Mechanical Basics of Laparoscopic Surgery

9

Carol E.H. Scott-Conner

Flawless and smooth completion of laparoscopic surgical procedures requires complete understanding of equipment, techniques, and regional anatomy. This chapter details some of the basic principles common to all laparoscopic surgical procedures. It should be read and thoroughly understood as a background to the technical chapters that deal with specific surgical procedures.

Equipment and Supplies

A few minutes of thought and planning may save a lot of time once the operation begins. Ascertain that all needed equipment is present and in working order and that the room is properly set up *before* scrubbing. For most laparoscopic equipment and supplies, there is a choice of manufacturers. Apparently similar devices frequently have subtle points of difference when compared to other brands. Thus, it is crucial for surgeons to be familiar with the particular brands in use in their own hospitals.

A troubleshooting guide, such as the one produced by the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES), facilitates finding and fixing problems with the insufflator, the light source, the video equipment, cautery, suction, and other complex devices. Such a chart may be laminated and affixed to the laparoscopy cart for ready reference. This is particularly important when laparoscopy is performed during the evening or night shift (e.g., for acute appendicitis) with personnel who may not be familiar with the equipment and its setup.

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Room Setup

The patient position and details of the room setup vary depending on the procedure to be performed. Laparoscopic surgery is extremely dependent on optimum patient and equipment position. Whereas during an *open* procedure the surgeon is free to move from side to side and vary his or her stance even from moment to moment to assume the ergonomically best position, the *laparoscopic* surgeon is limited by port placement. Think of the laparoscope as the surgeon's eyes and the two operating ports as the left and right hands. Although it is indeed possible to switch the laparoscope from one port to another, poorly positioned port sites limit visibility and access.

Plan the room setup so the surgeon can stand facing the quadrant containing the anticipated pathology. For example, laparoscopic cholecystectomy is comfortably performed by a surgeon standing to the patient's left, facing a monitor positioned at the patient's right shoulder (Fig. 9.1). Surgery

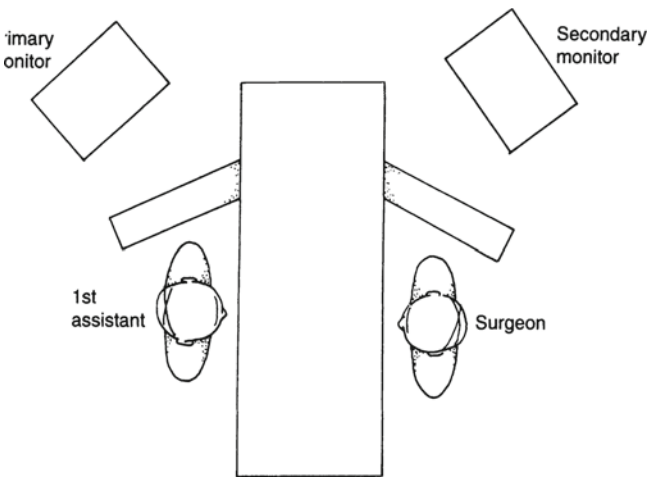

Fig. 9.1 (From Scott-Conner CEH (ed), The SAGES manual: fundamentals of laparoscopy and GI endoscopy. New York: Springer-Verlag, 1999, with permission)

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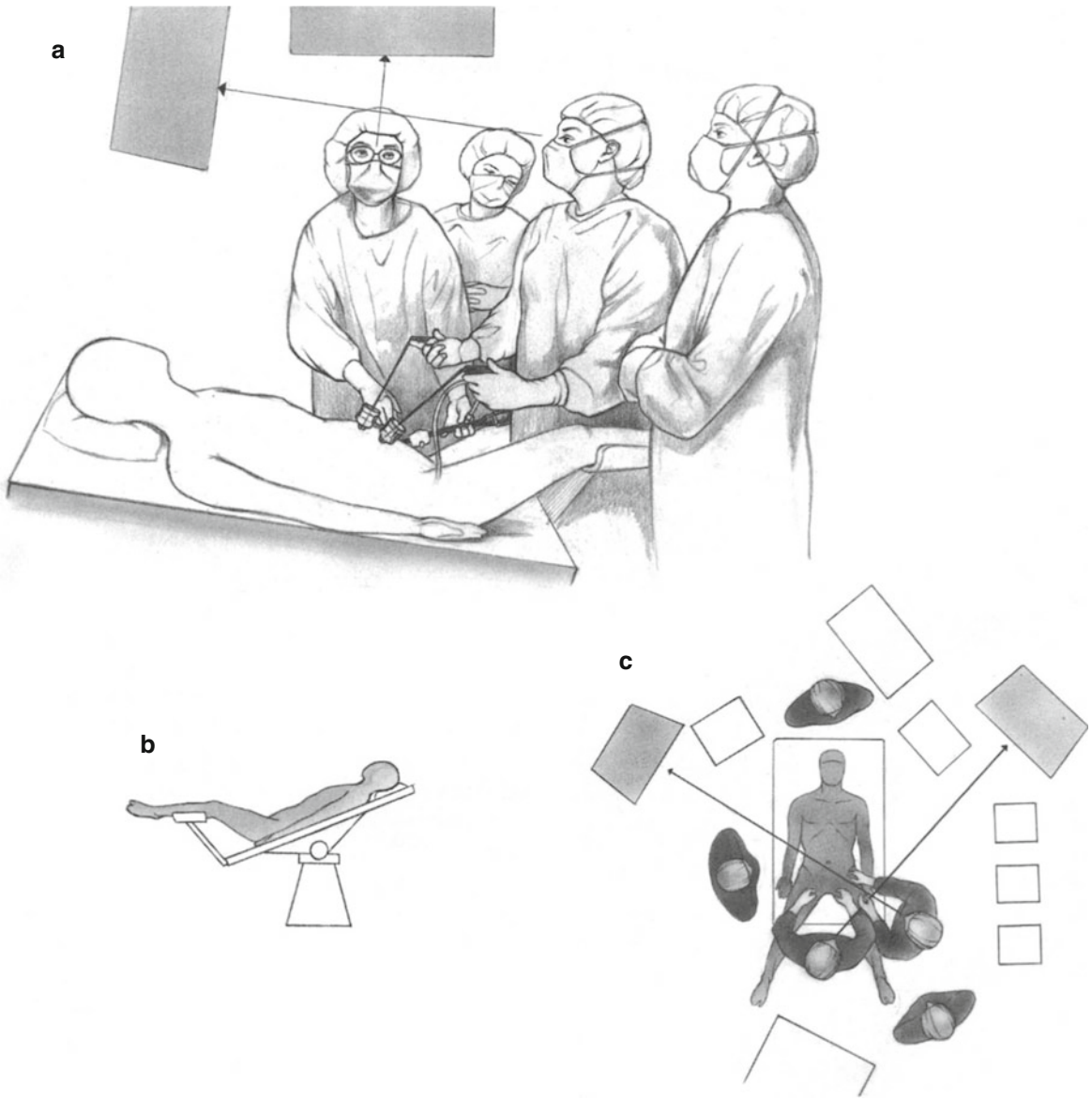

