The field of minimally invasive surgery has evolved rapidly since the first laparoscopic appendectomies and cholecystectomies were performed nearly 30 years ago. Minimally invasive approaches are now widely used for gastrointestinal resection, hernia repair, antireflux surgery, bariatric surgery, and solid-organ surgery, such as hepatic, pancreatic, adrenal, and renal resections. Although the techniques and equipment needed to access, expose, and dissect vary according to the type of operation and surgeon’s preference, a basic set of equipment is essential for any laparoscopic procedure: laparoscope, camera, light source, signal processing unit, video monitor, insufflator and gas supply, trocars, and surgical instruments. Understanding how to use and troubleshoot this equipment is critical for any surgeon who performs minimally invasive surgery.

In this chapter, we review the essentials of basic laparoscopic equipment, including the mechanics of normally functioning equipment and the various types of laparoscopic trocars and instruments. Additionally, we discuss potential technical difficulties that surgeons may encounter while using laparoscopic equipment and instruments and provide suggestions for troubleshooting these problems.

Laparoscopic Equipment

**LAPAROSCOPE AND CAMERA**

The purpose of the laparoscope and camera unit is to transmit high-quality images from the surgical field to the signal processing unit, which relays the images to the video monitor. Traditional laparoscopes have two separate channels. One channel contains a series of glass rods (known as the Hopkins rod-lens system) that transmit images from the surgical field to the eyepiece of the laparoscope. The second channel contains light fibers, which transmit light from an external source to the surgical field.

Laparoscopes may be straight or angled at the tip. Straight (0°) laparoscopes offer a view of whatever lies directly ahead of the laparoscope, whereas angled (e.g., 30° or 45°) scopes allow the surgeon to look around structures by rotating the scope [see Figure 1]. Typically, laparoscopes are either 5 or 10 mm in diameter and are usually 25 to 30 cm in length. Smaller diameter laparoscopes, such as 3 mm scopes, are also available, although they tend to be less durable [see Figure 2]. Longer laparoscopes (e.g., 40 to 45 cm) are also available and are frequently used in bariatric cases.

To transmit images from the laparoscope to the signal processing unit, a camera is attached to the eyepiece via a coupler [see Figure 3]. First-generation cameras developed in
the 1980s used a “one-chip” system to convert colors into electrical charges and relay those images. Most current-generation laparoscopic cameras use “three-chip” charge-coupled device systems, which sense primary colors (red, blue, green) and convert these colors to electrical charges. This enhancement allows for a higher image resolution. In one study, three-chip cameras provided up to 800 lines of horizontal resolution compared with 640 lines for a one-chip camera. Interestingly, the clinical impact of this superior resolution is unclear. In a 1995 study, surgeons and nurses who were blinded to either a one-chip or a three-chip system actually preferred the one-chip system. The authors concluded that the enhanced resolution offered by three-chip imaging may not have been appreciable to the human eye. However, subsequent improvements in color detection and light sensitivity over the last 15 years have made three-chip systems the standard in many operating rooms. Modern high-definition three-chip systems can offer more than 1,000 lines of resolution.

Digital laparoscopes are also available. These devices combine the laparoscope and camera into one unit. Rather than using the traditional rod-lens system, they contain an image sensor at the distal end of the laparoscope that transmits images. One advantage of digital laparoscopes is that flexible-tipped scopes can be used to provide additional visibility compared with traditional straight or angled scopes, which are rigid cylinders. Several types of light sources are used during minimally invasive procedures today. Halogen (150 watt), metal halide (50 to 270 watt), xenon (300 watt), and, more recently, light-emitting diodes (LEDs) are all high-intensity light sources capable of producing quality images on a video monitor. One of their main differences is their life span. Halogen and metal halide light sources typically last several hundred hours, whereas xenon bulbs may last up to 500 hours.

Despite their classic label as “cold light sources,” each of these light sources generates a substantial amount of heat. One study of three different xenon light sources found that temperatures near the outlet of the light source exceeded 1,000°F, whereas those near the tip of the fiberoptic cable approached 500°F. Temperatures at the tip of the laparoscope ranged from 140 to 212°F. Evidence of small bowel injury occurred after only 5 seconds of direct contact between the laparoscope and the bowel. In another study, charring of the surgical drapes occurred after 3 to 6 seconds of contact between the tip of the light cable and the surgical drapes. The surgeon must be cognizant of the risk of thermal burns from either the lighting equipment or the laparoscope.

