may be set at 20 to 30 mm Hg for port placement, it should be maintained at 8 to 12 mm for the rest of the case \(^{104}\). The risk of CO\(_2\) embolus is reduced by careful hemostasis because open venous channels are the portal of entry for gas into the systemic circulation. The anesthesiologist should continuously monitor the patient’s color, blood pressure, heart sounds, heartbeat, and end-tidal CO\(_2\) to allow early recognition of the signs of CO\(_2\) embolus.

If CO\(_2\) embolus is suspected or diagnosed, the surgeon must evacuate the CO\(_2\) from the peritoneal cavity and place the patient in the left lateral decubitus position, with the head below the level of the right atrium. A large-bore central venous line should be inserted immediately to allow aspiration of gas from the heart. Because the findings are nonspecific, the patient should be evaluated for other causes of cardiovascular collapse.

**Cardiovascular Complications**

Cardiac arrhythmias occur relatively frequently during laparoscopic surgery and are related to a number of factors, the most significant of which are hypercarbia and acidemia. Early reports of laparoscopy-associated arrhythmia were associated with spontaneous respiration; therefore, most anesthesiologists adopted the practice of mechanical ventilation during laparoscopic surgery. The incidence of hypercarbia is reduced by operating with intraperitoneal pressures at levels less than 12 mm Hg \(^{105}\).

The risk of cardiac arrhythmia may be reduced by using NO\(_2\) as a distending medium (see the preceding discussion in “Peritoneal Access”). Although NO\(_2\) is associated with a decreased incidence of arrhythmia, it is insoluble in blood and, therefore, its use may increase the risk of gas embolus. External lifting systems avoid the complication of hypercarbia and can provide protection against cardiac arrhythmia \(^{106}\).

Hypotension can occur because of decreased venous return secondary to very high intraperitoneal pressure, and this condition may be potentiated by volume depletion. Vagal discharge may occur in response to increased intraperitoneal pressure, which can cause hypotension secondary to cardiac arrhythmias \(^{106}\). These side effects should be considered when performing surgery on patients with preexisting cardiovascular disease.

**Gastric Reflux**

Gastric regurgitation and aspiration can occur during laparoscopic surgery, especially in patients with obesity, gastroparesis, hiatal hernia, or gastric outlet obstruction. In these patients, the airway must be maintained with a cuffed endotracheal tube, and the stomach must be decompressed (e.g., with a nasogastric tube). The lowest necessary intraperitoneal pressure should be used to minimize the risk of aspiration. Patients should be moved out of the Trendelenburg position before being extubated. Routine preoperative administration of metoclopramide, H2-blocking agents, and nonparticulate antacids reduces the risk of aspiration.

**Extraperitoneal Insufflation**

The most common causes of extraperitoneal insufflation are preperitoneal placement of the insufflating needle and leakage of CO\(_2\) around the cannula sites. Although this condition is usually mild and limited to the abdominal wall, subcutaneous emphysema can become extensive, involving the extremities, the neck, and the mediastinum. Another relatively common site for emphysema is the omentum or mesentery, a circumstance that may be mistaken for preperitoneal insufflation.
Subcutaneous emphysema may be identified by the palpation of crepitus, usually in the abdominal wall. Emphysema can extend along contiguous fascial plains to the neck, where it can be visualized directly. This finding may reflect mediastinal emphysema, which may indicate impending cardiovascular collapse (107–110).

The risk of subcutaneous emphysema is reduced by the proper positioning of the insufflation needle and by maintaining a low intraperitoneal pressure after placement of the desired cannulas. Other approaches that reduce the chance of subcutaneous emphysema include open laparoscopy and the use of abdominal wall lifting systems that make gas unnecessary.

If the insufflation occurred extraperitoneally, the laparoscope can be removed and the procedure can be repeated. Difficulty may ensue because of the altered anterior peritoneum. Open laparoscopy or the use of an alternate site, such as the left upper quadrant, should be considered. One approach is to leave the laparoscope in the expanded preperitoneal space while the insufflation needle is reinserted under direct vision through the peritoneal membrane caudad to the tip of the laparoscope (111).

In mild cases of subcutaneous emphysema, the findings quickly resolve after evacuation of the pneumoperitoneum, and no specific intraoperative or postoperative therapy is required. When the extravasation extends to the neck, it is usually preferable to terminate the procedure because pneumomediastinum, pneumothorax, hypercarbia, and cardiovascular collapse may result. Following termination of the procedure, it is prudent to obtain a chest X-ray. The patient’s condition should be managed expectantly unless a tension pneumothorax results, in which case immediate evacuation must be performed using a chest tube or a wide-bore needle (14 to 16 gauge) inserted in the second intercostal space in the midclavicular line.

Electrosurgical Complications

Complications of electrosurgery occur secondary to thermal injury from unintended or inappropriate use of the active electrode, current diversion to an undesirable path, or injury at the site of the dispersive electrode. Such complications may occur with the use of these instruments during laparoscopic, abdominal, or vaginal surgery. Active electrode injury can occur with either unipolar or bipolar instruments, whereas trauma secondary to current diversion and dispersive electrode accidents occur only with unipolar devices. Complications of electrosurgery are reduced by adherence to safety protocols coupled with a sound understanding of the principles of electrosurgery and the circumstances that can lead to injury (112).

Active Electrode Trauma

If the foot pedal is accidentally depressed, tissue adjacent to the electrode will be traumatized. Potential sites of injury include the bowel, ureter, and other intraperitoneal structures, or, if the electrode lies on the abdomen, the skin. Injury from direct extension of thermal effect can occur when the zone of vaporization or coagulation extends to large blood vessels or vital structures such as the bladder, ureter, or bowel. Bipolar instruments may reduce but do not eliminate the risk of thermal injury to adjacent tissue (113). Blood vessels should be isolated before electrosurgical coagulation, especially when they are near vital structures, and appropriate amounts of energy must be applied to allow an adequate margin of noncoagulated tissue.

The diagnosis of direct thermal visceral injury may be difficult. If unintended activation of the electrode occurs, nearby intraperitoneal structures should be evaluated carefully. The appearance can be affected by several factors, including the output of the generator, the type of electrode, its proximity to tissue, and the duration of activation. The diagnosis of visceral thermal injury is often delayed until signs and symptoms of fistula or peritonitis appear. Because these complications may not manifest until 2 to 10 days after surgery, patients should be advised to report any postoperative fever or increasing abdominal pain.

Thermal injury to the bowel, bladder, or ureter that is recognized at the time of laparoscopy should be managed immediately, taking into consideration the potential extent of the zone of coagulative necrosis (114). Incisions made with the focused energy from a pointed electrode are associated with a minimal amount of surrounding thermal injury. Prolonged or even transient contact with a relatively large-caliber electrode may produce a zone of thermal necrosis that may be much larger than visually apparent. In such cases, wide excision or resection of up to several centimeters of bowel may be necessary. The choice of route of access for any required surgical repairs depends in part on the nature of the injury and on the skills and training of the surgeon.

The incidence of unintended activation injuries can be reduced if the surgeon is always in direct control of electrode activation and if all electrosurgical hand instruments are removed from the peritoneal cavity when not in use. When removed from the peritoneal cavity, the instruments should be detached from the electrosurgical generator, or they should be stored in an insulated pouch near the operative field. These measures prevent damage to the patient’s skin if the electrode is accidentally activated.

Current Diversion

Current diversion occurs when the radiofrequency circuit follows an unintended path between the active electrode and the electrosurgical generator. This may occur with insulation defects, direct coupling, or capacitative coupling. In older, grounded systems, unlikely to be in use, current can be diverted if any part of the patient’s body touches a conductive and grounded object. In any of these situations, if the power density becomes high enough, unintended and severe thermal injury can result.

