Complications of Minimal Access Surgery

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INTRODUCTION

Initial development of "minimal access surgery" began in the animal laboratory and was later studied in selected academic centers. It was imported to the community hospitals only when its benefits and safety were established. The development of laparoscopic cholecystectomy was not designed to enhance the safety of the procedure, but rather to reduce the discomfort associated with the surgical incision. The fierce economical competition in medicine fueled by the managed care movement led to the rapid adoption of laparoscopic surgery among surgeons and gynecologist in community hospitals who were not formally trained in this technique and acquired their knowledge by subscribing to short courses.

Low complication rates were reported by centers specializing in laparoscopic surgery, mostly in academic centers. These centers were able to reduce the complication rate to minimum by developing proficiency in this surgery. Regrettably, many inexperienced surgeons perform this technique within sufficient training and are responsible for the majority of complications seen during the performance of laparoscopic surgery.

Physicians who performed <100 such procedures reported 14.7 complications per 1,000 patients. In contrast, experienced surgeon reported a complication rate of only 3.8 complications per 1,000 procedures. The Southern Surgeons Club Survey reported that the incidence of bile duct injury was 2.2% when the surgeon had previously performed <13 procedures. As surgeons gained experience, the incidence of bile duct injury dropped to 0.1% afterward.

ANESTHETIC AND MEDICAL COMPLICATIONS IN LAPAROSCOPY

Although all types of anesthesia involve some risk, major side effects and complications from anesthesia in laparoscopy are uncommon. Anesthetic complications include those that are more common in association with laparoscopic surgery as well as those that can occur in any procedure requiring general anesthetics. One-third of the deaths associated with minor laparoscopic procedures such as sterilization or diagnostic laparoscopy are secondary to complication of anesthesia.

Among the potential complications of all general anesthetics are:

- Hypoventilation
- Esophageal intubation
- Gastroesophageal reflux
- Bronchospasm
- Hypotension
- Narcotic overdose
- Cardiac arrhythmias
- Cardiac arrest.

Laparoscopy results in multiple postoperative benefits including fewer traumas, less pain, less pulmonary dysfunction, quicker recovery, and shorter hospital stay. These advantages are regularly emphasized and explained. With increasing success of laparoscopy, it is now proposed for many surgical procedures. Intraoperative cardiorespiratory changes occur during pneumoperitoneum and partial pressure of arterial carbon dioxide ($PaCO_2$) increases due to carbon dioxide (CO_2) absorption from peritoneal cavity. Laparoscopy poses a number of inherent features that can enhance some of these risks. For example, the Trendelenburg position, in combination with the increased intraperitoneal pressure provided by pneumoperitoneum by CO_2, exerts greater pressure on the diaphragm, potentiating hypoventilation, resulting hypercarbia, and metabolic acidosis. This position, combined with anesthetic agents that act as muscle relaxant opens the esophageal sphincter, facilitates regurgitation of gastric content, which, in turn, often leads to aspiration and its attendant complications of bronchospasm, pneumonitis, and pneumonia. Intraoperative aspiration pneumonia is very common in laparoscopy, but postoperative pneumonia is common after open surgery.

Various parameters of cardiopulmonary function associated with CO_2 insufflation include reduced partial pressure of arterial oxygen (PaO_2), oxygen (O_2) saturation, tidal volume and minute ventilation as well as an increased respiratory rate. The use of intraperitoneal CO_2 as a distension medium is associated with an increase in $PaCO_2$

and a decrease in pH. Increased abdominal pressure and elevation of the diaphragm may be associated with basilar atelectasis, which can result into right-to-left shunt and a ventilation-perfusion mismatch.

Although during laparoscopy, the patient's anesthetic care is in the hands of the anesthesiologist, it is important for the laparoscopic surgeon to understand the prevention and management of anesthetic complications by proper knowledge of risk involved with pneumoperitoneum.

Carbon Dioxide Embolism

Several case reports and experimental data suggest that the first finding during a CO_2 embolism may be a rapid increase in end-tidal CO_2 ($EtCO_2$) tension as some of the CO_2 injected into the vascular system is excreted into the lungs. As more gas is injected, a vapor lock is formed in portions of the lungs. Areas of the lung are ventilated but not perfused (i.e., become dead space) and the end-tidal CO_2 rapidly falls. In contrast, during an air embolism, the end-tidal CO_2 tension falls immediately. Other findings of a massive CO_2 embolism include a harsh, mill-wheel murmur, a marked decrease in blood pressure, and a decrease in hemoglobin-O_2 saturation. In minimal access surgery, the use of CO_2 was started just to minimize the risk of CO_2 embolism. CO_2 is the most widely used peritoneal distension medium. Part of the reason for this selection is the ready absorption of CO_2 in blood. It is 20 times more absorbable than room air; consequently, the vast majority of frequent microemboli that do occur are absorbed, usually by the splanchnic vascular system quickly and without any incident. However, if large amounts of CO_2 gain access to the central venous circulation, if there is peripheral vasoconstriction, or if the splanchnic blood flow is decreased by excessively high intraperitoneal pressure, severe cardiorespiratory compromise may result. The reported incidence of death due to CO_2 embolism is not clearly and authentically mentioned in any of the published article but it is assumed to be 1:10,000.