LED light sources are a fairly recent addition to the laparoscopic armamentarium and are purported to have numerous advantages. They are more efficient than other light bulbs (they release more light per watt) and emit less heat than standard light sources. Additionally, their life spans are anywhere from 10 to 100 times longer than standard light sources. However, they are more costly than traditional light sources (e.g., xenon).
SIGNAL PROCESSING UNIT (CAMERA CONTROL UNIT)

Once the camera has processed the images from the surgical field, the images are transmitted to a signal processing unit. The purpose of the signal processing unit is to transmit the signal from the camera to a variety of end devices, including printers, recording devices, and, most importantly, the video monitor. Several analog output signal formats are commonly used by signal processing units, including composite, Y/C (super video), and RGB (red/green/blue) signals [see Figure 5]. Composite signals, which use a single pin connection, are typically lower quality than Y/C or RGB signals. RGB signals, which use three wires for color and one wire for synchronization, often offer the best image.9

Digital video interface (DVI) and serial digital interface (SDI) signals are the two most commonly used digital signal outputs. DVI signals are essentially a digital version of an RGB signal. One limitation of DVI is that the cable length cannot be longer than 15 feet because of signal degradation.9 On the other hand, SDI cable lengths can be much longer without causing significant signal degradation.

VIDEO MONITOR

Most traditional video monitors used in the operating room will accept input from three types of analog signals: composite, Y/C, and RGB. Older laparoscopic camera systems typically output either composite or super video signals, whereas many current-generation systems also generate RGB output, which often provides higher-resolution images. However, even with the use of RGB signals, the resolution provided by traditional cathode ray tube monitors is somewhat limited (typically 600 lines or less).10 For enhanced resolution, including high-definition formats, digital monitors that accept DVI and SDI digital signals may be used with high-definition video cameras. These flat-panel digital monitors, which are also capable of accepting analog signals, are often ceiling-mounted displays that are capable of providing more than 1,000 lines of resolution (nearly twice the resolution of a typical television image).10

INSUFFLATOR AND GAS SUPPLY

The creation of pneumoperitoneum is one of the essential steps of laparoscopic surgery because it distends the abdominal wall and significantly enhances visualization of intra-abdominal structures. One of the first physicians to insufflate the abdomen was Dr. George Kelling, a German surgeon who is also credited with performing the first laparoscopic procedure in 1901.1 Interestingly, improved intra-abdominal visualization was not one of his primary goals. Rather, he wanted to arrest gastrointestinal bleeding by injecting large amounts of air into the peritoneal cavity to create extremely high intra-abdominal pressures (50 to 100 mm Hg).11 Shortly thereafter, a Swedish internist named Hans Christian Jacobaeus used a trocar with a bulb and a one-way valve to manually insufflate air into the abdomen. He referred to this new procedure as “laparoscopy.” His first 17 human cases were diagnostic procedures in patients with ascites. Unlike Kelling, Jacobaeus realized that laparoscopy had tremendous potential and published several articles in the European literature.11 Manual insufflation would remain the standard technique for the creation of pneumoperitoneum for another five decades.

In the 1960s, Dr. Kurt Semm, a German gynecologist who performed the first laparoscopic appendectomy in 1983, developed an automatic insufflator that monitored the pressure of pneumoperitoneum.12 This device not only provided surgeons with a reliable estimate of intra-abdominal pressure; it also allowed surgeons to operate with both hands because intermittent manual injection of air was no longer needed for maintenance of pneumoperitoneum.

One of the main areas of uncertainty during this time period was the optimal gas for pneumoperitoneum. The laparoscopic pioneers used room air primarily because it was readily available and cheap. Studies published as recently as 1980 suggested that the creation of pneumoperitoneum with room air was safe and cost-effective.13 However, its combustibility, poor solubility in the blood, and concern for venous air embolism have nearly eliminated the use of room air insufflation in today’s operating rooms.14 Likewise, insufflation with nitrous oxide was popular throughout the 1970s. Yet reports of intra-abdominal explosions have subsequently limited its popularity.15 Carbon dioxide is currently the most commonly used gas during insufflation. It is odorless, nonflammable, and highly soluble in blood, which reduces the likelihood of air embolisms. Although clinically significant hypercarbia and acidemia can occur, particularly in patients with cardiopulmonary comorbidities, most patients tolerate carbon dioxide pneumoperitoneum without any adverse effects.

To establish standard pressure pneumoperitoneum (typically 12 to 16 mm Hg), the insufflator must first be connected to the carbon dioxide cylinder. Tubing is then used to connect the insufflator to either a Veress needle or a laparoscopic port within the peritoneal cavity. Next, gas flow from the insufflator is initiated. Although the amount of gas needed to create adequate pneumoperitoneum varies according to patient size, abdominal wall compliance, and degree of gas leakage, several liters of carbon dioxide are usually adequate. To maintain pneumoperitoneum throughout a case, substantially more gas is needed. One report estimated that an average laparoscopic colectomy requires approximately 110 to 180 L of carbon dioxide.16

Most conventional insufflators use an intermittent pressure monitoring system. This allows the insufflator to decrease the gas flow if the intra-abdominal pressure exceeds a preset value. Conversely, it can increase gas flow to account for a
loss of gas either externally or through peritoneal absorption. Rather than cycling gas continuously, insufflators alternate between injecting gas every 2 to 3 seconds and monitoring the intra-abdominal pressure. One study that examined different types of low- and high-flow insufflators (9, 10, 16, and 30 L) found that those with high flow rates (e.g., 30 L) compensated for gas leakage better but produced higher intra-abdominal pressure peaks. Flow resistance and the rate of gas leakage, rather than flow capacity, were seen as the critical determinants of intra-abdominal pressure maintenance.17