Insulation Defects

If the insulation coating the shaft of a monopolar electrosurgical electrode becomes defective, it can allow current diversion to adjacent tissue, most often bowel, potentially resulting in significant injury. This happens in part because such defects create a zone of high current density (Fig. 23.20A). Therefore, the instruments should be examined before each procedure to detect worn or obviously defective insulation. When using monopolar laparoscopic instruments, the shaft of the device should be kept away from vital structures and, if possible, totally visible in the operative field.

Figure 23.20 Current diversion secondary to insulation defects and direct coupling. These events may occur with the use of monopolar instrumentation when there is a defect in the insulation (A) or, classically, to contact a conductive instrument that, in turn, touches other intraperitoneal structures. In the example depicted (B), the active electrode is touching the laparoscope, and current is transferred to bowel through a small enough contact point that thermal injury results. Another common target of such coupling is to noninsulated hand instruments.
Direct Coupling

Direct coupling occurs when an activated electrode touches and energizes another uninsulated metal conductor such as a laparoscope, cannula, or other instrument. Direct coupling is often used for hemostasis when a grasping instrument is used to occlude a blood vessel while a separate activated electrode is used to provide the energy for desiccation and coagulation. If this occurs while the noninsulated device rests against structures such as bowel or the urinary tract, injury may occur (Fig. 23.20B). The risk of direct coupling can be reduced by eliminating the simultaneous use of uninsulated instruments and monopolar electrodes. The surgeon should visually confirm that there is no contact with other conductive instruments before activating a monopolar electrode.

Capacitive Coupling

Capacitance is the ability of a conductor to establish an electrical current in an unconnected nearby circuit. An electrical field is established around the shaft of any activated unipolar electrode (including the cord), a circumstance that makes the electrode a potential capacitor. This field is harmless if the circuit is completed through a dispersive, low-power density pathway (Fig. 23.21). For example, if capacitive coupling occurs between a laparoscopic electrode and a metal cannula positioned in the abdominal wall, the current is harmlessly dispersed in the abdominal wall at the point where it connects with the dispersive electrode (Fig. 23.21A). However, if the metal cannula is anchored to the skin by a nonconductive plastic retaining sleeve or “gripper” (a hybrid system), the current cannot return to the abdominal wall because the sleeve acts as an insulator (Fig. 23.21B). Instead, the capacitor will have to “look” elsewhere to complete the circuit. The bowel or any other nearby conductor can become the target of a relatively high-power density discharge (Fig. 23.21C). This situation can occur when a unipolar electrode is inserted through an operating laparoscope that, in turn, is passed through a nonconductive plastic laparoscopic cannula. In this configuration, the plastic port acts as the insulator. If the electrode capacitively couples with the metal laparoscope, nearby bowel will be at risk for significant thermal injury (115). The circumstance occurs with the relatively new “single port” systems where the laparoscope and hand instruments, including monopolar electrodes, are passed through the same concentrated array of ports. This situation is identical to that of the “operating” laparoscope with an increased risk that the laparoscope or other instruments function as capacitors.

Figure 23.21 Capacitative coupling. A: All activated monopolar electrodes emit a surrounding charge, proportional to the voltage of the current. This makes the electrode a potential capacitor. B: Generally, as long as the charge is allowed to disperse through the abdominal wall, no sequelae result. However, if the “return” to the dispersive electrode is blocked by insulation, such as a plastic anchor (C), the current can couple to a conductive cannula or directly to bowel.

The risk of capacitative coupling-related complications can be reduced in a number of ways. First, it is important to avoid the use of hybrid laparoscope-cannula systems that contain a mixture of conductive and nonconductive elements. Instead, the use of all-plastic or all-metal cannula systems is preferred. It may be best to avoid or at least minimize the use of monopolar instruments using operating laparoscopes or multiport, single site access systems. If an operating laparoscope is to be used, all-metal cannula systems should be the rule unless there is no intent to perform unipolar electrosurgical procedures through the operating channel. Finally, minimizing the use of high voltage, modulated current (“coagulation” current) will reduce the risk of capacitative coupling.

Dispersive Electrode Burns

Modern electrosurgical units are designed with isolated circuits and impedance monitoring systems that shut down the machine if dispersive electrode (“patient pad”) detachment occurs. The use of isolated-circuit electrosurgical generators with dispersive electrode monitors has virtually eliminated dispersive electrode–related thermal injury. Dispersive electrode monitoring is accomplished by measuring the impedance in the dispersive electrode, "patient pad" (or the urinary tract, injury may occur (Fig. 23.22). For example, if capacitative coupling occurs between a laparoscopic electrode and a metal cannula positioned in the abdominal wall, the current is harmlessly dispersed in the abdominal wall at the point where it connects with the dispersive electrode (Fig. 23.21A). However, if the metal cannula is anchored to the skin by a nonconductive plastic retaining sleeve or “gripper” (a hybrid system), the current cannot return to the abdominal wall because the sleeve acts as an insulator (Fig. 23.21B). Instead, the capacitor will have to “look” elsewhere to complete the circuit. The bowel or any other nearby conductor can become the target of a relatively high-power density discharge (Fig. 23.21C). This situation can occur when a unipolar electrode is inserted through an operating laparoscope that, in turn, is passed through a nonconductive plastic laparoscopic cannula. In this configuration, the plastic port acts as the insulator. If the electrode capacitively couples with the metal laparoscope, nearby bowel will be at risk for significant thermal injury (115). The circumstance occurs with the relatively new “single port” systems where the laparoscope and hand instruments, including monopolar electrodes, are passed through the same concentrated array of ports. This situation is identical to that of the “operating” laparoscope with an increased risk that the laparoscope or other instruments function as capacitors.

Figure 23.22 Dispersive electrode burns. If the dispersive electrode becomes partially detached, the current density may increase to the point that a skin burn results.

Because a few ground-referenced machines without such safeguards may still be in use, it is important to know the type of electrosurgical unit used in the operating room. If the electrosurgical generator is ground referenced and if the dispersive electrode becomes detached, unplugged, or otherwise ineffective, the current seeks any grounded conductor, such as electrocardiograph patch electrodes or the conductive metal components of the operating table (Fig. 23.23). If the conductor has a small surface area, the current or power density may become high enough to cause thermal injury (Fig. 23.24).

Figure 23.23 Risk of ground-referenced generators. Current diversion along alternate pathways is a risk associated with ground-referenced electrosurgical generators, particularly if the dispersive electrode is detached. In the example depicted, the relatively high current density at the electrocardiogram electrode site may result in a skin burn.

Figure 23.24 Office hysteroscopy setup. Hysteroscopic procedures are facilitated with an electric examination table. Distension media may be positioned on an intravenous pole, but wide, cystoscopy tubing allows maintenance of higher intrauterine pressures suitable for viewing and performing simple procedures such as polypectomy or transcervical sterilization. A light source is necessary and a camera desirable. The camera is attached to the monitor and may be connected to a printer and/or video recorder. The camera head is attached to a flexible hysteroscope.
Great Vessel Injury

The most dangerous hemorrhagic complications are injuries to the great vessels, including the aorta and the vena cava, the common iliac vessels and their branches, and the internal and external iliac arteries and veins. The most catastrophic injuries occur secondary to insertion of an insufflation needle or the tip of the obturator (trocar) used to position the primary or ancillary cannulas. The vessels most frequently damaged are the aorta and the right common iliac artery as it branches from the aorta in the midline. The anatomically more posterior location of the vena cava and the iliac veins provides relative protection, but not immunity, from injury (116). After vascular injury, patients usually develop profound hypotension with or without hemoperitoneum. In some instances, blood is aspirated through the insufflation needle before the introduction of the distending gas. In such instances, the needle should be left in place while immediate preparations are made to obtain blood products and perform laparotomy. The bleeding frequently will be contained in the retroperitoneal space, which usually delays the diagnosis; consequently, hypovolemic shock may develop. To avoid late recognition, the course of each great vessel must be identified before completing the procedure. Because it is difficult to assess the volume of blood filling the retroperitoneal space, immediate laparotomy is indicated if retroperitoneal bleeding is suspected. A midline incision should be made to allow access to the great vessels. Upon entry into the peritoneal cavity, the aorta and vena cava should immediately be compressed just below the level of the renal vessels to gain at least temporary control of blood loss. The most appropriate course of action depends on the site and extent of injury. Vascular or general surgery consultation may be necessary to evaluate and repair significant vascular injuries. Although most of these injuries are small and amenable to repair with suture, some are larger and require the insertion of a vascular graft. Deaths have occurred as a result of these injuries.