Diagnosis of Carbon Dioxide Embolism

Carbon dioxide embolism is difficult to diagnose clinically. Among the presenting signs of CO_2 embolus are sudden, otherwise unexplained hypotension, cardiac arrhythmia, cyanosis, and the development of the classical "mill-wheel" or "water-wheel" heart murmur. The end-tidal CO_2 may increase and findings consistent with pulmonary edema may manifest. Accelerating pulmonary hypertension may also occur resulting in right-sided heart failure.

Prevention of Carbon Dioxide Embolism

Because gas embolism may occur as a result of direct intravascular injection via an insufflation needle, the surgeon should ensure that blood is not emanating from the needle prior to the initiation of insufflation. Gynecologic surgeons can uniformly reduce the risk of CO_2 embolus by operating in an environment where the intraperitoneal pressure is maintained at <20 mm Hg. In most instances, excepting the initial placement of trocar in an insufflated peritoneum, the surgeon should be able to function comfortably with the intraperitoneal pressure between 8 and 12 mm Hg, maximum 15 mm Hg. Such pressures may also provide protection from many of the other adverse cardiopulmonary events. The risk of CO_2 embolus is also reduced by the meticulous maintenance of hemostasis and avoiding open venous channels, which are the portal of entry for gas into the systemic circulation. Another option in high-risk patient is the use of "gasless" or "apneumic" laparoscopy, where extra- or intraperitoneal abdominal lifting mechanisms are used to create a working space for the laparoscopic surgeon. However, limitations of these devices have, to date, precluded their wide acceptance by most of the surgeons.

The anesthesiologist should continuously monitor the patient's skin colors, blood pressure, heart sounds, electrocardiogram, and end-tidal CO_2, so that the signs of CO_2 embolus are recognized early and can be managed.

Management of Carbon Dioxide Embolism

If a CO_2 embolism should occur:

- The patient should receive 100% O_2
- Insufflation should be stopped and the abdomen decompressed
- The patient should be placed with the right side elevated in the Trendelenburg position to avoid further entrapment of CO_2 in the pulmonary vasculature
- A central venous catheter, if placed rapidly, may allow aspiration of CO_2
- Full inotropic support should be instituted.

Cardiopulmonary bypass may be required to evacuate the gas lock and help remove the CO_2.

If CO_2 embolus is suspected or diagnosed, the operating room team must act quickly. The surgeon must evacuate CO_2 from the peritoneal cavity and should place the patient in the Durant or left lateral decubitus position, with the head below the level of the right atrium. A large bore central venous line should be immediately established to allow aspiration of gas from the heart. Because the findings are nonspecific, other causes of cardiovascular collapse should be considered.

Periodically, gases other than CO_2 are investigated for use for laparoscopy. Argon, air, helium, and nitrous oxide have all been used in an attempt to eliminate the problems associated with hypercarbia and peritoneal irritation seen with CO_2. The lack of solubility of air, helium, and argon effectively prevents hypercarbia that occurs with insufflation with CO_2, but increases the lethality many fold, if gas embolism occurs. Deaths from argon gas embolism, when the argon beam coagulator has been used during laparoscopy, suggest that this concern is real. Nitrous oxide has solubility similar to that of CO_2, but unfortunately it can support combustion. Explosions, when electrocautery was used following insufflation with nitrous oxide, have occurred. An intra-abdominal fire, when nitrous oxide was intended to be used for insufflation, has also been reported.

Cardiovascular Complications

Laparoscopic surgery requires the insufflation of CO_2 into the abdominal cavity. Complications associated with CO_2 insufflation include:

- Escape of CO_2 into the heart or pleural cavity
- Effects of the resultant increased intra-abdominal pressure on cardiac, renal, and liver physiology
- Effects of the absorbed CO_2 on cardiorespiratory function.

The fatal complication of CO_2 embolization to the heart and lung was discussed earlier. CO_2 is insufflated under 12–15 mm Hg pressure to elevate the abdominal wall and allow the camera the necessary distance to the organ operated on. Depending on the intra-abdominal pressure used and the position the patient is placed—head up or head down—several potential harmful physiologic derangements may occur.

Cardiac arrhythmias occur relatively frequently during the performance of laparoscopic surgery and are related to a number of factors, the most significant of which is hypercarbia and the resulting acidemia. Early reports of laparoscopy-associated arrhythmia were in association with spontaneous respiration. Consequently, most anesthesiologists have adopted the universal practice of mechanical ventilation during laparoscopic surgery. There are also a number of pharmacological considerations that lead the anesthesiologist to select agents that limit the risk of cardiac arrhythmia. The surgeon may aid in reducing the incidence of hypercarbia by operating with intraperitoneal pressures that are <15 mm Hg.

The use of an alternate intraperitoneal gas is another method by which the risk of cardiac arrhythmia may be reduced. However, while nitrous oxide is associated with a decreased incidence of arrhythmia, it increases the severity of shoulder tip pain, and, more importantly, is insoluble in blood. External lifting systems (apneumic laparoscopy) are another option that can provide protection against cardiac arrhythmia.