The possibility of peritoneal contamination or disease transmission through the flow of intraperitoneal fluid or particulate matter from the patient to the insufflator (and then to the next patient) has been a concern since the early days of laparoscopy. To address this concern, insufflator filters composed of mesh with 0.1- to 0.3-micron pores have been developed. The literature surrounding the effectiveness of these filters is limited. One study published in 1989 reported that rust, dust, and metal filings could be detected on insufflator filters.18 Another found that the use of a 0.3-micron filter reduced microbial colonization of gas cylinders and insufflators.19 However, a subsequent examination that used microscopy, mass spectrometry, and bacterial analysis showed no evidence of microbial or particulate matter trapping by the filters.20 To our knowledge, there have been no published reports of disease transmission related to insufflation. However, given the theoretical possibilities of contamination and disease transmission, insufflation filters are commonly used today.

GASLESS LAPAROSCOPY

Despite the near-universal use of insufflators during laparoscopy, a relatively small number of “gasless” laparoscopic cases have been performed since the early 1990s.21 Rather than using an insufflator to create pneumoperitoneum, “gasless” laparoscopy involves the use of an abdominal wall retraction system to enhance intra-abdominal visualization. The purported benefits of this technique are the absence of the physiologic risks of pneumoperitoneum, decreased cost, and increased intraoperative flexibility for the surgeon. For example, surgeons can use unlimited suction and can operate with conventional surgical instruments, such as right-angled clamps.22 However, the use of gasless laparoscopy remains uncommon today. This is likely attributable to the favorable safety profile of carbon dioxide pneumoperitoneum and limited visualization if pneumoperitoneum is not established. Additionally, most surgeons are not familiar with the technical aspects of “gasless” laparoscopy, including the retraction setup. There may be a role for gasless laparoscopy in the future, particularly for patients at high cardiopulmonary risk who may have difficulty tolerating carbon dioxide pneumoperitoneum.21

Laparoscopic Trocars

There are a wide variety of commercially available laparoscopic trocars, with their own specific characteristics. In general, trocars consist of two different components. The head of the trocar includes a diaphragm to prevent leakage of gas around the inserted instruments and a port for insufflation. The shaft is the portion that is inserted through the abdominal wall into the abdominal cavity and can vary in both length and diameter to accommodate patients with larger abdominal walls and instruments of various sizes. These components can be purchased either separately or as one unit and can be either disposable or reusable depending on the type of trocar used.

Additionally, all trocars come with an obturator, which inserts through both the head and the shaft to facilitate introduction of the trocar through the abdominal wall. The end of the obturator can be bladed (“cutting trocar”) or nonbladed (“noncutting trocar”). Cutting trocars sharply cut the abdominal wall on entry. They often come with a shield that retracts under force but reengages once that force has dissipated, such as on entry into the abdominal cavity. These trocars tend to create larger defects in the abdominal wall, which can lead to eventual hernia formation. Noncutting trocars also come in a variety of forms, all of which either pass through the abdominal wall bluntly or in a radially expanding fashion and thus leave a smaller fascial defect than cutting trocars of a similar diameter. In one prospective, multicenter, randomized study of noncutting versus cutting trocars in 244 elective laparoscopic procedures, the use of noncutting trocars was associated with significantly lower rates of intraoperative cannula site bleeding and postoperative wound complications. There were no significant differences in operative times or pain scores between the two groups. Although the authors routinely closed 10 mm or greater fascial defects when cutting trocars were used, similarly sized defects in the noncutting group were left open. There were no occurrences of late port-site hernias despite these defects remaining open. Thus, the authors felt that these ports did not require routine closure and likely have a lower rate of port-site hernia formation.23

Initial trocar placement and establishment of pneumoperitoneum typically occur via either an open technique or a direct puncture of the abdominal cavity. Each technique is associated with its own set of potential complications, and no single technique is absolutely safe. In the open technique, which was first described by Hasson in 1974,24 a small incision is made at the level of the umbilicus and the skin and soft tissue are sharply or bluntly dissected down to the linea alba. The linea alba is then opened sharply, and the peritoneum is opened under direct vision. Once inside the abdominal cavity, stay sutures are placed on the fascia and a blunt-tipped Hasson trocar is inserted into the defect and held in place by the fascial sutures. Pneumoperitoneum is then established through this trocar. Once the procedure is complete, the fascial defect can be closed using the previously placed sutures or with any additional sutures that are necessary to ensure proper closure.

The direct puncture technique employs the use of either a Veress needle to establish pneumoperitoneum or direct trocar placement into the abdominal cavity prior to the establishment of pneumoperitoneum. The Veress needle is a spring-loaded, hollow-bore, self-protecting needle created for accessing the abdominal cavity. When the needle meets resistance, the safety retracts, thus exposing the sharp point of the needle and allowing it to pass through the layers of the abdominal wall. As the needle enters the peritoneum, the resistance is lost and the safety reengages to protect the
intra-abdominal contents. The needle position can then be tested via a saline drop test or connected to the insufflation tubing to assess the opening pressure and initial flow. Once pneumoperitoneum is obtained and additional ports have been placed, the site of Veress entry should always be inspected to ensure that no bowel or vascular injuries have occurred.