Abdominal Wall Vessel Injury

The abdominal wall vessels most commonly injured during laparoscopy are the superficial inferior epigastric vessels as they branch from the femoral artery and vein and course cephalad in each lower quadrant. They are invariably damaged by the initial passage of an ancillary trocar-cannula system or by the introduction of a wider device later in the procedure. The problem may be recognized immediately by the observation of blood dripping along the cannula or out through the incision. However, the bleeding may be obstructed by the cannula until it is withdrawn at the end of the operation.

The more serious injuries are those to the deep inferior epigastric vessels, which are branches of the external iliac artery and vein that course cephalad but are deep to the rectus fascia and often deep to the muscles (Fig. 23.3). More laterally located are the deep circumflex iliac vessels, which are not often encountered in laparoscopic surgery. Laceration of these vessels may cause profound blood loss, particularly when the trauma is unrecognized and causes extraperitoneal bleeding.

Signs of injury, in addition to blood dripping down the cannula, include the postoperative appearance of shock and abdominal wall discolorization or hematoma located near the incision. In some instances, the blood may track to a more distant site, presenting as a pararectal or vulvar mass. Delayed diagnosis may be prevented by laparoscopic evaluation of each peritoneal incision after removal of the cannula.

Superficial inferior epigastric vessel trauma usually stops bleeding spontaneously; therefore, expectant management is appropriate. A straight ligature carrier can be used to repair lacerated deep inferior epigastric vessels. Alternatively, a Foley catheter may be inserted through the cannula, inflated, put on traction, and held in place with a clamp for 24 hours. If a postoperative hematoma develops, local compression should be used initially. Open removal or aspiration of the hematoma should not be undertaken because it may inhibit the tamponade effect and increase the risk of abscess. If the mass continues to enlarge or if signs of hypovolemia develop, the wound must be explored.

Intraperitoneal Vessel Injury

Hemorrhage may result from inadvertent entry into a vessel or failure of a specific occlusive technique. In addition to delayed hemorrhage, there may be a further delay in diagnosis at laparoscopy as a result of the restricted visual field and the temporary occlusive pressure exerted by CO₂ in the peritoneal cavity.

Inadvertent division of an artery or vein is usually evident immediately. Transected arteries may go into spasm and bleed minutes to hours later, going unnoticed temporarily because of the limited visual field of the laparoscope. Therefore, at the end of the procedure, all areas of dissection must be carefully examined. Carbon dioxide should be vented, which decreases the intraperitoneal pressure so that blood vessels temporarily occluded by higher pressure can be recognized.

Gastrointestinal Complications

The stomach, the small bowel, and the colon can be injured during laparoscopy. Mechanical entry into the large or small bowel can occur 10 times more often when laparoscopy is performed in patients who have had prior intraperitoneal inflammation or abdominal surgery. Loops of intestine can adhere to the abdominal wall under the insertion site and be injured (117). More laterally located are the deep circumflex iliac vessels, which are not often encountered in laparoscopic surgery. Laceration of these vessels may cause profound blood loss, particularly when the trauma is unrecognized and causes extraperitoneal bleeding.

Insufflation Needle Injuries

Needle entry into the gastrointestinal tract may be more common than reported because it may go unnoticed and without further complication. Gastric entry may be identified by the increased filling pressure, asymmetric distention of the peritoneal cavity, or aspiration of gastric particulate matter through the lumen of the needle. Initially, the hollow, capacious stomach may allow the insufflation pressure to remain normal. Signs of bowel entry are the same as those for gastric injury, with the addition of feculent odor.

If particulate debris is identified, the needle should be left in place, and an alternate insertion site should be identified, such as the left upper quadrant. Immediately after successful entry into the peritoneal cavity, the site of injury can be identified. Defects must be repaired immediately by laparoscopy or laparotomy.

Trocar or Obturator Injuries

Damage caused by a sharp tipped obturator or trocar is usually more serious than needle injury. Inadvertent gastric entry usually is associated with stomach distention because of aerophagia, difficult or improper intubation, or mask induction with inhalation anesthetic. Most often the injury is created by the trocar-cannula system used for primary access. Ancillary cannulas may result in visceral injury, although placement of these cannulas...
under direct vision helps reduce the risk of injury. The risk of gastric perforation can be minimized with the selective use of preoperative nasogastric or oral gastric suction when left upper-quadrant entries are used or when the intubation was difficult. Open laparoscopy likely has little impact on the risk for gastrointestinal complications, particularly those related to adhesions to the anterior abdominal wall from previous surgery. For high-risk patients, left upper quadrant needle and trocar-cannula insertion with a properly decompressed stomach may be preferable (119–122).

If the trocar of a primary cannula penetrates the bowel, the condition is usually diagnosed when the mucosal lining of the gastrointestinal tract is visualized. If the large bowel is entered, a feculent odor may be noted. However, the injury may not be recognized immediately because the cannula may not stay within the bowel or may pass through the lumen. Such injuries usually occur when a single loop of bowel is adherent to the anterior abdominal wall. The injury may not be recognized until peritonitis, abscess, enterocutaneous fistula, or death occurs (123,124). Therefore, at the end of the procedure, the removal of the primary cannula must be viewed either through the cannula or an ancillary port, a process facilitated by routine direct visualization of closure of the incision of the primary port.

Trocar-related injuries to the stomach and bowel require repair as soon as they are recognized. If the injury is small, a trained operator can repair the defect under laparoscopic direction using a double layer of running 2-0 or 3-0 absorbable sutures. Extensive lesions may require resection and reanastomosis, which in most instances requires at least a small laparotomy. The preoperative use of mechanical bowel preparation in selected high-risk cases minimizes the need for laparotomy or colostomy, but recent evidence suggests that bowel surgery, if necessary, may be safely performed in unprepared bowel (125).

Dissection and Thermal Injury

When mechanical bowel trauma is recognized during the dissection, treatment is the same as that described for trocar injury. Should the injury involve radiofrequency electrical energy, it is important to recognize that the zone of desiccation and coagulation may exceed the area of visual damage. This is especially true if the exact mechanism of the thermal injury is unknown or if injury results from contact with a relatively large surface area electrode that would be more likely to create a large coagulation injury. Conversely, bowel injury created under direct vision with a radiofrequency needle or blade electrode is associated with little collateral coagulation effect and can be managed similar to a mechanically induced lesion. Consequently, surgical repair should be implemented considering these factors, and should include, if necessary, resection of ample margins around the injury. Thermal injury may be handled expectantly if the lesion seems superficial and confined, such as when fulguration (noncontact arcing of high-voltage current) involves bowel. In such instances, the depth of injury is generally less than half a millimeter. In a study of 33 women with such injuries who were managed expectantly in the hospital, only 2 required laparotomy for repair of perforation (126).

Urologic Injury

Damage to the bladder or ureter may occur secondary to mechanical or thermal trauma incurred during laparoscopic procedures. Ideally, such injury should be prevented; otherwise, as is the case for most complications, it is preferable to identify the trauma intraoperatively.

Bladder Injury

Bladder injury can result from the perforation of the undrained bladder by an insufflation needle or trocar, or it may occur while the bladder is being dissected from adherent structures or from the anterior uterus (127,128). The frequency of injury is difficult to estimate and varies with the procedure. Estimates of the frequency of unintentional cystotomy associated with laparoscopic hysterectomy range from 0.4% to 3.2% and appear to be more frequent in the context of a previous cesarean section (129,130). The injury may be readily apparent by direct visualization. If an indwelling catheter is in place, hematuria or pneumaturia (CO₂ in the catheter drainage system) may be noticed. A bladder laceration can be confirmed by injecting sterile milk or a diluted methylene blue solution through a transurethral catheter. Thermal injury to the bladder, however, may not be apparent initially and, if missed, can present as peritonitis or a fistula.