Fig. 9.2

around the esophageal hiatus is best performed with the patient in a modified lithotomy position, the surgeon standing behind the patient's legs, and the monitor at the left shoulder or head of the bed (Fig. 9.2). Even a relatively minor detail such as whether the arms are tucked at the side or placed out on arm boards becomes significant. In the technical chapters dealing with specific laparoscopic procedures, the important points relevant to each operation are explained. For now, suffice it to say that no detail is unimportant.

Choice of Laparoscope: Straight Versus Angled?

A straight (0°) laparoscope is easy to use and may be adequate for basic laparoscopic procedures in which the scope is easily brought to an en face view from a standard umbilical port site. The angled laparoscope allows the surgeon to view a structure from several viewpoints through a single trocar site and thus provides good flexibility. For some laparoscopic procedures, such as laparoscopic choledochotomy, Nissen fundoplication, and inguinal hernia repair, an angled laparoscope is virtually a necessity. Most commonly, laparoscopes with 30° or 45° angles are used.

The commonest error with an angled laparoscope is to point the angle *away* from the area of interest rather than *toward* it. It is easy for the neophyte camera holder to become confused unless a simple principle is kept in mind: Always remember that the angle of the laparoscope points away from the point of entry of the light handle (Fig. 9.3). Instruct the camera handler to hold the laparoscope cradled in the hand with the light cord between the thumb and forefinger. This comfortable and stable grip allows the camera holder easily to angle the scope to one side or the other by pronating or

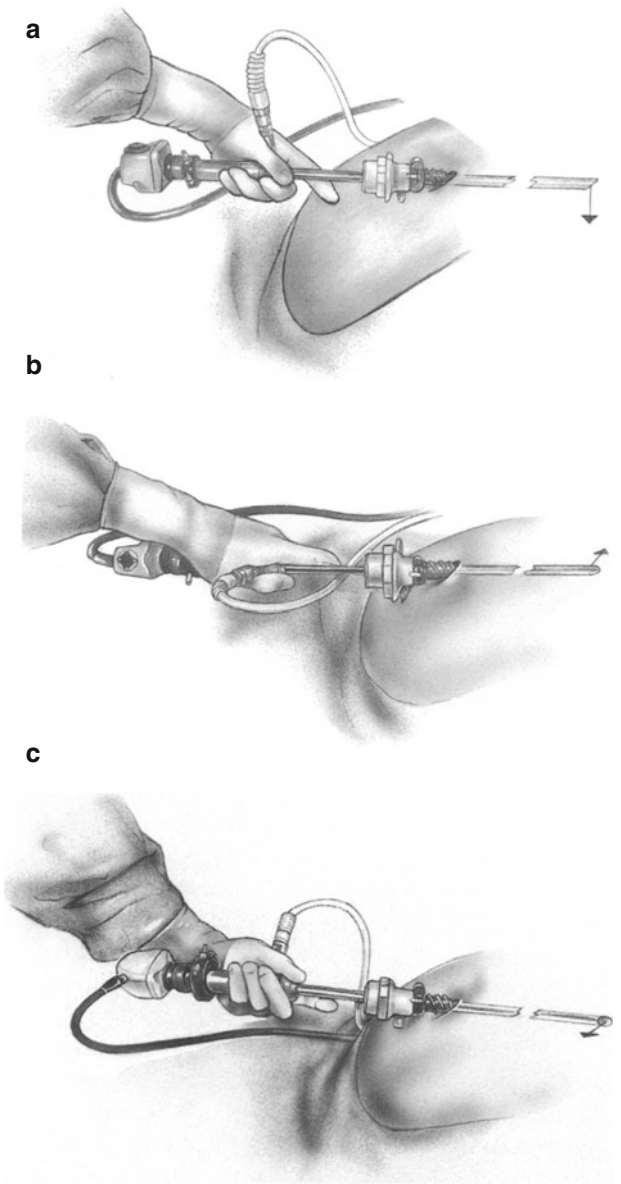

Fig. 9.3

supinating the wrist. If this causes the horizon to tilt noticeably, compensate by rotating the camera on the scope, if necessary.

Many experienced laparoscopic surgeons use an angled laparoscope (usually a 30° scope) as their standard scope. Become accustomed to an angled laparoscope by using it for laparoscopic cholecystectomy and note how it facilitates visualization of both sides of critical structures.

Choice of Initial Puncture Site

When planning trocar sites, particularly the initial puncture site, examine the abdomen for masses and scars from previous surgery and plan the location of the probable operative field. Think in terms of relative distance rather than fixed landmarks.

The umbilicus is a common site for primary entry and placement of the initial trocar. Use this site unless you have a specific reason to prefer an alternate position. Because the umbilicus represents the point where fascia and skin are adherent, entry is easy. The resulting scar is easily hidden in the skin creases around the umbilicus or is incorporated in a midline incision if conversion is required. The position of the umbilicus relative to the costal margin and symphysis pubis varies from one individual to another, particularly with increasing amounts of abdominal fat. Therefore, when considering this initial entry site for a particular patient, take note of how high or low the umbilicus is situated.