Although trocars may be safely inserted into the peritoneal cavity prior to the establishment of pneumoperitoneum, this technique is not employed by many surgeons because of fear of injury to intra-abdominal contents. Within the past decade, several manufacturers have developed “optical trocars.” These optical trocars, which may be bladed or nonbladed, have been designed with a clear tip to allow visualization of the layers of the abdominal wall while the trocar is being inserted. Manufacturers of these trocars contend that this added level of visibility during trocar insertion enhances the safety of trocar insertion. However, randomized data supporting this assertion are currently lacking. As each access technique has its own set of complications, it is helpful for the surgeon to be familiar with a variety of techniques so that he or she may employ the technique most suitable for the specific situation.

Laparoscopic Instruments

In general, laparoscopic instruments are designed such that their end effectors will mimic the instrumentation of open surgery. These end effectors are typically mounted on a 30 cm shaft that measures 5 mm in diameter [see Figure 6]. Some instruments can come on 45 cm shafts designed for use in bariatric surgery, and some are available only in shafts with 10 mm diameters, thus necessitating a larger trocar. Nearly all instruments are designed such that the shaft will rotate through 360° of rotation while keeping the handles stationary. The handles come in a variety of sizes and grip styles and should be trialed to find a set that provides both comfort and proper ergonomics. Additionally, a variety of ratcheting and locking mechanisms are available, and surgeons should find the set that best suits their specific needs.

There are a variety of instruments designed for laparoscopic dissection. The Maryland dissector [see Figure 7] has an end effector that is curved similar to a curved snap and is one of the more popular dissecting instruments. It can be used to dissect ductal and vascular structures but should not be used to grasp delicate tissue as crush injuries may ensue. Additionally, the pointed tips can inadvertently injure intra-abdominal structures, so care must be taken to keep the instrument in view as much as possible. Laparoscopic right-angled dissectors are also available for dissection of vascular and ductal structures. Blunt graspers come in a wide variety of shapes and sizes. Some, such as the laparoscopic Babcock grasper [see Figure 8], are designed to be atraumatic and are used for the manipulation of most intra-abdominal structures. Others are more traumatic, such as the laparoscopic Allis grasper, but allow for a stronger purchase on tougher or thicker tissue, such as the gallbladder. Laparoscopic biopsy forceps, needle drivers, scissors, staplers, clip appliers, probes, sponges, and retractors are also all commercially available in a wide variety of forms. It is worthwhile to become familiar with several different instruments as instrumentation will likely vary between institutions.

Laparoscopic Energy Sources

The energy sources used to obtain hemostasis in laparoscopic surgery are similar to those employed in open surgery. Monopolar, bipolar, and ultrasonic energy sources all come in forms suitable for use in laparoscopic cases. Bipolar and ultrasonic energy sources have significantly decreased operative times for more complex laparoscopic cases as larger vessels can now be controlled with these instruments rather than with staplers, Endo-Loops (Ethicon Endosurgery, Cincinnati, OH), or laparoscopic suturing. Although the physics principles that govern these energy sources are the same in open and laparoscopic surgery, there are several aspects of laparoscopic surgery that have unique implications and merit further discussion.

When using monopolar electrocautery, an alternating current of 50,000 Hz is created in a generator and is passed onto an active electrode, through the patient, and eventually back to the generator via a return electrode. Significant heat will be generated in the tissue adjacent to the active electrode. Thus, the active electrode should have a very small surface area (such as a hook or the tip of a Maryland dissector) to allow the electricity to be focused on a small area. Conversely, the return electrode, which is the grounding pad normally placed on the patient’s lower extremity, should have a large

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**Figure 6** A typical laparoscopic instrument. Courtesy of KARL STORZ Endoscopy-America, Inc.

**Figure 7** A laparoscopic Maryland dissector. Courtesy of KARL STORZ Endoscopy-America, Inc.

**Figure 8** A laparoscopic Babcock grasper. Courtesy of KARL STORZ Endoscopy-America, Inc.
surface area so that minimal heat is generated at the site and no inadvertent thermal injuries occur. In open surgery, it is standard practice to grasp a bleeding vessel with a pair of forceps and then touch the forceps with the tip of the electrocautery to obtain hemostasis. This phenomenon of electrical transference from the active electrode to another conducting instrument is referred to as direct coupling. In laparoscopic surgery, direct coupling can occur purposefully but can also occur inadvertently when an instrument is placed in close proximity to another instrument that is electrically active. The current may transfer to the nonactive instrument or any other metal substance, including the laparoscope itself. These instruments may then discharge their electrical current to surrounding structures, resulting in accidental thermal injuries. Thus, whenever monopolar electrocautery is being employed, it is important to ensure that there is a safe distance between the active instrument and all other metallic objects. Additionally, if there are disruptions in the insulation of the active instrument, electricity may be discharged to surrounding structures through these cracks, again leading to inadvertent thermal injury. The Insulscan (Medline Industries, Mundelein, IL) is a device designed to look for insulation disruptions in laparoscopic instruments. Although it does add time to the setup of the case as instruments must be passed through the unit individually, it may aid in preventing thermal injuries, which could require significantly more time to repair laparoscopically.