Hypotension can also occur secondary to excessively increased intraperitoneal pressure resulting in decreased venous return and resulting decreased cardiac output. This undesirable result may be potentiated, if the patient is volume depleted. Hypotension secondary to cardiac arrhythmias may also be a consequence of vagal discharge in response to increased intraperitoneal pressure. All of these side effects will be more dangerous for the patient with preexisting cardiovascular compromise.

Gastric Reflux during Laparoscopy

Patients undergoing laparoscopy are usually considered at high risk of acid aspiration syndrome due to gastric regurgitation, which might occur due to the rise in intragastric pressure consequent to the increased IAP. However, during pneumoperitoneum, the lower esophageal sphincter tone far exceeds the intragastric pressure and the raised barrier pressure limits the incidence of regurgitation.

Many study aimed to evaluate whether or not the use of intermittent positive pressure ventilation via the laryngeal mask airway that is associated with a higher risk of gastroesophageal reflux when compared with intermittent positive pressure ventilation via a tracheal tube in patients undergoing day-case gynecological laparoscopy in the head-down position.

Generally, gastric regurgitation and aspiration are complications potentiated by laparoscopic surgery. Some patients are at increased risk, including those with obesity, gastroparesis, hiatal hernia, or any type of gastric outlet obstruction. In such patients, it is important to quickly secure the airway with a cuffed endotracheal tube and to routinely decompress the stomach with a nasogastric or orogastric tube. The surgeon can contribute to aspiration prophylaxis by operating at the lowest necessary intraperitoneal pressure. Patients should be taken out of the Trendelenburg position prior to being extubated. The adverse effects of aspiration may be minimized with the routine preoperative administration of metoclopramide, H2 blockers, and nonparticulate antacids.

Extraperitoneal Gas

During laparoscopic surgery, a number of the complications associated with pneumoperitoneum or its achievement are described in the vascular, gastroenterologic, urologic, and anesthetic sections. However, the problem of extraperitoneal placement or extravasation of gas has not been considered. In some instances, this complication occurs as a result of deficient technique (incorrect placement of insufflation needles; excessive intraperitoneal pressure); while in others, the extravasation is related to gas tracking around the ports or along the dissection planes themselves.

Subcutaneous emphysema may occur if the tip of the Veress needle does not penetrate the peritoneal cavity prior to insufflation of gas. The gas may accumulate in the subcutaneous tissue or between the fascia and the peritoneum. Extraperitoneal insufflation, which is associated with higher levels of CO_2 absorption than intraperitoneal insufflation, is reflected by a sudden rise in the $EtCO_2$, excessive changes in airway pressure, and respiratory acidosis.

Subcutaneous emphysema most commonly results from preperitoneal placement of an insufflation needle or leakage of CO_2 around the cannula sites, the latter frequently because of excessive intraperitoneal pressure. The condition is usually mild and limited to the abdominal wall. However, subcutaneous emphysema can become extensive, involving the extremities, the neck, and the mediastinum. Another relatively common location for emphysema is the omentum or mesentery, a circumstance that the surgeon may mistake for preperitoneal insufflation.

Diagnosis

Usually, the diagnosis will not be a surprise for the surgeon that will have had difficulty in positioning the primary cannula within the peritoneal cavity. Subcutaneous emphysema may be readily identified by the palpation of crepitus, usually in the abdominal wall. In some instances, it can extend along contiguous fascial planes to the neck, where it can be visualized directly. Such a finding may reflect the development of mediastinal emphysema. If mediastinal emphysema is severe or if pneumothorax is developing, the anesthesiologist may report difficulty in maintaining a normal pCO_2, a feature that may indicate impending cardiovascular collapse.

Prevention

The risk of subcutaneous emphysema during laparoscopic surgery is reduced by proper positioning of an insufflation needle. Prior to insertion, it is important to check the insufflation needle for proper function and patency and to establish the baseline flow pressure by attaching it to the insufflation apparatus. The best position for insertion is at the base of the umbilicus, where the abdominal wall is the thinnest. The angle of insertion varies from 45° to near 90°, depending upon the patient's weight, the previous abdominal surgery, and type of anesthesia as described in the section on prevention of vascular injuries. The insertion action should be smooth and firm until the surgeon observing and listening to the device passing through the layers—two (fascia and peritoneum) in the umbilicus and three (two layers of fascia; one peritoneum) in the left upper quadrant feels that placement is intraperitoneal.

No one test is absolutely reliable at predicting intraperitoneal placement. Instead, a number of tests should be used. Of course, aspiration of the insufflation needle should precede all other evaluations. Two tests depend upon the preinflation intraperitoneal pressure. If a drop of water is placed on the open end of the insufflation needle, it should be drawn into the low-pressure intraperitoneal environment of the peritoneal cavity. Although some disagree, the elevation of the anterior abdominal wall is a reasonable way of creating a negative intraperitoneal pressure. Perhaps, a more quantitative way of demonstrating the same principle is to attach the tubing to the needle after insertion but prior to initiating the flow of gas. Elevation of the abdominal wall should result in creation of a low or negative intraperitoneal pressure (1–4 mm Hg). Insufflation should be initiated at a low flow rate of about 1 L/min until the surgeon has confidence that proper placement has been achieved. Loss of liver dullness should occur when about 500 mL of gas has entered the peritoneal cavity. The measured intraperitoneal pressure should be below 10 mm Hg but up to 14 mm Hg, if the patient is obese. Abdominal distension should be symmetrical. If, at any time, the surgeon feels that the needle is not located intraperitoneally, it should be withdrawn and reinserted. Once the peritoneal cavity has been insufflated with an adequate volume of gas, the primary trocar is introduced. The laparoscope is introduced, and, if the cannula is satisfactorily located, the tubing is attached to the appropriate port.