In the patient with a normally placed umbilicus, an infraumbilical "smile" incision works well for laparoscopic cholecystectomy. An obese patient with a low-lying umbilicus may require a supraumbilical "frown" incision or possibly a midline or right paramedian entry site placed even higher.

Alternate puncture sites include the subcostal region. Here, the costal arch provides counterpressure against which the Veress needle is easily passed into the abdomen. Subcostal entry sites are particularly useful for laparoscopic procedures done with the patient in the lateral position (e.g., laparoscopic splenectomy) or in the extremely obese patient.

Patient Preparation

An orogastric or nasogastric tube should be passed after induction of anesthesia to decompress the stomach. This maneuver minimizes the chance of inadvertent injury and significantly facilitates visualization. For laparoscopic procedures in the lower abdomen, catheter drainage of the bladder is needed. Monitoring devices should include end-tidal CO_2 measurement and pulse oximetry.

Creating Pneumoperitoneum

Closed Technique with Veress Needle

Begin with the operating table at a comfortable height for working on the anterior abdominal wall. Place the patient in 10–15° Trendelenburg position. Estimate the distance between the abdominal wall and the abdominal aorta by palpating the aorta. In a thin patient, this distance may be only 3 cm. Make a 1-cm incision at the chosen entry site and deepen the incision to expose the anterior rectus fascia. This is most easily done by spreading with a hemostat. The incision must be large enough to accept the 10-/11-mm trocar if a 10-mm laparoscope is being used. It is better to err on the side of slightly larger, as a small incision causes the trocar sheath to catch at the skin level.

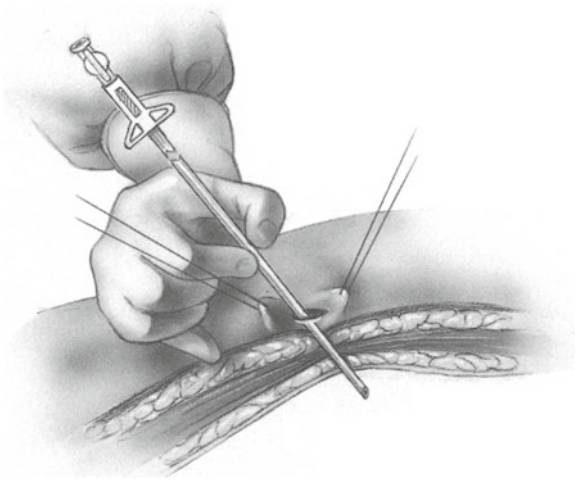

Fig. 9.4

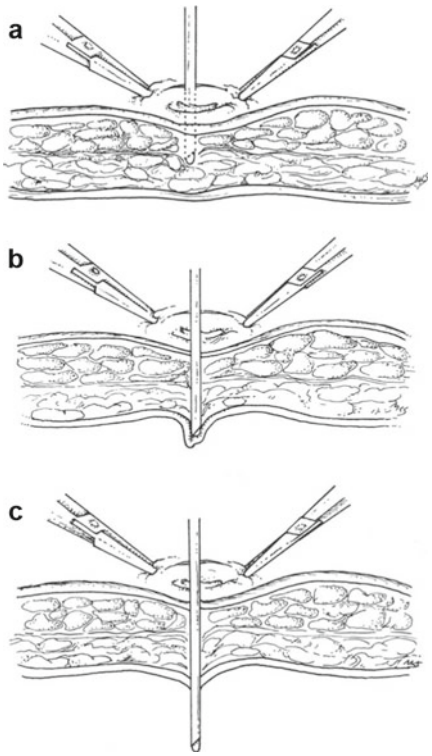

Fig. 9.5 (From Scott-Conner CEH (ed), The SAGES manual: fundamentals of laparoscopy and GI endoscopy. New York: Springer-Verlag, 1999, with permission)

Expose the fascia for a distance of about 10 mm in a vertical direction. If the subcutaneous fat is thick and it is difficult to visualize the fascia, apply a Kocher clamp to the underside of the umbilicus and pull up. The umbilicus is adherent to the fascia, and this traction pulls the fascia into view. Then apply a Kocher clamp to the lower margin of the exposed fascia and elevate the clamp in an anterior direction to increase the distance between the abdominal wall and the great vessels.

Now grasp the Veress needle between thumb and forefinger (Fig. 9.4) and hold it like a dart. After the tip of the needle has been inserted into the abdominal wall, place one drop of saline in the hub of the needle. Aim the needle roughly in the direction of the sacral promontory. As the needle passes through the abdominal wall, one should feel a pop as it passes through the fascia and another when it penetrates the peritoneum (Fig. 9.5). At this point, the drop of saline in the hub should be drawn into the peritoneal cavity owing to the negative pressure that exists in the peritoneal cavity with traction upward on the abdominal wall. Confirm this by placing another drop of saline in the hub of the needle and then elevating the abdominal wall to create more negative pressure. If the drop of fluid is not drawn into the peritoneal cavity, readjust the position of the needle. If this move is unsuccessful, withdraw the needle and reinsert it. When the needle appears to be in the proper position, perform a confirmatory test by attaching a syringe containing 10 ml of saline in the hub of the needle and inject the saline into the abdominal cavity. Then attempt to aspirate the fluid. If the needle is in the peritoneal cavity, no fluid is aspirated. If turbid fluid is aspirated, suspect that the needle has entered bowel. If blood returns, remove the needle and promptly insert a Hasson cannula as described below and insert the laparoscope to inspect the abdominal cavity for vascular injury.