In addition to direct coupling, capacitative coupling can occur in laparoscopic cases where metal trocars are being used. Capacitative coupling occurs when two conductors are separated by a nonconductor. If the active electrode of a laparoscopic instrument is inserted through a metal trocar, the insulation surrounding the instrument acts as a nonconductor and can function as a capacitor. The capacitor generates a electrostatic field between the active electrode and the metal trocar. As electricity passes through the active electrode, the electrostatic field can transfer energy to the metal trocar, which will then discharge the energy in the form of heat, leading to burns of the skin and abdominal wall. The use of nonconductive plastic trocars will avoid this phenomenon.

Two bipolar energy sources are now commercially available for laparoscopic use. These devices, the LigaSure (ValleyLab, Boulder, CO) and the EnSeal (Ethicon Endosurgery), both pass low-voltage, high-frequency current between two active electrodes at the tips of the instruments. According to the manufacturers, the tissue between these two electrodes is effectively coagulated and sealed for vessels as large as 7 mm in diameter. Both instruments include a blade to divide the tissue once it has been coagulated. The instruments themselves generate very little heat, so there is minimal lateral spread of thermal injury.

Ultrasonic shears use mechanical energy rather than electrical current to seal vessels and divide tissue. The most commonly used device is the Harmonic Ace (Ethicon Endosurgery), which requires a generator that produces an electrical signal, which in turn is converted into a mechanical vibration at a frequency of 55,500 Hz. This mechanical vibration is amplified as it travels down the shaft of the instrument and into the active blade of the device, which generates heat to coagulate vessels and divides tissue without requiring a separate knife for cutting. The active blade of the instrument will remain hot for some time after use, and direct contact with surrounding tissues should be avoided.

Diamantis and colleagues compared the various sources of energy by using monopolar electrocautery, bipolar electrocautery, the LigaSure, and the UltraCision (Ethicon Endosurgery, ultrasonic shears) to ligate the short gastric vessels in rabbits. They found that monopolar and bipolar electrocautery frequently failed to achieve adequate hemostasis and resulted in significant thermal spread, leading to perforation of the adjacent gastric wall. The LigaSure and UltraCision devices successfully coagulated 100% of the vessels for which they were used. Both modalities had minimal side thermal injury, but the LigaSure had slightly less histologic evidence of inflammation and thermal injury than the UltraCision on postoperative days 7 and 14. These two modalities were clearly safer and more effective than either monopolar or bipolar electrocautery.

Troubleshooting Laparoscopic Equipment

Although few studies have measured the frequency, etiology, cost, or clinical impact of laparoscopic equipment misuse and malfunction, equipment problems during laparoscopic surgery are quite common. One study that used video recording during 30 laparoscopic cholecystectomies found that 90% of cases were affected by a problem with the basic technical equipment. Fifty-five percent of these incidents were the result of equipment malfunction related to an equipment defect, improper device setting, or faulty connection. Another study that examined 62 laparoscopic cases concluded that at least one equipment failure occurred in 42% of cases. Human error contributed to nearly half of these failures.

Given the multitude of potential sources for equipment failure, a systematic approach to equipment troubleshooting is key. In this section, we discuss some of the most common equipment problems that the surgeon may experience in the operating room and offer a methodical approach to address these issues [see Table 1].

Images on the Video Monitor Are Too Dark

The light source, light cable, laparoscope, camera, and video monitor must all function optimally to provide video images with adequate lighting. If the lighting is poor, several steps can be taken to address the issue. Blood will absorb a significant portion of the light, making the overall image appear darker; thus, blood should be cleared from the field if possible. Next, connections between each of the components should be checked to ensure that each component is properly attached to the system. In the aforementioned observational study of laparoscopic cholecystectomies, “faulty” equipment connections were present in nearly one third of cases. If the connections are intact, the current settings for both the video monitor and the light source should be checked. If the settings on the video monitor have been altered (e.g., brightness), they should be adjusted back to the default settings. The light intensity from the light source can also be increased. While making this adjustment, the surgeon should note the number of hours that the current light bulb has been in use. Many light sources display this number on the front of the machine. If the number of hours exceeds the accepted life
### Table 1 Laparoscopic Equipment Troubleshooting