The risk of subcutaneous emphysema may be reduced by maintaining a low intraperitoneal pressure following the placement of the desired cannulas operate below 15 mm Hg and usually work at about 10 mm Hg. Although primary blind insertion of sharp trocar has been demonstrated to be as safe as secondary insertion following pneumoinsufflation, the relative incidence of subcutaneous emphysema is unknown.

Management

Subcutaneous emphysema often presents a management dilemma. Rarely, subcutaneous emphysema has pathophysiologic consequences. More often, it is extremely uncomfortable for the patient and is often disfiguring and alarming for patients and family. When subcutaneous emphysema is severe, physicians may feel compelled to treat it, but the currently described techniques are often invasive or ineffective.

If the surgeon finds that the insufflation has occurred extraperitoneally, there exists a number of management options. While removing the laparoscope and repeating the insufflation is possible, it may be made more difficult because of the new configuration of the anterior peritoneum. Open laparoscopy or the use of an alternate sites such as the left upper quadrant should be considered. One attractive approach is to leave the laparoscope in the expanded preperitoneal space while the insufflation needle is reinserted through the peritoneal membrane, caudal to the tip of the laparoscope under direct vision.

For mild cases of subcutaneous emphysema, no specific intra- or postoperative therapy is required, as the findings, in at least mild cases, quickly resolve following evacuation of the pneumoperitoneum. When the extravasation extends to involve the neck, it is usually preferable to terminate the procedure, as pneumomediastinum, pneumothorax, hypercarbia, and cardiovascular collapse may result. Following the end of the procedure, it is prudent to obtain a chest X-ray. The patient should be managed expectantly unless a tension pneumothorax results, when immediate evacuation must be performed, using a chest tube or a wide bore needle (14–16 gauge) inserted in the second intercostal space in midclavicular line.

ELECTROSURGICAL COMPLICATIONS

Unlike open surgery where hemostasis (control of bleeding) is accomplished by pressure and careful application of fine clamps and ligatures, laparoscopic surgery must rely on electrosurgery to achieve hemostasis. Excessive use of energy can burn a hole in the wall of the organ involved. Current can also cause injury to adjacent organs and even distant organs. Complications of electrosurgery occur secondary to thermal injury from one of three basic causes. The first is thermal trauma from unintended or inappropriate use of the active electrode(s). The second from current diverting to another, undesirable path, causing injury remote from the immediate operative field. Third is injury at the site of the "return" or dispersive electrode. Active electrode injury can occur with either unipolar or bipolar instruments, while trauma secondary to current diversion or dispersive electrode accidents only occur with the unipolar technique. Complications of electrosurgery are reduced with strict adherence to safety protocols coupled with a sound understanding of the circumstances that can lead to undesirable effects on tissue.

Active Electrode Trauma

Unintended activation in open space without touching the tissue is one of the more common mechanisms by which the active electrode causes complications. Such a complication frequently occurs when an electrode, left untended within the peritoneal cavity, is inadvertently activated by compression of the hand switch or depression of the foot pedal. Control of the electrosurgical unit (ESU) or generator by someone other than the operating surgeon is also a source of accidental activation of the electrode.

Direct extension is another mechanism by which the active electrode(s) cause complications. The zone of vaporization or coagulation may extend to involve large blood vessels or vital structures such as the bladder, ureter, or bowel. Bipolar current reduces, but does not eliminate, the risk of thermal injury to adjacent tissue. Consequently, care must be taken to isolate blood vessels prior to desiccation, especially when near vital structures and to apply appropriate amounts of energy in a fashion that allows an adequate margin of noninjured tissue.

Diagnosis

During minimal access surgery, the diagnosis of direct thermal visceral injury may be suspected or confirmed intraoperatively. Careful evaluation of nearby intraperitoneal structures should be made if unintended activation of the electrode occurs. The visual appearance will depend upon a number of factors including the type of the electrode, its proximity to tissue, the output of the generator, and the duration of its activation. High power density activations will often result in vaporization injury and will be more easily recognized than lower power density lesions that result in desiccation and coagulation.

The diagnosis of visceral thermal injury is often delayed until the signs and symptoms of fistula or peritonitis present. This will be particularly true with desiccation injury. Because these complications may not present until 2 to at least 10 days following surgery, long after discharge, both the patient and the physician must be made aware of the possible consequences. Consequently, patients should be advised to report any fever or increasing abdominal pain experienced postoperatively.

Prevention

Electrosurgical injuries are largely prevented if: (a) the surgeon is always in direct control of electrode activation and (b) 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 to the operative field. These measures prevent damage to the patient's skin, if the foot pedal is accidentally depressed.