Assuming that the Veress needle has entered the abdominal cavity uneventfully, attach the tube leading to the CO_2 insufflator. Begin at low flow or regulate the inflow to a rate of 1 L/min. The initial reading in the gauge measuring intra-abdominal pressure should be 5–10 mmHg if the needle is in the free peritoneal cavity. After 3–4 L of gas has been injected into the peritoneal cavity, percuss the four quadrants of the abdomen to confirm that the gas is being evenly distributed. This confirms proper needle placement. Increase the flow rate until the intra-abdominal pressure has reached 15 mmHg. At this stage, remove the Veress needle and insert the trocar cannula into the previous umbilical incision. Direct this device in the direction of the sacral promontory and exert gradual pressure with no sudden motions until it has penetrated the abdominal cavity. Then connect the insufflation device to the cannula and continue insufflation to maintain the desired intra-abdominal pressure. This initial cannula should have a diameter of 10–11 mm for the standard 10-mm laparoscope.

Open Technique with Hasson Cannula

The Hasson cannula is designed to be inserted under direct vision through a minilaparotomy incision. It is thus the method of choice in the previously operated abdomen when a scar encroaches on the proposed insufflation site. Some surgeons use this method preferentially for all cases.

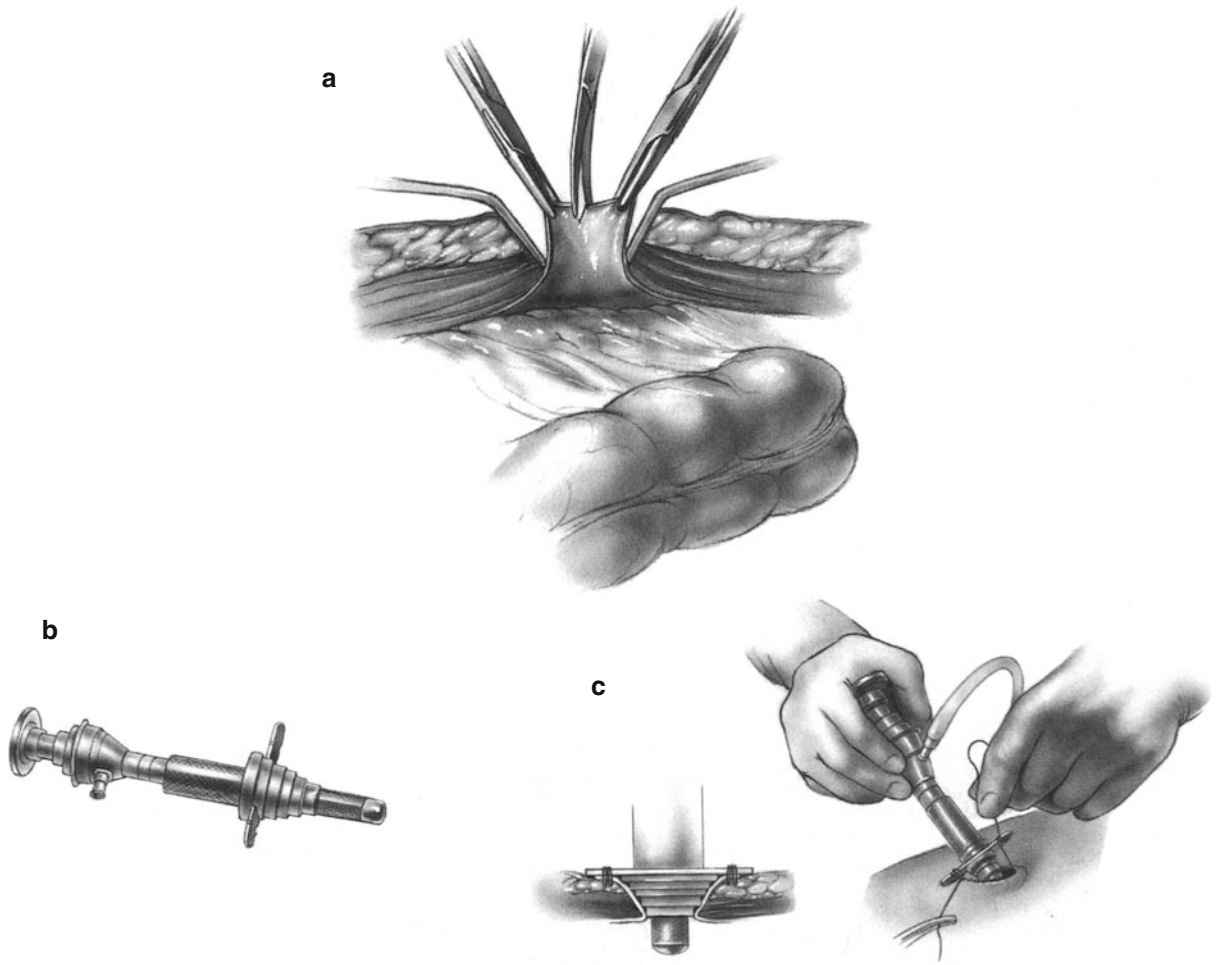

Fig. 9.6

Make a vertical 2- to 3-cm incision in the umbilicus and adjacent subumbilical area with a scalpel. Then identify the rectus fascia in the midline. Make a scalpel incision through the fascial layer and identify the peritoneum. Insert the index finger and carefully explore the undersurface of the fascia for adherent bowel. Open the peritoneum under direct vision with a scalpel. The commonest error is to make the incision too small. The peritoneal incision should comfortably admit the surgeon's index finger, and the skin incision should allow easy visualization of the peritoneum. After visual and finger exploration ascertains that the abdominal cavity has been entered, insert the Hasson cannula under direct vision (Fig. 9.6). This cannula has an adjustable olive-shaped obturator that partially enters the small incision. Insert a heavy PG suture, one on the left and another through the fascia on the right aspect of the incision. These sutures are used to anchor the cannula and at the end of the procedure to close the incision.

Attach each suture to the respective wing of the Hasson cannula, which firmly anchors the olive obturator in the incision and prevents loss of pneumoperitoneum. After this step has been accomplished, insufflate CO_2 as previously described. When the pressure reaches 12–15 mmHg, the telescope is inserted and the operation can begin.