<table>
<thead>
<tr>
<th>Main Problem</th>
<th>Equipment Issue</th>
<th>Relevant Equipment</th>
<th>Troubleshooting Maneuver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Images on the video monitor are too dark</td>
<td>A connection between two pieces of equipment is faulty</td>
<td>Light source, light cable, laparoscope, camera, video monitor</td>
<td>Confirm that each piece of equipment is properly connected to the system</td>
</tr>
<tr>
<td></td>
<td>Improper setting (e.g., brightness, gain)</td>
<td>Video monitor, camera, light source</td>
<td>Adjust back to default settings</td>
</tr>
<tr>
<td></td>
<td>Poor light intensity from the light source</td>
<td>Light source</td>
<td>Ensure that bulb is within accepted life span; increase intensity of light source or replace bulb</td>
</tr>
<tr>
<td></td>
<td>Light intensity from the source is adequate, but light from the laparoscope tip is poor</td>
<td>Light cable, laparoscope</td>
<td>If there are numerous breaks in the fiberoptic bundles of the light cable, replace the cable; if not or if the fiberoptic bundles cannot be inspected, replace either the cable or the scope and assess for improvement in light intensity</td>
</tr>
<tr>
<td>Images on the video monitor are foggy or blurry</td>
<td>Laparoscope is not focused</td>
<td>Laparoscope, camera</td>
<td>Focus the laparoscope</td>
</tr>
<tr>
<td></td>
<td>Condensation is present on the tip of the laparoscope</td>
<td>Gas warming/humidifying devices, laparoscope, warming devices, antifogging solutions</td>
<td>Use of any of these warming or antifogging techniques is reasonable (although data are lacking)</td>
</tr>
<tr>
<td></td>
<td>Liquid or particulate matter is present on the tip of the laparoscope</td>
<td>Laparoscope</td>
<td>Wipe the tip of the laparoscope off (ideally using gauze rather than the viscera)</td>
</tr>
<tr>
<td></td>
<td>Smoke is obscuring the surgical field</td>
<td>—</td>
<td>Open one of the ports to let smoke escape</td>
</tr>
<tr>
<td></td>
<td>Condensation has accumulated within the laparoscope or coupler</td>
<td>Laparoscope, coupler</td>
<td>Detach laparoscope from camera (and coupler if possible) and wipe lens; if condensation is within the scope lens system, the scope should be replaced</td>
</tr>
<tr>
<td>Images on the video monitor are abnormally colored</td>
<td>Improper setting (e.g., color, brightness)</td>
<td>Video monitor</td>
<td>Adjust back to default settings</td>
</tr>
<tr>
<td></td>
<td>White balancing has not been performed correctly</td>
<td>Laparoscope, camera, camera control unit</td>
<td>White balance the laparoscope</td>
</tr>
<tr>
<td></td>
<td>Video monitor has become magnetized</td>
<td>Video monitor</td>
<td>“Degauss” the video monitor (applies to cathode ray tube systems only)</td>
</tr>
<tr>
<td>There is no image on the video monitor</td>
<td>Connection between two pieces of equipment is faulty, or a piece of equipment is not turned on</td>
<td>Light source, light cable, laparoscope, video monitor</td>
<td>Confirm that each piece of equipment is properly connected to the system and is turned on</td>
</tr>
<tr>
<td></td>
<td>Analog or digital cables are not correctly plugged in</td>
<td>Video signal processor, analog or digital cable, video monitor</td>
<td>Ensure that the cables are plugged into the appropriate “out” connector of the signal processing unit and the “in” connector of the video monitor</td>
</tr>
<tr>
<td></td>
<td>Light bulb has burned out</td>
<td>Light source/bulb</td>
<td>Replace the light bulb</td>
</tr>
<tr>
<td>Abdominal insufflation is inadequate</td>
<td>No gas in the cylinder</td>
<td>Gas cylinder</td>
<td>Replace the cylinder</td>
</tr>
<tr>
<td></td>
<td>Cylinder valve is closed</td>
<td>Gas cylinder</td>
<td>Open the cylinder valve</td>
</tr>
<tr>
<td></td>
<td>Veress needle or trocar is not within the peritoneal cavity</td>
<td>Veress needle or trocar</td>
<td>Place Veress needle or trocar into the peritoneal cavity</td>
</tr>
<tr>
<td></td>
<td>Something is compressing the insufflation tubing</td>
<td>Insufflation tubing</td>
<td>Remove source of external compression</td>
</tr>
<tr>
<td></td>
<td>Stopcock on the trocar is set to block airflow</td>
<td>Trocar</td>
<td>Adjust stopcock so that gas flow may proceed</td>
</tr>
<tr>
<td></td>
<td>Flow rate or maximum insufflation pressure settings are incorrect</td>
<td>Insufflator</td>
<td>Adjust flow rate or maximum insufflation pressure appropriately</td>
</tr>
<tr>
<td></td>
<td>Incompatibility between insufflator and filter</td>
<td>Insufflator, filter</td>
<td>Ensure that the filter is compatible with insufflator (relevant for high-flow insufflators)</td>
</tr>
<tr>
<td></td>
<td>There is an air leak somewhere in the system</td>
<td>Trocars</td>
<td>Ensure that gaps between trocars and fascia are minimized; close valves on ports so that intraperitoneal gas does not escape</td>
</tr>
<tr>
<td></td>
<td>Inadequate abdominal wall relaxation</td>
<td>None</td>
<td>Additional sedation or paralytic</td>
</tr>
</tbody>
</table>
span for that bulb, the bulb should be replaced. Room light sources should also be dimmed if their brightness is impairing the quality of the video monitor images.