Routine preoperative bladder drainage usually prevents trocar-related cystotomies. Separation of the bladder from the uterus or other adherent structures requires good visualization, appropriate retraction, and excellent surgical technique. Sharp mechanical dissection is preferred, particularly when relatively dense adhesions are present. Very small-caliber injuries to the bladder (1 to 2 mm) may be treated with bladder catheterization for 3 to 7 days. If repair is undertaken immediately, catheterization is unnecessary. When a larger injury is identified, it can be repaired laparoscopically (127,128,131). If the laceration is near the trigone or involves the trigone, an open procedure should be used. The mechanism of injury should be taken into consideration in making this evaluation because electrical injuries often extend beyond the visible limits of the apparent defect. If a coagulation-induced thermal injury occurred, the coagulated portion should be excised.

For small lesions, closure may be performed with layers of absorbable 2-0 to 3-0 sutures. Postoperative catheterization with either a transurethral or suprapubic catheter should be maintained for 2 to 5 days for small fundal lacerations and for 10 to 14 days for injuries to the trigone. Cystography should be considered before the urinary catheter is removed.

Ureteral Injury

One of the most common causes of ureteral injury during laparoscopy is electrosurgical trauma (113,132,133). Ureteral injury can occur after mechanical dissection, including linear cutting and stapling devices (133–135). Although intraoperative recognition of ureteral injury is possible, the diagnosis is usually delayed (132,133). Ureteral lacerations may be confirmed intraoperatively, visually, or following the intravenous injection of indigo carmine. Thermal injury presents up to 14 days after surgery with fever, abdominal or flank pain, and peritonitis. Leukocytosis may be present, and intravenous pyelography shows extravasation of urine or urinoma. Mechanical obstruction from staples or a suture may be recognized intraoperatively by direct visualization. Cystoscopy following the intravenous injection of indigo carmine may be used to confirm failure of the dye to pass through the ureter. Abdominal ultrasound may be helpful, but a CT urogram can more precisely identify the site and degree of the obstruction. Unrecognized ureteral obstruction may present a few days to 1 week after surgery with flank pain and often fever (136).

Discharge or continuous incontinence is a delayed sign of ureterovaginal or vesicovaginal fistula. A vesicovaginal fistula can be confirmed by filling the bladder with methylene blue and then detecting dye on a tampon previously placed in the vagina. With a ureterovaginal fistula, the methylene blue will not pass into the vagina, but it can be detected with the intravenous injection of indigo carmine.
Knowledge of the course of the ureter through the pelvis is a prerequisite to reducing the risk of injury. The ureter can usually be seen through the peritoneum of the pelvic sidewall between the pelvic brim and the attachment of the broad ligament. Because of variation from one patient to another or the presence of disease, the location of the ureter can become obscured, making it necessary to enter the retroperitoneal space. The techniques used for retroperitoneal dissection are important factors in reducing the risk of ureteric injury. Blunt and sharp dissection with scissors is preferred, although hydrodissection can be used (137). The selective placement of ureteral stents may be helpful in preventing injury.

Ureteral injury can be treated immediately if it is diagnosed intraoperatively. Although limited damage may heal over a ureteral stent left in place for 10 to 21 days, repair is indicated in most patients. Laparoscopic repair of ureteric lacerations and transections is performed, but most injuries require laparotomy (132, 138).

Incomplete or small obstructions and lacerations may be treated successfully with either a retrograde or antegrade ureteral stent. Urinomas may be drained percutaneously. If a stent cannot be placed successfully, a percutaneous nephrostomy should be performed before operative repair is undertaken. Repair may be accomplished by excision and reanastomosis, or, more commonly, ureteric reimplantation with or without facilitating procedures such as a psoas hitch or a Boari flap.

Neurologic Injury

Peripheral nerve injury is usually related either to poor positioning of the patient or to excessive pressure exerted by the surgeons. Positioning the patient in lithotomy while she is awake may decrease this risk because the patient can determine whether any undue pressure or discomfort is felt (139). Nerve injury may occur as a result of the surgical dissection.

In the extremities, the trauma may be direct, such as when the common peroneal nerve is compressed against a stirrup. The femoral nerve or the sciatic nerve or its branches may be overstretched and damaged by excessive flexion or external rotation of the hips. The peroneal nerve may be injured by compression if the lateral head of the fibula rests against the stirrup (139–141). Brachial plexus injuries may occur secondary to the surgeon or assistants leaning against an abducted arm during the procedure. If the patient is placed in a steep Trendelenburg position, the brachial plexus may be damaged because of the pressure exerted on the shoulder joint. In most cases, sensory or motor deficits are found as the patient emerges from anesthesia. The likelihood of brachial plexus injury can be reduced with adequate padding and support of the arms and shoulders or by placing the patient’s arms in an adducted position.

Most injuries to peripheral nerves resolve spontaneously. The time to recovery depends on the site and severity of the lesion. For most peripheral injuries, full sensory nerve recovery occurs in 3 to 6 months. Recovery may be hastened by the use of physical therapy, appropriate braces, and electrical stimulation of the affected muscles. Open microsurgery should be performed for transection of major intrapelvic nerves.

Incisional Hernia and Wound Dehiscence

Incisional hernia after laparoscopy was reported in more than 900 cases (98, 99). The most common defect is dehiscence that develops in the immediate postoperative period. Hernias may be asymptomatic or may cause pain, fever, periumbilical mass, obvious evisceration, and the symptoms and signs of mechanical bowel obstruction. Although no incision is immune to the risk, defects that are larger than 10 mm in diameter are particularly vulnerable (99, 142, 143).

Richter’s hernias contain only a portion of the intestine in the defect, and the diagnosis is often delayed because the typical symptoms and findings of mechanical bowel obstruction may be absent. The initial symptom is usually pain. These hernias most often occur in incisions that are lateral to the midline where there is a greater amount of preperitoneal fat creating a potential space for incarceration. Fever can be present if incarceration occurs, and peritonitis may result from subsequent perforation. The condition is difficult to diagnose, requires a high index of suspicion, and may be confirmed with ultrasonography or CT (144).

In most cases, these occurrences can be prevented by using small-caliber cannulas, when possible, and with routine fascial and peritoneal closure of defects made by peritoneal access. The risk of inadvertent incorporation of the intestine into the wound can be reduced by viewing the closure with a smaller-caliber laparoscope passed through a narrow caliber ancillary port. All ancillary cannulas should be removed under direct vision to ensure that bowel is not drawn into the incision and that there is an absence of active incisional bleeding.

The management of laparoscopic incisional defects depends on the time of presentation and the presence and condition of entrapped bowel. Evisceration always requires surgical intervention. If the condition is diagnosed immediately, the intestine is replaced in the peritoneal cavity (if there is no evidence of necrosis or intestinal defect), and the incision is repaired, usually with laparoscopic guidance. If the diagnosis is delayed or the bowel is incarcerated or at risk of perforation, laparotomy is necessary to repair or resect the intestine.

Infection

Wound infections after laparoscopy are uncommon; most are minor skin infections that can be treated successfully with expectant management, drainage, or antibiotics (145). Severe necrotizing fasciitis rarely occurs. Bladder infection, pelvic cellulitis, and pelvic abscess were reported (146).

Laparoscopy is associated with a much lower risk of infection than open abdominal or vaginal surgery. Prophylactic antibiotics should be offered to selected patients (e.g., those with enhanced risk for bacterial endocarditis and those for whom total hysterectomy is planned). Patients should be instructed to monitor their body temperature after discharge and to report immediately a temperature higher than 38°C.