Occasionally, there is difficulty or uncertainty about inserting the initial trocar cannula into the abdomen. In such cases, do not hesitate to abandon the blind steps of inserting the Veress needle or the trocar cannula and to switch to an open "minilaparotomy" for insertion of a Hasson cannula.

Management of Hypotension During Laparoscopy

When the patient deteriorates after induction of pneumoperitoneum, the safest immediate response is to withdraw any instruments into the trocars and release the pneumoperitoneum while seeking the cause of the problem. Among the possible causes are the following:

Interference with venous return. The increased intra-abdominal pressure is not always tolerated, especially in frail, elderly patients. Compounding the problem are the

frequent use of reverse Trendelenburg position and relative hypovolemia due to bowel preparation or overnight fasting prior to surgery. Often the procedure can resume if additional volume is infused and the insufflator is set at a lower pressure. Some patients do not tolerate pneumoperitoneum, and the procedure must then be converted to an open laparotomy.

Hypercapnia. Cardiac dysrhythmias may be induced by CO_2 pneumoperitoneum, which may produce hypercapnia and occasionally hypoxia. A sudden increase in the end-tidal CO_2 level may indicate subcutaneous emphysema, preperitoneal trapping of CO_2, or injection of CO_2 into the liver by incorrect positioning of the Veress needle. Subcutaneous emphysema may be the result of an excessively high intra-abdominal pressure. Extraperitoneal CO_2 insufflation may progress to pneumomediastinum and subcutaneous emphysema. After checking all of these possibilities, the anesthesiologist can generally maintain the patient with hyperventilation. Gas embolus is rare if aspiration is performed before CO_2 is insufflated.

Tension pneumothorax. This should be suspected if unexpected hypotension occurs during the operation. It is particularly apt to occur during laparoscopic surgery in the vicinity of the esophageal hiatus.

Intra-abdominal or retroperitoneal bleeding. Bleeding related to trocar insertion is another cause of hypotension and should be suspected when no other cause is found. A quick survey of the abdomen with the laparoscope is indicated. Look for hematomas, especially arising in the retroperitoneum. If the laparoscopic search is not adequate, do not hesitate to make an emergency midline laparotomy incision, leaving all of the instruments and trocars in place. Explore the retroperitoneal area for damage to the great vessels, including the aorta, vena cava, and iliac vessels.

Secondary Trocar Placement

Place secondary trocars in accordance with the triangle rule: Think of the laparoscope (the surgeon's eyes) as being at the apex of an inverted isosceles triangle with the primary and secondary operating ports as the left and right hands, as shown in Fig. 9.7 for performance of laparoscopic Nissen fundoplication. Proper placement of these operating ports is crucial. For that reason inspect the abdomen with the laparoscope and, if necessary, insert one of the ports that will be used for retraction before placing the operating ports. For example, when setting up ports for a laparoscopic cholecystectomy, place the most lateral retracting port first. Then grasp the fundus of the gallbladder and try lifting it to get a feeling for the degree of mobility of the gallbladder and liver. Finally, place the two operating ports.

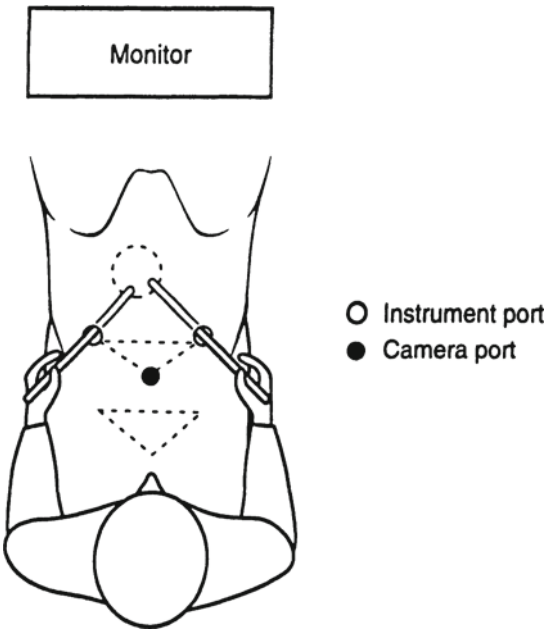

Fig. 9.7 (From Scott-Conner CEH (ed), The SAGES manual: fundamentals of laparoscopy and GI endoscopy. New York: Springer-Verlag, 1999, with permission)

Adopt a two-handed technique early in your laparoscopic career. This is the only way to become proficient with the maneuvers needed for laparoscopic suturing and knot tying. Instruments placed through the primary and secondary operating ports should intersect at the operative field at an angle of 60–90°. If you are uncertain, try out a contemplated trocar site by passing a long spinal needle through the insufflated abdominal wall into the field under direct vision and observe the position and angle at which it enters the operative field.

Additional trocars are frequently placed to allow retraction and assistance. Trocar diagrams given in textbooks, including this one, are just guidelines as each case is slightly different. If you are having difficulty, consider whether inserting another trocar for additional retraction or to substitute for an ill-placed port might help. It is generally necessary to leave the original trocar in place to avoid loss of the pneumoperitoneum.

Ergonomic Considerations

Once the ports have been placed, adjust the operating table and dim the overhead lights. The optimum table position allows the hands to be held at approximately elbow height with instruments in the trocars. Because laparoscopic

instruments are longer than conventional instruments, it is generally necessary to lower the table. Adjust the position of the operating table to allow gravity to displace viscera (reverse Trendelenburg for upper abdominal surgery, Trendelenburg for lower abdominal surgery with the operative side rotated up). If lowering the table has made it impossible to position the patient optimally, raise the table and stand on a platform to compensate.

Laparoscopic Dissection and Hemostasis

Because even a small amount of bleeding absorbs light and obscures visualization, laparoscopic dissection places strong emphasis on careful hemostasis. For basic procedures such as laparoscopic cholecystectomy, monopolar hook cautery works well. The blunt back side of the hook may be used, cold, as a blunt dissector, and the hook then used to elevate, cauterize, and divide small structures. The back side of the hook may be used with cautery as a spatula cautery tip. The tip of the suction irrigator is also a useful dissecting tool. Curved "Maryland" dissectors, endoscopic right-angle clamps, and a variety of blunt graspers are used to stabilize and dissect in a manner analogous to that used for open surgery (Fig. 11.40).