If troubleshooting maneuvers targeted toward the connections, settings, and light source do not resolve the issue, the light cord and laparoscope should be evaluated. Breaks in the fiberoptic bundles can cause degradation in the quality of the images. Some lighting cables have a transparent covering that allows these breaks to be seen. These will appear as points of light along the length of the cable. If there are numerous breaks in the bundles, the cable should be replaced. If there are no visible breaks, the laparoscope should be replaced and the effect on the video image should be noted. Some surgeons also recommend setting the light source and camera shutters to “manual” in poor lighting scenarios. An improvement in the image quality following either of these maneuvers reflects a problem with the shutter in either the light source or the camera, respectively.

The brightness of the light that is emitted from the laparoscope tip can be deceiving. The light may appear to be bright enough when simply looking at the tip, but this does not ensure that the intensity is adequate. Additionally, although the surgeon may be tempted to increase either the gain on the camera control unit or the brightness on the monitor, these maneuvers should be performed with caution. They may increase the image brightness on the monitor, but the need to perform these steps suggests that there is a defect somewhere in the system. Increasing either the gain or brightness can also reduce the image quality.

IMAGES ON THE VIDEO MONITOR ARE FOGGY OR BLURRY

Foggy or blurry images on the video monitor are a common cause of impaired visualization during laparoscopic surgery. One reason for a blurry image is that the laparoscope simply is not focused. To prevent this problem, surgeons can focus the laparoscope before it is inserted by pointing the laparoscope at an object on the surgical field, such as a piece of gauze or a suture packet. Alternatively, the scope can be focused after insertion into the abdomen (e.g., using the liver as a focal point).

Perhaps the most common cause of blurry imaging is the presence of liquid, particulate material (e.g., adipose tissue), or smoke on either the laparoscope lens or in the surgical field. Liquids such as irrigation fluid, ascites, and blood can all obscure the surgical field. Condensation on the laparoscope lens is probably the most common cause of lens fogging because of liquids. This condensation forms on the lens because the temperature of the lens (i.e., the laparoscope) is usually lower than body temperature during the establishment and maintenance of pneumoperitoneum. Given that the intra-abdominal humidity typically ranges from 85 to 95% during laparoscopy, the presence of lower temperatures near the front lens causes the dew point to be reached, which results in the production of condensation on the lens. At an intra-abdominal humidity of 85%, the scope temperature must exceed 93°F to prevent lens condensation. Some recommend maintaining a scope temperature of at least 98.6°F.

Given these observations and recommendations, there has been a substantial amount of interest in the use of warmed (typically 98.6 to 113°F) and humidified (50 to 95%) gas. If gas flows directly from the insufflator to the patient (without warming or humidification), it will enter the peritoneal cavity at approximately 70°F and 0% humidity. On the other hand, if warmed, humidified gas is sent from the insufflator (or gas is sent from the insufflator through a warming, humidification system and then to the patient), it can enter the peritoneal cavity at body temperature. In addition to the potential benefit of improved visualization attributable to condensation prevention, there is some evidence that warm, humidified gas can also reduce hypothermia and pain. However, several randomized controlled trials have failed to show either a clinical benefit or a decrease in lens fogging with the use of warmed, humidified air. Although the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) has not issued formal recommendations regarding this issue, the European Association for Endoscopic Surgery guidelines for pneumoperitoneum state that the clinical effects of warmed, humidified gas are “minor” and the data regarding its influence on pain are “contradictory.”

Additional maneuvers to reduce laparoscopic lens fogging include laparoscope warming and the use of antifogging solutions. Numerous warming techniques have been described, including placing the scope into a container of warm liquid, using warm sterile towels, or even modifying the scope to include a built-in warming mechanism. Antifogging solutions, such as the Fog Reduction and Elimination Device (FRED; Covidien Autosuture, Mansfield, MA) and Resoclear (Resorba Wundversorgung; Nuremberg, Germany), have also been developed and used extensively. Although these maneuvers are anecdotally effective and have strong face validity, definitive data regarding these laparoscopic warming techniques and antifogging solutions are lacking.

Wiping the laparoscope tip on the viscera—often the liver or small bowel—is another maneuver that is commonly used and is often effective. However, this should be performed cautiously as laparoscope tip temperatures can exceed 200°F. One study found microscopic evidence of thermal injury to the bowel after only 5 seconds of direct contact between the laparoscope and viscera.

Moisture can also accumulate at various points within the system, including between the laparoscope lenses, on the eyepiece of the laparoscope, and on the coupler. Condensation on the eyepiece and coupler can be addressed by detaching the camera (and coupler if possible) and wiping the lenses. Condensation between the laparoscope lenses suggests a malfunction in the seal and will most likely require laparoscope replacement and repair.