Hysteroscopy

The hysteroscope is an endoluminal endoscope, adapted from the urological cystoscope that can be used to aid diagnosis or to direct the performance of a variety of intruterine procedures. Hysteroscopic lysis of intrauterine adhesions was first described in 1973 (147). The technique of endoscopically guided electrosurgical resection was adapted from urology to gynecology for the removal of uterine leiomyomas (148). Hysteroscopic division of uterine septa was originally developed using a mechanical technique with specially designed scissors (149). Hysteroscopic destruction of the endometrium, generally termed endometrial ablation (EA), was originally reported using Nd:YAG laser vaporization, but subsequent innovators used the urological resectoscope to ablate the endometrium using electrosurgical coagulation, resection, or vaporization (150–152). Hysteroscopically guided thermal ablation with heated fluid was described, as the only endoscopically guided technique for nonresectoscopic EA. Developments in the design of
endoscopes resulted in smaller-diameter instruments that retain the ability to provide a high-quality image and facilitate the use of hysteroscopy in an office or procedure room setting.

Diagnostic Hysteroscopy

The goal for evaluation of the uterine cavity is to obtain either a sample of the endometrium, usually for the detection of hyperplasia or neoplasia, or to identify structural abnormalities, typically a uterine septum or focal lesions, such as adhesions, polyps, or myomas. Blind endometrial sampling is the diagnostic mainstay for the detection of endometrial hyperplasia, whereas transvaginal ultrasonography, hysteroscopy, MRI and hysteroscopy are options for the detection and characterization of structural anomalies. **Hysteroscopic examination is probably superior to hysterography for evaluation of the endometrial cavity, but the diagnostic accuracy of transvaginal ultrasonography is comparable, especially when intravaginal saline is used as a contrast medium, a procedure called sonohysterography or saline infusion sonography (SIS)** (153–156). MRI and ultrasound-based techniques have the advantage of allowing evaluation of the myometrium, whereas office-based hysteroscopy allows simultaneous removal of small polyps and even some myomas. Diagnostic hysteroscopy provides information not obtained by blind endometrial sampling, such as detection of endometrial polyps or submucous leiomyomas (157–163). Malignant or hyperplastic polyps or other localized lesions can be identified with hysteroscopy and removed via directed biopsy (160). Blind curettage remains an effective approach for the identification of global endometrial histopathology (157, 162, 164). Following are potential indications for diagnostic hysteroscopy:

1. Unexplained abnormal uterine bleeding
   - Premenopausal
   - Postmenopausal
2. Selected infertility cases
   - Abnormal hysteroscopy or transvaginal ultrasonography
   - Unexplained infertility
3. Recurrent spontaneous abortion

For many patients, diagnostic hysteroscopy can be performed in an office or procedure room setting with minimal discomfort and at a much lower cost than in a surgical center or a traditional operating room. For some, concerns about patient comfort or a preexisting medical condition may preclude office hysteroscopy. In many patients hysteroscopy can provide more information than blind curettage, but it should be used prudently. For most patients, other diagnostic or therapeutic measures can be undertaken before, or instead of, diagnostic hysteroscopy. For example, for women in the late reproductive years who have abnormal uterine bleeding (AUB) or for those with postmenopausal bleeding, transvaginal sonography or office endometrial biopsy or curettage is typically adequate to evaluate for neoplasia and provide enough information to support an initial management strategy. In the absence of a satisfactory diagnosis or if unexplained bleeding continues without response to treatment, further investigation is appropriate, using one or a combination of ultrasound, endometrial sampling, SIS, or office hysteroscopy. For women in their earlier reproductive years who have AUB, medical or expectant management may be used initially, depending on the severity and inconvenience of the bleeding. For those who do not respond to medical treatments such as oral contraceptives, further diagnostic procedures such as transvaginal ultrasonography, SIS, or hysteroscopy with biopsy can be performed (165).

For women with infertility, hysterosalpingography is the best initial imaging step because it provides information about the patency of the oviducts. In the presence of a suspicious or identified abnormality in the endometrial cavity, hysteroscopy or sonohysterography can be performed to confirm the diagnosis, to better define the abnormality, and perhaps to direct the removal of a lesion. Some experts consider hysteroscopy or MRI mandatory for such patients because of the high occurrence of false-negative radiologic images in those with intruterine anomalies (166). In women with previous in vitro fertilization failure, there is evidence that hysteroscopic identification and treatment of these “missed” anomalies improves pregnancy rates (167). Confirmation of patency of the oviduct is unnecessary in women who have recurrent abortions; therefore, these patients can be evaluated primarily with hysteroscopy.

Operative Hysteroscopy

A number of intrauterine procedures can be performed under endoscopic direction, including adhesiolysis, sterilization, division of a uterine septum, resection of myomas and polyps, removal of retained products of conception, and endometrial destruction through Nd:YAG laser vaporization or radiofrequency resection, desiccation, or vaporization. Hysteroscopy may be used to direct the removal of foreign bodies, including imbedded intrauterine contraceptive devices (IUDs).

Foreign Body

If the string of an IUD is absent, the device usually can be removed with a specially designed hook or a toothed curette (e.g., Novak). When removal is difficult or impossible, the location of the device may be confirmed by hysteroscopy, allowing removal with a grasping forceps. If the device is not seen or if only a portion is visible hysteroscopically and the remainder is imbedded in the myometrium, then individualized management is recommended, usually following appropriate imaging studies to identify the more precise location of the device.

Septum

When recurrent pregnancy loss is associated with a single corpus containing a uterine septum, hysteroscopic division of the septum improves reproductive outcome at a rate comparable to abdominal metroplasty, with reduced morbidity and cost (see Chapter 33) (168–173). There are fewer data regarding infertility but there is some evidence that metroplasty does improve fecundity (174). Confirmation of the external architecture of the corpus is important and can be achieved using either MRI or three-dimensional ultrasound. One group described an office method of “see and treat” where dissection is continued until attaining two of three criteria (pain, bleeding, the visualization of myometrial fibers) to determine the end point of septal transection (175). This procedure can be successfully performed in the office setting using local anesthesia protocols, with additional 0.05% lidocaine with 1/200,000 epinephrine directly injected into the septum. The procedure may be performed mechanically with scissors or with energy-based techniques such as the Nd:YAG laser or an electrosurgical knife, needle, or loop. Because most septa have few vessels, scissors can be used to
Endometrial Polyps

Endometrial polyps are associated with abnormal uterine bleeding and infertility. Although such polyps can be removed with blind curettage, many are missed (157, 159, 162, 163). Therefore, known or suspected endometrial polyps are treated more successfully with hysteroscopic guidance, which usually can be performed as an office procedure. Hysteroscopy may be used either to evaluate the result of blind curettage, to determine if the polyp is avulsed, or to direct the use of grasping forceps or small caliber scissors. Alternatively, for larger polyps, special polyp snares, electrosurgical needles, or a uterine resectoscope may be used to sever the stalk or morcellate the lesion. For patients with infertility and endometrial polyps, it is not clear whether or not polyp number and size are related to outcome (176). Consequently, removal of all accessible polyps should be attempted if the process can be completed with minimal trauma.

Leiomyomas

Hysteroscopy may be used to remove selected leiomyomas that involve the uterine cavity in women with heavy menstrual bleeding, infertility, or recurrent first trimester spontaneous pregnancy loss (155, 177–183). This approach is limited based on the location, size, and number of the lesions. Preoperative administration of gonadotropin-releasing hormone (GnRH) agonists may help shrink submucous myomas, facilitating their complete removal, and more importantly, reduce operating time and systemic absorption of distension media (184–186).