Management

Once diagnosed, thermal injury to bowel, bladder, or ureter, recognized at the time of laparoscopy, should immediately be managed appropriately, considering the potential extent of the zone of coagulative necrosis. The extent of thermal trauma will depend upon the characteristics of the energy transferred to tissue. An electrosurgical incision made with the focused energy from a pointed electrode will be associated with a minimal amount of surrounding thermal injury and may be repaired in a fashion identical to one created mechanically. However, with desiccation injury created as a result of prolonged contact with a relatively large caliber electrode, the thermal necrosis may extend centimeters from the point of contact. In such instances, wide excision or resection will be necessary.

Remote Injury

Remote injury due to current diversion can occur when an electrical current finds a direct path out of the patient's body via grounded sites other than the dispersive electrode. Alternatively, the current can be diverted directly to other tissue before it reaches the tip of the active electrode. In either instance, if the power density becomes high enough, unintended and severe thermal injury can result.

These injuries can only occur with ground-referenced ESUs because they lack an isolated circuit. In such generators, when the dispersive electrode becomes detached, unplugged, or otherwise ineffective, the current will seek any grounded conductor. If the conductor has a small surface area, the current or power density may become high enough to cause thermal injury. Examples include electrocardiograph patch electrodes or the conductive metal components of the operating table.

Modem ESUs are designed and built with isolated circuits and impedance monitoring systems or active electrode monitoring system. Consequently, if any part of the circuit is broken, an alarm sounds, and/or the machine “shuts down”, thereby preventing electrode activation. Since the widespread introduction of such generators, the incidence of burns to alternate sites has become largely confined to cases involving the few remaining ground-referenced machines.

Insulation Failure

Failure in the insulation coating the shaft of a laparoscopic electrosurgical electrode can allow current diversion to adjacent tissue. The high power density resulting from such small points of contact fosters the creation of a significant injury. During laparoscopic surgery, bowel is frequently the tissue near to, or in contact with, the shaft of the electrode, making it the organ most susceptible to this type of electrosurgical injury. The fact that the whole shaft of the electrode is frequently not encompassed by the surgeon's visual field at laparoscopy makes it possible that such an injury can occur unaware to the operator.

Prevention of complication of insulation failure starts with the selection and care of electrosurgical hand instruments. Loose instrument bins should be replaced with containers designed to keep the instruments from damaging each other. The instruments should be examined prior to each case, searching for worn or obviously defective insulation. When found, the damaged instrument should be removed and repaired or replaced. Despite all efforts, unobserved breaks in insulation may rarely occur. While the use of disposable instruments is often claimed as a way of reducing the incidence of insulation failure, there is no guarantee that this is the case, as invisible defects may occur in the manufacturing process. Furthermore, the insulation on disposable electrodes is thinner and more susceptible to trauma. Consequently, when applying unipolar electrical energy, the shaft of the instrument should be kept free of vital structures and, if possible, totally visible in the operative field.

Direct Coupling

During minimal access surgery, direct coupling occurs when an activated electrode touches and energizes another metal conductor such as a laparoscope, cannula, or other instrument. If the conductor is near to, or in contact with, other tissue, a thermal injury can result. Such accidents often happen following unintentional activation of an electrode. Prevention of direct coupling is facilitated by removal of the electrodes when not in use and visually confirming that the electrode is not in inappropriate contact with other conductive instruments prior to activation.

Capacitive Coupling

Many capacitive coupling of diathermy current have been reported as causes of occult injury during surgical laparoscopy. Capacitance reflects the ability of a conductor to establish an electrical current in an unconnected but nearby circuit. An electrical field is established around the shaft of any activated laparoscopic unipolar electrode, a circumstance that makes the electrode a capacitor. This field is harmless if the circuit is completed via a dispersive, low power density pathway. If capacitive coupling occurs between the laparoscopic electrode and a metal cannula positioned in the abdominal wall, the current without any complication returns to the abdominal wall where it traverses to the dispersive electrode. However, if the metal cannula is anchored to the skin by a nonconductive plastic retaining sleeve or anchor (a hybrid system), the current will not return to the abdominal wall because the sleeve acts as an insulator. Instead, the capacitor will have to search elsewhere to complete the circuit. Consequently, bowel or any other nearby conductor can become the target of a relatively high power density discharge. The risk is greater with high voltage currents such as the coagulation output on an electrosurgical generator. This mechanism is also more likely to occur when a unipolar electrode is inserted through an operating laparoscope that, in turn, is passed through a plastic laparoscopic port. 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.

During minimal access surgery, prevention of capacitive coupling can largely be accomplished by avoiding the use of hybrid laparoscope cannula systems that contain a mixture of conductive and nonconductive elements. Instead, it is preferred that all plastic or all metal cannula systems be used. When and if operating laparoscopes are employed, all metal cannula systems should be the rule unless there is no intent to perform unipolar electrosurgical procedures through the operating channel.

Risk of this injury is very much minimized if low voltage radiofrequency current (cutting) is used and when the high voltage outputs are avoided.