For more extensive surgery, an ultrasonic scalpel or shears allow better hemostasis with less threat of damage to adjacent structures than cautery. Heat is generated by ultrasonic vibration of an active blade. Because this device works best when the active blade is placed against well-supported tissues, it is most commonly used with a slightly curved grasping tip. The tissue to be divided is grasped and gently compressed as the shears are activated. With the correct combination of ultrasonic power and compression, the tissue within the shears is first coagulated and then cut. A lower power setting, or less pressure on the tissue, produces more coagulation and slower cutting. Higher power and greater compression produce a cutting effect. The cutting speed is inversely proportional to the effectiveness of hemostasis. This instrument greatly facilitates advanced procedures such as Nissen fundoplication where sizable vessels (the short gastrics) must be divided.

Laparoscopic Suturing

Laparoscopic procedures that require suturing are considered advanced procedures; yet, the ability to place one or two sutures may enable the laparoscopic surgeon to avoid conversion to open surgery if a minor mishap occurs during basic laparoscopic procedures such as laparoscopic appendectomy. Every laparoscopic surgeon should have basic laparoscopic suturing and knot-tying skills. Practice suturing in a box trainer until you are facile.

Port placement is crucial for successful laparoscopic suturing. As previously mentioned, the primary and secondary ports should bring instrument tips together at an angle of 60–90° in the field. These ports should generally be at least 6 in. apart at the skin to avoid "dueling trocars," a situation where two trocars rub against and over or under each other at every movement.

Knots may be tied intracorporeally in a manner analogous to that used during open surgery or extracorporeally. Intracorporeal tying has the broadest range of applications and is briefly described here. For intracorporeal tying, the entire needle and suture are passed into the abdomen. The suture is cut short (generally around 10 cm): just long enough to be able to produce the loops required for intracorporeal knotting but short enough that the tail can be easily manipulated. Generally a pliable braided material such as silk or PG is used. The size of the suture must be appropriate to the intended purpose; for instance, during laparoscopic Nissen fundoplication, a heavier suture must be used to approximate the diaphragmatic crura than is used to anchor the fundoplication. Sutures for laparoscopic applications are ideally either dark or brightly fluorescent (rather than beige) to facilitate easy visualization.

Interrupted suturing requires that the laparoscopic surgeon be able to place a stitch accurately, pass it through tissue, and securely tie a knot. Tactile feedback is limited, and only visual cues are available. Two needle holders, each capable of securely grasping and holding a needle, are used. Needle holders with curved tips facilitate manipulation in the limited laparoscopic field. Load the needle forehand in the right-hand needle driver. Pass the needle through the tissue with a scooping motion. Following the curve of the needle requires a different set of motions than the simple supination used during open surgery. Watch the needle pass through the tissue and adjust your hand motions to pass it in a smooth, atraumatic fashion.

Grasp the needle with the left-hand needle holder and release the right. Pull the needle through the tissue with the left-hand needle holder.

Intracorporeal knots are placed and tied by the familiar "instrument-tying" method used during open surgery. The sequence of movements to create the first throw of a square knot is shown in Fig. 9.8. The second throw is shown in Fig. 9.9.

Continuous suturing is more rapid because only two knots are needed. Applications are limited, however.

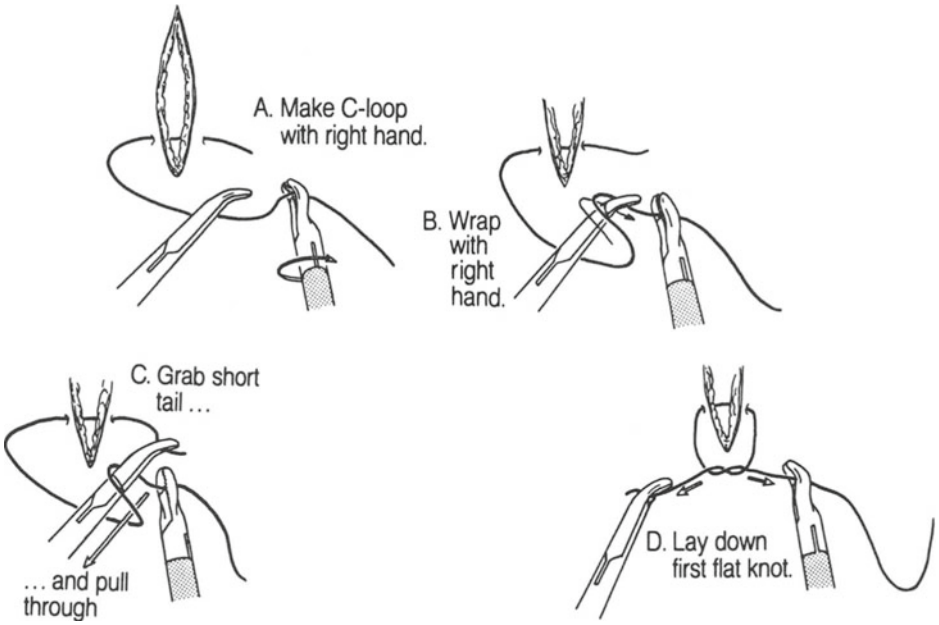

Fig. 9.8 (From Scott-Conner CEH (ed), The SAGES manual: fundamentals of laparoscopy and GI endoscopy. New York: Springer-Verlag, 1999, with permission)