To help document and evaluate the results of hysteroscopically directed myoma surgery, a classification system was developed that is based on the proportion of the myoma that is in the uterine cavity. In patients with myomas that are 3 cm or less in diameter and entirely intracavitary (type 0), excision is feasible and in many instances relatively easy, whereas in large type II lesions an abdominal approach with laparoscopy or laparotomy is necessary. Small type 0 leiomyomas may be removed following transection of the stalk with scissors or an electrode attached to a uterine resectoscope. For larger type 0 lesions, or for type I myomas, electrosurgical morcellation with a resectoscope is necessary before removal. For a limited number of type II myomas, careful dissection into the avascular plane interposed between the tumor and the myometrial pseudocapsule may be attempted, provided that satisfactory ultrasonography or MRI demonstrated an adequate margin of myometrium between the deepest aspect of the lesion and the uterine serosa. It may be preferable to undertake such procedures with laparoscopic monitoring to verify that bowel is not adjacent to the zone of dissection. Patients should be counseled that for some type I and many type II myomas, more than one procedure might be required to complete excision (178, 187). The use of intrauterine prostaglandin F2α was described to facilitate extrusion of type II myomas (188).

Endometrial Ablation

Heavy menstrual bleeding that does not respond to oral medical therapy may be managed by EA using coagulation, resection, or vaporization, provided the patient is willing to forgo future fertility (51). Alternatively, if future fertility is desired, a levonorgestrel-releasing intrauterine contraceptive device can provide virtually equal clinical outcomes (189, 190). Ablation may be performed with the laser, radiofrequency electrosurgical desiccation, resection, or vaporization using a uterine resectoscope, or by any of a number of nonresectoscopic techniques, including those employing thermal balloons, cryotherapy, heated free fluid, or microwave or bipolar radiofrequency energy (151, 152, 187, 191–195). Many of these endometrial ablation devices can be used in an office setting using local anesthetic protocols.

Endometrial resection is an EA technique performed with an electrosurgical loop electrode to shave the endometrium and superficial myometrium (109, 142, 143, 150, 196, 197). Vaporization utilizes specially designed electrodes that are attached to standard resectoscopes but which are capable of destroying large volumes of tissue without morcellation (187). Ablation is achieved using ball or barrel-shaped electrodes that coagulate the endometrial surface (51, 152). Complications of these procedures include fluid overload, electrolyte imbalances (if nonelectrolytic or even isomotic media are used), uterine perforation, bleeding, and intestinal and uterine tract injury (198, 199). The risk of uterine perforation may be reduced by using a combination of resection or vaporization and electrosurgical ablation; the latter is most suitable for the thinner areas of the myometrium in the cornu (177).

The preoperative use of GnRH analogues or danazol may reduce operating time. GnRH may reduce bleeding and the amount of fluid absorbed into the systemic circulation (186).

For many women, these procedures succeed in reducing or eliminating menses without hysterectomy or long-term medical therapy (51, 200). Success rates vary and depend on the duration of follow-up and the definition of success. For many patients, amenorrhea is the goal, whereas for others, it is normalization of menses. About 75% to 95% of patients are satisfied with the surgical procedure after 1 year. Amenorrhea rates range from about 30% to 90% (depending in part upon the technique), but 40% to 50% of patients have amenorrhea, is a useful number to quote to patients considering the procedure. In comparative studies, there is no advantage of laser over electrosurgical techniques (198, 201). The nonresectoscopic techniques have similar clinical outcomes, thus reducing the need for resectoscopic ablation. However, the nonresectoscopic approaches all have limitations defined by the size or configuration of the endometrial cavity. Consequently, for those women with heavy menstrual bleeding who are not suitable for nonresectoscopic techniques because of large uteri (>12 cm sounded length), resectoscopic endometrial ablation remains a viable option (161, 202).

The long-term efficacy and impact of ablation or resection on women with adenomyosis is unknown. Because some endometrium inevitably cannot be ablated, there is the potential for endometrial cancer; therefore, postmenopausal women who underwent ablation or resection should take progestin as a part of hormonal therapy (203).

Sterilization

Sterilization can be performed under hysteroscopic guidance, an approach that eliminates the disadvantages and risks associated with abdominal or laparoscopic techniques (204). Two such techniques are available and others are under development. The Essure® system comprises a nickel-titanium coil with a Dacron filament that can be inserted relatively quickly in an office or procedure room setting (see Chapter 10). The Adiana® device uses a rice grain–sized porous silicon plug that is positioned in the proximal tube following the application of an aliquot of RCM®1 current. It is designed for office use under local anesthesia. North American protocols require that hysterosalpingography be performed 3 months after the procedure to ensure that bilateral tubal occlusion took place.

Synechiae

Asherman syndrome is the presence of adhesions in the endometrial cavity resulting in infertility or recurrent spontaneous abortion with or without
amennorhea. These synechiae may be detected on a hysterosgram or sonohystogram, but are best shown with diagnostic hysteroscopy. Relatively thin, fragile synechiae may be divided with the tip of a rigid diagnostic hysteroscope (205). Thicker lesions may require division by semirigid or rigid scissors or energy-based instruments such as a resectoscope or an operative hysteroscope with either a radiofrequency electrode or an Nd:YAG laser. Reproductive outcome depends on the extent of the preoperative endometrial damage (206,207). This is another hysteroscopic procedure that is amenable to performance in the office, at least in selected cases without complete obliteration, but the surgeon must be careful to maintain orientation within the endometrial cavity.

Patient Preparation and Communication

Diagnostic hysteroscopy procedures traditionally were performed in the office or clinic settings, and operative hysteroscopy usually was performed in an operating room or hospital surgical center. Much is changing; in a number of centers, 90% of the operative hysteroscopies are performed in an office procedure room setting using local and verbal anesthesia. The patient should understand the rationale for the procedure, and the anticipated discomfort, the potential risks, and the expectant, medical, and surgical alternatives. The nature of the procedure and the chance of therapeutic success should be explained, and she should be given a realistic estimate of success based on the operator’s experience.

Diagnostic Hysteroscopy: Risks

The risks of diagnostic hysteroscopy are few, and those complications that occur rarely have severe consequences (199). The uncommon adverse events that should be discussed with the patient include perforation, bleeding, and those related to anesthesia and the distention media. After diagnostic hysteroscopy, most patients have slight vaginal bleeding and occasionally, lower abdominal cramps. Severe cramps, dyspnea, and upper abdominal and right shoulder pain can develop if CO\(_2\) is used as the distension media and it passes through the fallopian tubes into the peritoneal cavity. Consequently, even in an office environment, the patient should be encouraged to have a friend or relative escort her home.

Operative Hysteroscopy: Risks

Counseling before operative hysteroscopy varies depending on the planned procedure, the type of anesthesia, and the procedure location—office or operating room. Overall, the risks of operative hysteroscopy are higher than those of diagnostic hysteroscopy, but these increased risks are largely confined to procedures such as adhesiolysis of severe intrauterine synechiae or resection of leiomyomas that are either large or that extend deeply into the myometrium. These risks include those associated with anesthesia, which are intrinsic to all hysteroscopic procedures, and are related to the specific surgical procedure to be performed. With any hysteroscopic procedure, air embolus is a possibility, as are complications associated with the gaseous or fluid distention media used. Hypotonic distension media may not be tolerated in some patients if there is significant intravascular absorption, especially in patients with underlying cardiovascular disease. The patient must be aware of the risks associated with uterine perforation, which range from failure to complete the procedure, to hemorrhage, or damage to the intestines or the urinary tract. If such complications occur, laparotomy may be necessary to repair the injury.

Equipment and Technique

The equipment required for hysteroscopy depends on the reason for the procedure. The surgeon must be knowledgeable about the equipment, its mechanisms, and the technical specifications to facilitate efficiency, optimal clinical outcome, and a decreased probability of complications. A typical hysteroscopy setup for diagnostic and minor operative procedures is shown in Figures 23.24 and 23.25. Core competencies required for hysteroscopy are as follows:

1. Patient positioning and cervical exposure
2. Anesthesia
3. Cervical dilation
4. Uterine distention
5. Visualization and imaging
6. Intrauterine cutting and hemostasis
7. Other instrumentation

Patient Positioning and Cervical Exposure

Hysteroscopy is performed in a modified dorsal lithotomy position; the patient is supine, and the legs are held in stirrups. For hysteroscopic procedures performed while the patient is conscious, comfort must be considered in conjunction with the need to gain good exposure of the perineum. Stirrups that hold and support the knees, calves, and ankles permit prolonged procedures. “Candy cane” stirrups are inappropriate for hysteroscopic surgery and for conscious patients.