Dispersive Electrode Burns

The use of isolated circuit generators with return electrode monitors has all but eliminated dispersive electrode-related thermal injury. Return electrode monitoring (REM) is actually accomplished by measuring the impedance (sometimes called resistance) in the dispersive electrode, which should always be low because of the large surface area. To accomplish this, most return electrode monitors, actually, are divided into two electrodes, allowing the generator to compare the impedance from the two sides of the pad. If the overall impedance is high or if there is a significant difference between the two sides, as is the case with partial detachment, the active electrode cannot be activated. Without such devices, partial detachment of the patient pad could result in a thermal injury because reducing the surface area of the electrode raises the current density. It is important for the surgeon to establish what type of ESU is being used in each case. Absence of an REM system is a reason for increased scrutiny of the positioning of the dispersive electrode, both before the surgery begins, and as the operation progresses.

Electrode Shields and Monitors

A United States-based company (Electroscope Inc.) markets a system that helps to reduce further the chance of director capacitive coupling. A reusable shield is passed over the shaft of the laparoscopic electrode prior to its insertion into the peritoneal cavity. This shield protects against insulation failure and detects the presence of significant capacitance. Should an insulation break occur or when capacitance becomes threatening, the integrated monitoring system automatically shuts down the generator. The shield enlarges the effective diameter of the electrode by about 2 mm, making it necessary to use larger caliber laparoscopic ports.

Despite perceptions to the contrary, electrosurgery has been rendered a safe modality for use in surgical procedures. However, safe and effective application of electrical energy requires an adequate understanding and implementation of basic principles as well as the availability of modern electrosurgical generators and appropriate education of medical and support staff. Care and prudence must be exercised when utilizing electricity within the peritoneal cavity. The zone of significant thermal injury usually extends beyond that of the visible injury, a feature that must be borne in mind when operating in close proximity to vital structures such as bowel bladder, ureter, and large and important blood vessels. It is equally important to impart the minimal amount of thermal injury (if any) necessary to accomplish the task at hand, even around nonvital structures, by using the ideal power output and the appropriate active electrodes.

HEMORRHAGIC COMPLICATIONS

Hemorrhagic complications may occur as a consequence of entry into the peritoneal cavity or as a result of trauma incurred to blood vessels encountered during the course of the procedure.

Hemorrhage Associated with Access Technique

Great Vessel Injury

During access, the most dangerous hemorrhagic complications of entry are to the great vessels, including the aorta and vena cava as well as the common iliac vessels and their branches, the internal and external iliac arteries and veins. The incidence of major vascular injury is probably underreported, but has been estimated to range widely from 0.93 to 9 per 10,000 cases. The trauma most often occurs secondary to insertion of an insufflation needle, but may be created by the tip of the trocar. However, not uncommonly, the injury is associated with the insertion of ancillary laparoscopic ports into the lower quadrants. The vessels most frequently damaged are the aorta and the right common iliac artery, which 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. While most of these injuries are small amenable to repair with suture, some have been larger, requiring ligation with or without the insertion of a vascular graft. Not surprisingly, death has been reported in a number of instances.

Diagnosis: If great vessels are injured, most often the problem presents as profound hypotension with or without the appearance of a significant volume of blood within the peritoneal cavity. In some instances, the surgeon aspirates blood via the insufflation needle, prior to introduction of distension gas. Frequently, the bleeding may be contained in the retroperitoneal space, a feature that usually delays the diagnosis. Consequently, the development of hypovolemic shock in the recovery room may well be secondary to otherwise unrecognized laceration to a great vessel. To avoid the late recognition, it is important to evaluate the course of each great vessel prior to completing the procedure.

Prevention: There are a number of ways by which the incidence of large vessel trauma can be minimized. Certainly, it is essential that the positioning of ancillary or secondary trocar in the lower quadrants be performed under direct vision. This is more difficult for the primary cannula. It has been suggested that the use of "open laparoscopy" for the initial port entirely avoids the issue of great vessel injury secondary to insufflation needles and trocars. However, open laparoscopy has its own potential drawbacks such as increased operating time, the need for larger incisions, and a greater chance of wound infection, all without eliminating the incidence of bowel injury at entry.

The risk of large vessel injury should be reduced if careful attention is paid to access technique and equipment used. If used, both insufflation needles and the trocar should be kept sharp and surgeon should use same instrument each time. The safety sheath of the insufflation needle should be checked to ensure that both the spring and the sliding mechanism are functioning normally. Many disposable trocar-cannula systems are constructed with a safety mechanism that covers or retracts the trocar following passage through the fascia and peritoneum. However, there are currently no available data that demonstrate a reduction in the incidence of major vessel injury with the use of these devices.

The application of appropriate technique is based upon a sound understanding of the normal anatomic relationships between the commonly used entry points and the great vessels. A "safety zone" exists inferior to the sacral promontory in the area bounded superiorly by the bifurcation of the aorta, posteriorly by the sacral curve, and laterally by the iliac vessels. 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. Such positioning requires elevation of the abdominal wall while angling the insufflation needle about 45º to horizontal. The tactile and visual feedback created when the needle passes through the fascial and peritoneal layers of the abdominal wall, if recognized and heeded, may prevent overaggressive insertion attempts. Such proprioceptive feedback is diminished with disposable needles as compared to the classic Veress model. Instead, the surgeon must listen to the "clicks" as the needle obturator retracts when it passes through the rectus fascia and the peritoneum. The needle should never be forced.