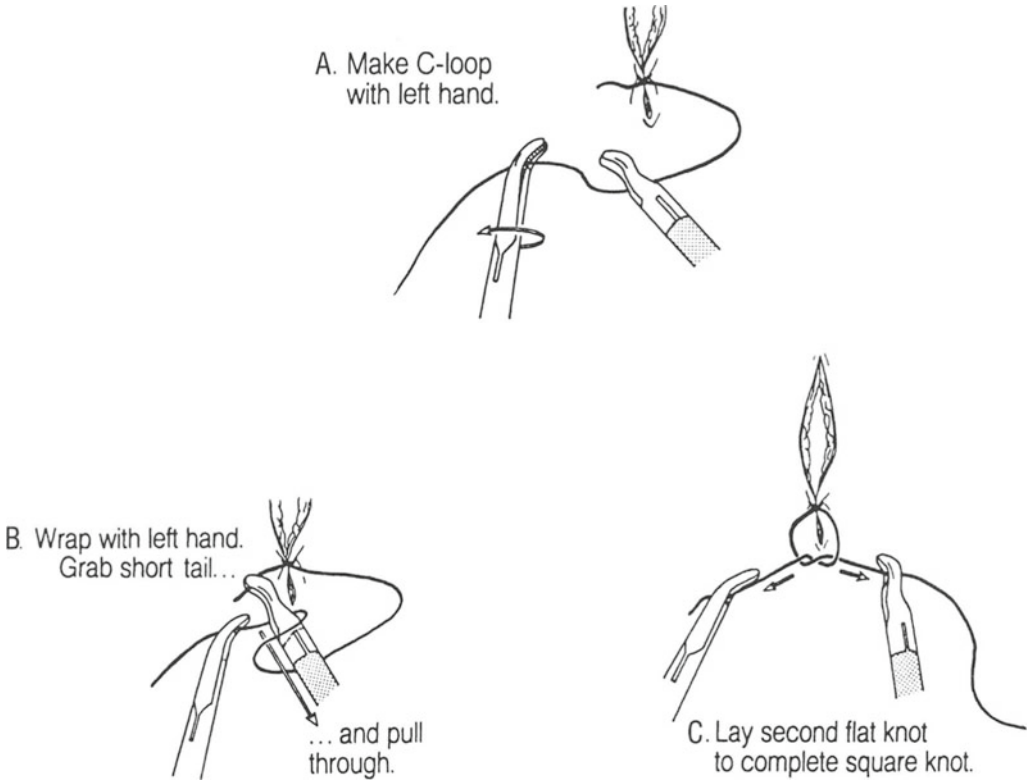

Fig. 9.9 (From Scott-Conner CEH (ed), The SAGES manual: fundamentals of laparoscopy and GI endoscopy. New York: Springer-Verlag, 1999, with permission)

Using a Pretied Suture Ligature

Pretied endoscopic suture ligatures are available and useful for simple applications (e.g., ligating a cystic duct if the clip closure appears tenuous). They are commonly loaded with chromic catgut because this material swells slightly as it absorbs water, rendering the knot even more secure. Pretied ligatures are best used to secure the stump of a structure that has already been divided or to ligate the base of an appendix. They are not applicable to the problem of applying a tie in continuity because you must be able to pass the loop over the structure to be ligated.