The smallest speculum possible should be used to expose the cervix. A bivalve speculum hinged on only one side allows its removal without disturbing the position of the tenaculum and hysteroscope. The use of weighted specula should be avoided in conscious patients because of the discomfort involved.

Anesthesia

The anesthetic requirements for hysteroscopy vary greatly, depending on the patient’s level of anxiety, the status of her cervical canal, the procedure, and the outside diameter of the hysteroscope or sheath. In some patients, diagnostic hysteroscopy is possible without anesthesia, especially if the patient is parous or if narrow-caliber (<3 mm in outside diameter) hysteroscopes and sheaths are used (208). The pain of cervical dilation is avoided or minimized with the preprocedural use of oral or vaginal misoprostol (see below) or by inserting a laminaria “tent” in the cervix 3 to 8 hours before the procedure. Laminaria are thin rods of natural (slippery elm) or synthetic construction that, when passed through the internal os, expand over several hours thereby dilating the cervix. However, if laminaria are left in place too long (e.g., longer than 24 hours), the cervix may overdilate, which is counterproductive for CO\(_2\) insufflation.

For most diagnostic and many operative procedures, effective cervical anesthesia is obtained using local anesthesia, allowing the
hysteroscopy to be done in an office procedure room. Evidence suggests that the paracervical block may be the most effective. Following exposure of the cervix with a vaginal speculum, a spinal needle can be used to instill about 3 mL of 0.5% to 1% lidocaine into the anterior lip of the cervix to allow attachment of a tenaculum and manipulation of the exocervix. While the exact location and depth of the injection varies with providers and studies, the uterosacral ligament location (about 4 mm deep at approximately at the 4- and 8-o'clock positions as one looks at the cervix) was demonstrated successful. Care must be taken to avoid intravascular injection. An alternative technique is the use of an intracervical block where the anesthetic agent is injected evenly around the circumference of the cervix, attempting to reach the level of the internal os. The efficacy of this approach is unclear based on published studies. Recognizing the complex innervation of the uterus, alternative or additional topical anesthesia may be applied to the cervical canal or to the endometrium, or both, using anesthetic spray, gel, or cream. It is unclear how effective these approaches are because many of the study protocols seemed to allow inadequate time between application and initiation of the procedure. Careful technique, with waiting periods between performing the blocks, should be emphasized. A number of options were presented, including instillation of 5 mL of 2% mepivacaine into the endometrial cavity with a syringe, or the application of similar amounts of 2% lidocaine gel. Many operative procedures can be performed with these techniques combined, if deemed necessary, with the oral or intravenous use of anxiolytics or analgesics, although the use of such systemic agents mandates continuous monitoring of blood pressure and oxygenation and the availability of appropriate resuscitative staff and equipment. An important component of the optimal use of local anesthesia is allowing sufficient time from the injection or application of the agents before the commencement of the procedure. While injectable local anesthetic agents such as lidocaine and mepivacaine may have an onset of action in 2 to 3 minutes, it may take up to 15 to 20 minutes to obtain a maximal effect. If local anesthesia is not deemed appropriate, regional or general anesthesia may be used in the context of a surgical center or operating room.

Cervical Dilation
In many instances, and particularly in vaginally parous women, dilation of the cervix will be unnecessary, especially if narrow caliber hysteroscopic systems are used. Dilation will be necessary some of the time, and, although seemingly simple, cervical stenosis or suboptimal technique can result in perforation that compromises the entire procedure. If the objective lens of the endoscope cannot be placed in the endometrial cavity the hysteroscopy cannot be done. The process of dilation should be undertaken carefully, respecting the orientation of the cervix to the axis of the vaginal canal (version) and that of the corpus to the cervix (flexion). In difficult circumstances, simultaneous ultrasound may be valuable, and difficult dilation may be facilitated directly with the hysteroscope.

There are a number of options available to facilitate cervical dilation. There is evidence that prostaglandin E2 (misoprostol) administered 400 µg orally or 200 to 400 µg vaginally, approximately 12 to 24 hours before the procedure facilitates cervical dilation. Misoprostol alone may not be effective in postmenopausal women, but one well-designed randomized trial demonstrated that vaginal estrogen, administered daily for 2 weeks before the procedure facilitates the effect of the prostaglandin in this group of patients. Alternatively, there is evidence that intraoperatively administered intracervical vasopressin (0.05 U/mL, 4 cc at 4 and 8 o'clock) substantially reduces the force required for cervical dilation. Regardless of the circumstance, the cervix should be dilated asatraumatically as possible. It is best to avoid using a uterine sound because it can traumatize the canal or the endometrium, causing unnecessary bleeding and uterine perforation.

Uterine Distention
Distention of the endometrial cavity is necessary to create a viewing space. The choices include CO₂ gas, high-viscosity 32% dextran 70, and a number of low-viscosity fluids, including glycine, sorbitol, saline, and dextrose in water. A pressure of 45 mm Hg or higher is generally required for adequate distention of the uterine cavity and to visualize the tubal ostia. To minimize extravasation, this pressure should not exceed the mean arterial pressure. For each of the fluids, there are several methods used to create this pressure by infusion into the endometrial cavity.

Sheaths
A rigid hysteroscope is passed into the endometrial cavity through an external sheath. The design and diameter of the sheath reflect both the dimensions of the endoscope and the purpose of the instrument. Typical diagnostic hysteroscopes have a sheath slightly wider than the telescope, allowing infusion of the distention media. Operative sheaths have additional channels to permit the passage or efflux of distention media and the insertion of laser fibers, electrosurgical instruments or semirigid scissors, biopsy devices, or grasping forceps. These sheaths are usually 5 to 8 mm in diameter, and some allow continuous flow of distention media in and out of the endometrial cavity.

Figure 23.25 Office hysteroscopy instruments. An assembled continuous flow operating hysteroscope with a 5.5-mm diameter external sheath is shown in (A). A 5-French semirigid scissors occupies the working channel. An additional biopsy forceps is shown in (B). Tubing transporting media to the system is shown in (C) going into a 3-mm external diameter flexible and steerable hysteroscope (D). A medical video camera is attached to the hysteroscope (F) and the light source is attached at (E). An open speculum (G) facilitates removal with instruments in place. A small dilator (H) or series of dilators will be necessary for a large number of patients. A tenaculum (I) attached to the cervix frequently facilitates both dilation and entry of the hysteroscope into the endometrial cavity.

Media
CO₂ provides an excellent view for diagnostic purposes, but it is unsuitable for operative hysteroscopy and for diagnostic procedures when the patient is bleeding because there is no effective way to remove blood and other debris from the endometrial cavity. To prevent CO₂ embolus, the gas must be instilled by an insufflator that is especially designed for the procedure—the intrauterine pressure is kept below 100 mm Hg and the flow rate is maintained at less than 100 mL per minute.

Normal saline is a useful and safe medium for procedures that do not require radiofrequency electricity from standard monopolar resectoscopes. Even if there is absorption of a substantial volume of solution, saline typically does not cause electrolyte imbalance. Therefore, saline is a good fluid for minor procedures performed in the office. The development of bipolar radiofrequency instrumentation for hysteroscopic surgery allowed the application of saline as a distending medium in even more advanced and complex procedures.