It is critical to note that these anatomic relationships may vary with body type and with the orientation of the patient to the horizontal position. In women of normal weight and body habitus, in the horizontal recumbent position, the bifurcation of the aorta is located immediately beneath the umbilicus. However, in obese individuals, the umbilicus may be positioned up to 2 or more cm below bifurcation. Fortunately, this circumstance allows the insufflation needle to be directed in a more vertical position—those between 160 and 200 pounds between 45 and 90°, while those women over 200 pounds at nearly 90°. Women placed in a head-down position (Trendelenburg position) will shift their great vessel more superiorly and anteriorly in a fashion that may make them more vulnerable to an entry injury. Consequently, positioning of the insufflation needle, and at least the initial trocar and cannula, should be accomplished with the patient in a horizontal position. This approach additionally facilitates the evaluation of the upper abdomen, an exercise that is limited if the intraperitoneal content is shifted cephalad by the patient's head-down position.

The risk of great vessel injury is likely reduced by insufflating the peritoneal cavity to adequate pressure. An intraperitoneal pressure of 20 mm Hg, while not desirable for prolonged periods of time, can aid in separating the abdominal wall from the great vessels during the process of insertion of a sharp trocar.

Management: If blood is withdrawn from the insufflation needle, it should be left in place while immediate preparations are made to obtain blood products and perform laparotomy. If the diagnosis of hemoperitoneum is made upon initial visualization of the peritoneal cavity, a grasping instrument may be used, if possible, to temporarily occlude the vessel. While it is unlikely that significant injury can predictably be repaired by laparoscopically directed technique, if temporary hemostasis can be obtained, and the laceration visualized, selected, localized lesions can be repaired, with suture, under laparoscopic guidance. Such an attempt should not be made by any other than experienced and technically adept surgeons. Even if such an instance exists, fine judgment should be used so as not to delay the institution of lifesaving, open surgical repair.

Most surgeons should gain immediate entry into the peritoneal cavity and immediately compress the aorta and vena cava just below the level of the renal vessels, gaining at least temporary control of blood loss. At that juncture, the most appropriate course of action, including the need for vascular surgical consultation, will become more apparent.

Abdominal Wall Vessels

Most commonly injured abdominal wall vessels are the inferior epigastric and superior epigastric vessel. They are invariably damaged by the initial passage of an ancillary trocar or when a wider device is introduced 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, it is not uncommon for the cannula itself to obstruct the bleeding until withdrawal at the end of the case.

More sinister are injuries to the deep inferior epigastric vessels, branches of the external iliac artery and vein that also course cephalad, but are deep to the rectus fascia and often deep to the muscles themselves. More laterally located are the deep circumflex iliac vessels that are uncommonly encountered in laparoscopic surgery. Laceration of these vessels may cause profound blood loss, particularly when the trauma is unrecognized and causes extraperitoneal bleeding.

Diagnosis: Diagnosis of abdominal wall vasculature injury is by visualization of the blood dripping down the cannula or by the postoperative appearance of shock, abdominal wall discoloration, and/or a hematoma located near to 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 at the end of the procedure by laparoscopically evaluating each peritoneal incision following removal of the cannula.

Prevention: With the help of telescope, transillumination of the abdominal wall from within will, at least in most thin women, allow for identification of the superficial inferior epigastric vessels. However, the deep inferior epigastric vessels cannot be identified by this mechanism because of their location deep to the rectus sheath. Consequently, prevention of deep inferior epigastric vessel injury requires that the surgeon understand the anatomic course of these vessels.

The most consistent landmarks are the median umbilical ligaments (obliterated umbilical arteries) and the entry point of the round ligament into the inguinal canal. At the pubic crest, the deep inferior epigastric vessels begin their course cephalad between the medially located medial umbilical ligament and the laterally positioned exit point of the round ligament. The trocar 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 trocar laterally, it should be positioned 3–4 cm lateral to the median umbilical ligament or lateral to the lateral margin of the rectus abdominis muscle. Too lateral an insertion will endanger the deep circumflex epigastric artery. The operator may further limit risk of injury by placing a No. 22 spinal needle through the skin at the desired location, directly observing the entry via the laparoscope. This not only provides more reassurance that a safe location has been identified, but the easily visualized peritoneal needle hole gives the surgeon a target for inserting the trocar with greater precision.

A common mistake is to fashion the incision appropriately, only to direct the trocar medially in its course through the abdominal wall, thereby injuring the vessels. Another factor that may contribute to the risk of injury is the use of large diameter trocar. Consequently, for this and other reasons, the surgeon should use the smallest trocar necessary for performance of the procedure.

Management: Superficial inferior epigastric artery lacerations usually respond to expectant management. Rotation of the cannula to a position where compression is possible is also helpful. Rarely is a suture necessary.

We have found that the use of a straight suture passer is most useful for the ligation of lacerated deep inferior epigastric vessels. A number of other devices and techniques have been introduced that facilitate the accomplishment of this task. To summarize, the trocar and cannula are removed. Then, under laparoscopic visualization and using a ligature carrier, a ligature is placed through the incision and directed laterally and inferiorly, where it is held by a grasping forceps. The ligature carrier is removed and subsequently passed through the incision again, without a suture, but this time medial and inferior to the lacerated vessels. The suture is threaded into the carrier from within the peritoneal cavity and is then externalized and tied. For small incisions, narrower than the diameter of the surgeon's finger, the knot may be tightened with a knot manipulator.