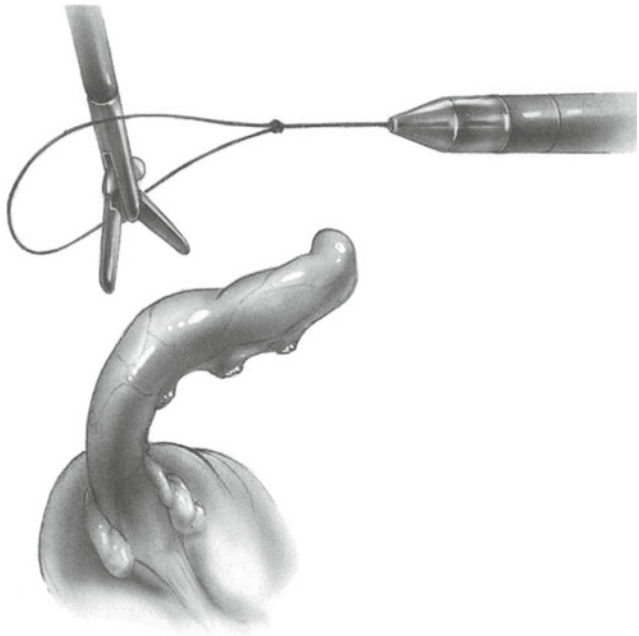

Fig. 9.10

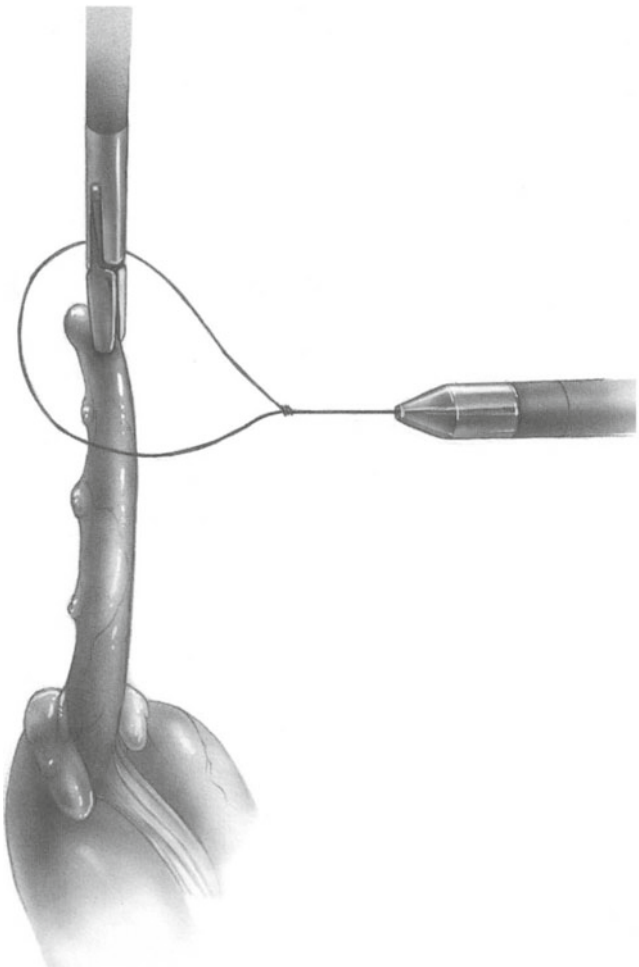

Fig. 9.11

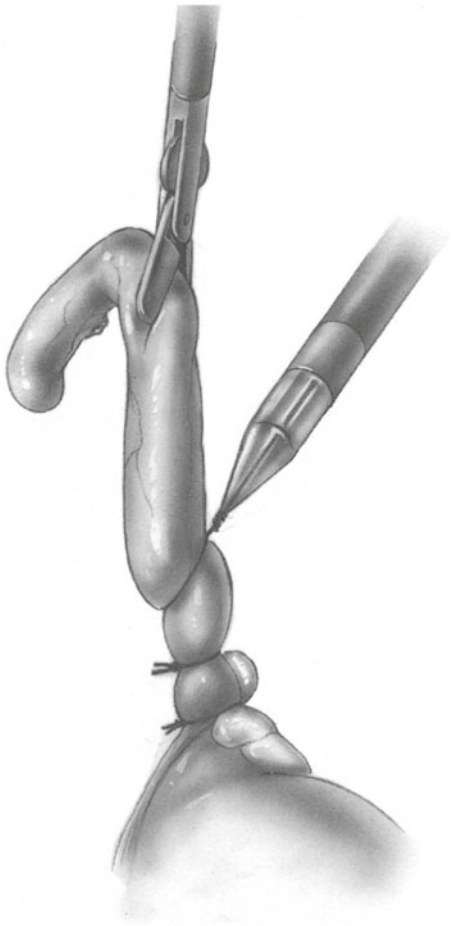

Fig. 9.12

To use a pretied endoscopic ligature, pass it into the field and slowly advance the loop. As the loop comes into contact with tissue, it absorbs water and softens, becoming limp and therefore much more difficult to handle. Avoid this problem by keeping the loop away from tissue until you are ready to close it. Pass a grasper through another port and pass it *through the loop* of the pretied ligature (Fig. 9.10). Ignore the loop and grasp the stump of the structure to be ligated (Fig. 9.11). Then slide the loop down the grasper until it encircles the stump. The loop is quite large, and drawing up on the tail to make the loop slightly smaller may facilitate this maneuver. Shorten the loop with care, as it is not possible to enlarge the loop again. Once the stump is surrounded, place the tip of the knot pusher against the base exactly where you want the knot to sit. Slowly tighten the loop while maintaining slight tension on the stump with the grasper (Fig. 9.12). Withdraw the knot pusher through the trocar and pass endoscopic scissors down to cut the ligature. As with all monofilament sutures, leave a tail of about 2 mm for security. Withdraw the grasper and inspect the ligated stump for security.

Laparoscopic Stapling

Laparoscopic stapling may be performed intra- or extracorporeally with the same staplers used during open surgery. Purely intracorporeal stapling is possible using an endoscopic linear cutting stapler that passes through a 12-mm port. This stapler may be used to secure the base of an appendix; then, loaded with smaller staples, it may be fired across the mesentery. It fires two triple rows of staples and cuts between them. The device is illustrated and its use described in Chap. 47.

Closing Trocar Sites

Any port site larger than 5 mm must be sutured closed to prevent hernia formation. Special suture passers are available to facilitate passing a suture through the skin incision at the trocar site and thence through all the layers of the abdominal wall and back out under direct vision. The suture is then tied at the level of the fascia to close the trocar site securely. These sutures are especially useful in obese patients.

Troubleshooting Equipment

Many hours of frustration can be avoided if laparoscopic surgeons take the time to become thoroughly familiar with the specific equipment in use in their particular operating suite. Adopt a standardized terminology for all the individual instruments you use so it is easy for the scrub person to pass you the specific grasper you need. Know where supplies and equipment are kept. A troubleshooting chart, such as that developed by SAGES, should be easily accessible.

Loss of Working Space

If visualization is difficult and the working space seems to be collapsing, feel the abdominal wall and check the pressure reading on the insufflator. If the abdominal wall is tense and flat and the insufflator pressure readings are normal or high, the problem is likely to be inadequate muscle relaxation. Instruct the anesthesiologist to correct the situation.

Conversely, a loose, limp, flaccid abdominal wall and low insufflator pressures mean inadequate CO_2. This may be due to an empty cannister, a dislodged insufflator line, or leaks in the system.

Avoiding Complications

Although each procedure has its unique complications, there are a set of problems shared by all laparoscopic operations. They are briefly considered here.

Hypercarbia from absorption of CO_2 gas is prevented by hyperventilation and vigilance on the part of the anesthesiologist. An occasional patient does not tolerate the physiologic stress of pneumoperitoneum, and conversion to open surgery may be needed.

Gas embolus is signaled by a sudden jump in end-tidal CO_2 followed by a rapid fall as cardiac output goes to zero. This rare complication is avoided by aspirating to check for blood before insufflating CO_2 through the Veress needle and employing special precautions during procedures (e.g., hepatic resection) where venous sinusoids are cut.

Bleeding from the abdominal wall is a common, annoying complication of trocar site placement. Blood may run down the instruments or laparoscope to obscure the view during surgery or cause hematoma or hemoperitoneum after surgery is complete. Avoid this situation by making the lower abdominal trocar sites lateral to the border of the rectus sheath (to avoid the inferior epigastric vessels), by avoiding umbilical puncture sites in cirrhotic patients (to avoid entering the dilated veins of a caput medusae), and by inspecting trocar sites as the last step before withdrawing the laparoscope. Generally such bleeding can be controlled by sutures through the abdominal wall.

Visceral or vascular injury during Veress needle or trocar placement is avoided by following the guidelines for Veress needle placement outlined in the previous sections. Place secondary trocars under direct vision. If visceral or vascular injury is suspected, leave the Veress needle or trocar in situ as you convert to a formal laparotomy. This may tamponade any bleeding and greatly facilitates finding the site of injury.

Further Reading

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