IMAGES ON THE VIDEO MONITOR ARE ABNORMALLY COLORED

When presented with this scenario, the surgeon should first ensure that the monitor settings are correct. The previous surgical team may have intentionally changed the monitor settings during a previous case, or maintenance staff could have inadvertently changed the settings between cases. The surgeon should also ensure that the camera has been “white balanced” appropriately. White balancing is typically performed by placing a white object, such as gauze, in front of the laparoscope-camera unit. After focusing on this white object, a white balance button can be pushed on either the camera head or the camera control unit. This maneuver...
allows the image to set the video output voltage levels so that a white image is created when the scope is targeted on a white object.17 If white balancing is omitted or performed incorrectly, the images on the video monitor may appear abnormally colored.

Traditional video monitors that use a cathode ray tube can also become magnetized over time, creating distorted colors and images. This often appears as a purplish discoloration around the image.19 Although most monitors will automatically remove the magnetic forces when turned on (referred to as “degaussing”), manual degaussing may need to be performed as well. Many video monitors have manual degauss buttons for this reason.

TROUBLESHOOTING — 9

There is No Image on the Video Monitor

This scenario usually occurs when a component in the system is improperly connected or not powered on. The surgeon should first ensure that the light source, signal processing unit (camera control unit), and video monitor are all turned on and properly connected to each other. The bulb in the light source should also be checked to ensure functionality. Next, the connections between the signal processing unit and the video monitor should be inspected to ensure that the analog or digital cables are connected to the appropriate “out” or “in” connectors. These cables are typically plugged into the “out” connector of the signal processing unit and the “in” connector of the video monitor. Similarly, if a second video monitor is used, the monitor-to-monitor cable should be plugged into the “out” connector of the first monitor and the “in” connector of the second monitor. Finally, the analog or digital signal connector that the video cable is plugged into should match the type of video signal that is selected on the monitor interface. These recommendations are summarized succinctly in the SAGES Laparoscopy Troubleshooting Guide.38

Abdominal Insufflation Is Inadequate

Before insufflation is initiated, the surgical team should ensure that the amount of gas in the cylinder is adequate and the cylinder valve is open. The surgeon should verify that the Veress needle or the laparoscopic trocar is within the peritoneal cavity rather than the preperitoneal space, retroperitoneum, omentum, or another intra-abdominal structure. Insufflation into a location other than the peritoneal cavity usually results in low or absent flows and high pressures. Once intraperitoneal placement of the access device has been achieved, insufflation can proceed at a flow rate selected by the surgeon. If the gas flow remains poor, the team should ensure that the insufflator, the insufflation tubing, and the Veress needle or trocar are connected appropriately. Sources of external compression on the tubing should be addressed, and if the tubing is connected to a trocar, the stopcock on the trocar should be adjusted to allow for insufflation. The minimal flow rate and maximal intra-abdominal pressure should also be checked.

Incompatibility between the insufflator and the filter or blockage of the filter can also cause a disruption in gas flow. In this scenario, the insufflator senses a high intra-abdominal pressure and consequently reduces flow, which leads to inadequate pneumoperitoneum. This is mainly an issue for high-flow insufflators (30 to 40 L per minute) because specialized filters may be needed to accommodate the high flow rates. Although many companies have addressed this issue by manufacturing compatible tubing and filters, the surgical team must be mindful of this problem, particularly in settings where products from multiple manufacturers are used.

Once the desired intra-abdominal pressure has been reached, the surgeon may have difficulty maintaining an adequate pneumoperitoneum. In addition to performing each of the steps outlined above (i.e., checking the gas cylinder, sources of tubing compression, ensuring that stopcocks on additional trocars are closed), the surgeon should ensure that there are no leaks around the trocar sites or through the trocars themselves. If leaks are detected around the trocar sites, gaps between the trocars and the surrounding fascia and abdominal wall tissue should be minimized or occluded. Additional fascial sutures may be needed. If air is leaking through a trocar, the trocar cap should be checked to ensure that it is properly secured to the shaft. If leakage persists, an instrument should be inserted and removed to realign the diaphragm with the trocar. If these measures fail to resolve the problem, the trocar may need to be replaced. Adequate abdominal muscle relaxation should also be confirmed. If the surgeon suspects inadequate relaxation (the patient is moving or the abdominal wall appears to be “tight”), a discussion with the anesthesia team regarding additional sedation or paralysis is appropriate.

Conclusion

As laparoscopic procedures continue to increase in frequency and complexity, it will become progressively more important to be mindful of these simple troubleshooting maneuvers to keep these procedures flowing smoothly and safely. Although surgeons must have intricate knowledge of their laparoscopic instrumentation, it is equally important for the other members of the surgical team to be familiar with both the equipment and the myriad of potential problems that can arise during these procedures. When all members of the surgical team can work together to quickly overcome any equipment issues during laparoscopic cases, operating room efficiency will improve and better outcomes can be anticipated.

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References


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