Dextran 70 is useful for patients who are bleeding because it does not mix with blood. However, it is expensive and tends to “caramelize” on instruments, which must be disassembled and thoroughly cleaned in warm water immediately after each use. Anaphylactic reactions, fluid overload, and electrolyte disturbances can occur.
Intrauterine Cutting and Hemostasis

Image Documentation

A small video camera can be used to teach and to coordinate the procedure with the operating room team. It allows the acquisition of still or video images for future reference or teaching. When a video recorder is used, the camera should be attached directly to the recorder to preserve the image quality. A small video camera can be used to teach and to coordinate the procedure with the operating room team. It allows the acquisition of still or video images for future reference or teaching. When a video recorder is used, the camera should be attached directly to the recorder to preserve the image quality.

Video Imaging

Although diagnostic hysteroscopy may be performed with direct visualization, it is best to use video guidance for prolonged operations. Video imaging is important for teaching and recording pathology and procedures. The camera must be sensitive because of the narrow diameter of the endoscope and the frequently dark background of the endometrial cavity, particularly when it is enlarged.

Light Sources and Cables

Adequate illumination of the endometrial cavity is essential. Because it runs from a standard 110- or 220-volt wall outlet, the light source requires no special electrical connections. For most cameras and endoscopes, the element must have at least 150 watts of power for direct viewing and preferably 250 watts or more for video and operative procedures.

Endoscopes

Hysteroscopes are available in two basic types—flexible and rigid. Flexible hysteroscopes are self-contained in that they do not require a sheath; the single integrated channel is used to transmit gas or fluid to the endometrial cavity for distention. As a result, these instruments are generally of smaller diameter than rigid systems. In addition, they can be designed to be “steerable,” allowing angled viewing. Flexible hysteroscopes utilize fiberoptic bundles rather than lenses to transmit the image to the observer and, consequently, have lower resolution than rigid instruments of a similar diameter and typically do not have a channel with a caliber suitable for most hand instruments. Rigid hysteroscopes are more durable and provide a superior image. The most commonly used hysteroscopes are 3 to 4 mm in diameter, although those using fibers can be smaller than 2 mm in diameter.

Rigid endoscopes require an angled (fore-oblique) lens to provide the angled view useful for operative hysteroscopy and are available in 0-degree, 12- to 15-degree, and 25- to 30-degree models. The 0-degree telescope provides a panoramic view and is best for diagnostic procedures. Hysteroscopes with 25- to 30-degree angles are most often used for cannulation of the fallopian tubes or placement of sterilization devices, whereas 12- to 15-degree designs are a suitable compromise useful for diagnosis and ablation or resection. The utility of endoscopes with larger fore-oblique views may be offset by the tendency of resectoscopic electrodes to leave the visual field on full extension.

Figure 23.26 Hysteroscope optics. Panoramic (0°) and oblique (15° and 30°) viewing angles.
1. Before undertaking anything but simple operative procedures using these agents, baseline serum electrolyte levels should be determined.

**Distention Media**

**Carbon Dioxide**

Carbon dioxide is highly soluble in blood; consequently such emboli as occur are usually clinically significant, and, in rare instances, CO₂ emboli may result in serious intraoperative morbidity and even death (221–223). These risks can be eliminated by avoiding the use of CO₂ with operative procedures, by ensuring that the insufflation pressure is always lower than 100 mm Hg, and that the flow rate is lower than 100 mL per minute. The insufflator used must be especially designed for hysteroscopy; it is difficult to set laparoscopic insufflator flow rates below 1,000 mL per minute.

**Dextran 70**

Dextran 70 is a hyperosmolar medium that, rarely, can induce an allergic response or coagulopathy (224,225). Similar to other types of distention media, if sufficient volumes are infused, vascular overload and heart failure can occur (226,227). Because dextran is hydrophilic, it can draw six times its own volume into the systemic circulation. Consequently, the volume of this agent should be limited to less than 300 mL.

**Low-Viscosity Fluids**

The low-viscosity fluids—1.5% glycine, 3% sorbitol, and 5.0% mannitol—are used commonly because of their low cost, compatibility with standard electrosurgery, and availability in large-volume bags. However, should these electrolyte-free and usually hypotonic media be absorbed to excess in the systemic circulation, they can create serious fluid and electrolyte disturbances, a potentially dangerous complication that can result in pulmonary edema, hyponatremia, heart failure, cerebral edema, and even death. There are a number of published guidelines describing the steps required to reduce the risk of fluid overload at the time of hysteroscopy (228).
measured. Women with cardiopulmonary disease should be evaluated carefully. The selective preoperative use of agents such as GnRH agonists may reduce operating time and media absorption. Intracervical injection of 8 mL dilute in vasopressin (0.01 U/mL) immediately prior to surgery is effective at reducing the amount of systemic absorption of distending media (229). The duration of this effect may be limited to approximately 20 to 30 minutes, so repeat dosing may be useful for optimal effect.

2. In the operating room, media infusion and collection should take place in a closed system to allow accurate measurement of the "absorbed" volume. The volume should be measured continuously with a device specifically designed for the purpose or, if such a system is not available, calculated every 10 minutes by support staff who are trained in these calculations and unencumbered by duties that may interfere with this task.

3. The lowest intrauterine pressure necessary for adequate distention should be used to complete the operation, preferably at a level that is below the mean arterial pressure. A good range is 70 to 80 mm Hg, which can be achieved with a specially designed pump or by maintaining the meniscus of the infusion bag 1 m above the level of the patient’s uterus. If greater intrauterine pressure is needed for adequate distention, the anesthesiologist may temporarily raise the mean arterial pressure by administration of a vasoactive agent such as phenylephrine.

4. Deficits of more than 1 L require repeat measurement of serum electrolyte levels and consideration of dose of intravenous furosemide appropriate to the patient’s renal function. When such a deficit exists, the procedure should be completed expeditiously. If the deficit reaches a preset limit (1.5 to 2 L), the procedure should be terminated, and a diuretic such as mannitol or furosemide should be used as needed. Patients with cardiovascular compromise will typically have a lower tolerance for fluid deficits, a circumstance that mandates setting a lower limit for systemic absorption and consequent termination of the procedure (230).

Perforation

Perforation may occur during dilation of the cervix, positioning of the hysteroscope, or as a consequence of the intrauterine procedure. With complete perforation, the endometrial cavity typically does not distend, and the visual field is generally lost. When perforation occurs during dilation of the cervix, the procedure must be terminated, but, because of the blunt nature of the dilators, usually there are no other injuries. If the uterus is perforated by the activated tip of a laser, or electrode, there is a risk for bleeding or injury to the adjacent viscera. Therefore, the operation must be stopped and laparoscopy or laparotomy should be performed. Injury to the uterus is relatively easy to detect with a laparoscope. However, mechanical or thermal injury to the bowel, ureter, or bladder is more difficult to detect and laparoscopy is frequently inadequate to make a complete evaluation. If the patient’s condition is managed expectantly, she should be advised of the situation and asked to report any symptoms of bleeding or visceral trauma such as fever, increasing pain, nausea, and vomiting.

Bleeding

Bleeding that occurs during or after hysterectomy results from trauma to the vessels in the myometrium or injury to other vessels in the pelvis. Myometrial vessels are more susceptible to laceration. Resectoscopic procedures require myometrial dissection for procedures such as endometrial resection or type II myomectomy. In planning operations that involve deep resection, autologous blood can be obtained before surgery. The risk for bleeding may be reduced by the preoperative injection of dilute vasopressin into the cervical stroma (229). The risk of injury to branches of the uterine artery can be lowered by limiting the depth of resection in the lateral endometrial cavity near the uterine isthmus, where ablative techniques should be considered. When bleeding is encountered during resectoscopic procedures, the ball electrode can be used to desiccate the vessel electrosurgically. Intractable bleeding may respond to the injection of dilute vasopressin or to the inflation of a 30-mL Foley catheter balloon or similar device in the endometrial cavity (177).

Thermal Trauma

Thermal injury to the intestine or ureter may be difficult to diagnose, and symptoms may not occur for several days to 2 weeks. Therefore, the patient should be advised of the symptoms that could indicate peritonitis.

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