There are other less uniformly successful methods for attaining hemostasis from a lacerated deep inferior epigastric vessel. The most obvious is the placement of large, through-and-through mattress sutures. These are usually removed about 48 hours later. Electrodesiccation may be successful. Either a unipolar or bipolar grasping forceps is passed through another ancillary cannula taking care to identify, grasp, and adequately desiccate the vessel. Either continuous or "blended" current is used at appropriate power outputs for the machine and the electrode. Another method that has enjoyed some success is temporary compression with the balloon of a Foley catheter, passed through the incision into the peritoneal cavity, then secured and tightened externally with a clamp. While some suggest that the balloon should be left in place for 24 hours, the delicate channel may be damaged by the clamp, making it impossible to deflate the balloon. For this reason, we not recommend this option.

Intraperitoneal Vessel Injury

The bleeding may result from inadvertent entry into a vessel failure of a specific occlusive technique or human error in the application of the selected technique. Furthermore, in addition to the problem of delayed hemorrhage inherent in transection of arteries, there may be further delay in diagnosis at laparoscopy because of the restricted visual field and the temporary occlusive pressure exerted by the CO_2 within the peritoneal cavity.

Diagnosis: During laparoscopy, inadvertent division of an artery or vein will usually become immediately self-evident. However, in some instances, transected arteries will go into spasm only to begin bleeding minutes to hours later, an event that may temporarily go unnoticed due to the limited field of view presented by the laparoscope. Consequently, at the end of the procedure, all areas of dissection should be carefully examined. In addition, the CO_2 should be vented, decreasing the intraperitoneal pressure to about 5 mm Hg, allowing recognition of vessels occluded by the higher pressure.

Prevention: Attention to meticulous technique is at least as important in laparoscopically-directed surgery as it is for open or vaginal cases. During dissection, vessels should be identified and occluded prior to division, a task made simpler by the magnification afforded by the laparoscope. If suture is used to occlude a vessel, it must be, of the appropriate caliber, positioned with an adequate pedicle and tied snugly with a secure knot. Electrosurgery, if used, should be applied in the appropriate waveform and power density and for a time adequate to allow for sufficient tissue desiccation. Clips should be of a size appropriate for the vessel and they must be applied in a secure fashion, also with an adequate pedicle of tissue. Care should be exercised to avoid manipulation of pedicles secured with clips or suture, as such trauma could adversely affect the security of the closure. When linear stapling devices are employed, the appropriate staple size should be selected and the tissue encompassed in the staple line should be of uniform thickness. Failure to maintain relatively uniform tissue thickness may result in inadequate compression of blood vessels that course through the thinner areas of the pedicle.

Management: Transected vessels should be secured immediately. If electrosurgical desiccation is used to maintain or achieve hemostasis, the use of a serial ammeter is useful to demonstrate the endpoint of energy application. There is evidence that artery larger in diameter than 3 mm is less reliably occluded with desiccation than are those 3 mm or less. Care must be exerted to avoid blind clamping and electrosurgical desiccation, even with bipolar instruments, especially when <1 cm from ureter or bowel. When a vessel is in such a location, it is usually preferable to secure it with a clip.

Identification of small vessel bleeding and ooze is often facilitated by the use of copious irrigation and even underwater examination. Capillary ooze may be managed with higher voltage fulguration currents using electrodes with a bulbous tip. When using electrosurgery for this purpose, the use of electrolyte-containing solutions should be avoided, as they disperse current, rendering the technique ineffective. Instead, the low viscosity fluids such as glycine are recommended as, in addition to being nonconductive, they may facilitate localization of the vessels.

GASTROINTESTINAL COMPLICATIONS

Following laparoscopy, it is not uncommon for the patient to experience nausea. However, in some instances, the problem becomes severe. Gastrointestinal viscera potentially injured during the performance of gynecologic laparoscopy and include the stomach, the small bowel, and the colon.

Insufflation Needle Injuries

Needle entry into the stomach almost invariably happens in the presence of gastric distension. While this may occur secondary to aerophagia, the complication is frequently related to difficult or improper intubation or to the use of mask induction with an inhalation anesthetic. Mechanical entry into large or small bowel may occur in any instance, but is up to 10 times more common when laparoscopy is performed on patients with previous intraperitoneal inflammation or abdominal surgery. In such instances, loops of intestine can adhere to the abdominal wall under the insertion site. Perforation may also occur following an overly aggressive attempt to insert the insufflation needle.

Recognition

Recognition of gastric entry by the insufflation needle may follow identification of any or all of the signs of extraperitoneal entry, including increased filling pressure, asymmetric distension of the peritoneal cavity, or the aspiration of gastric particulate matter through the lumen of the needle. However, the hollow, capacious nature of the stomach may allow the initial insufflation pressure to remain normal. Unfortunately, in some instances, the problem is not identified until the trocar is inserted and the gastric mucosa identified by direct vision. Recognition of bowel entry usually follows observation of the signs described above for gastric injury, with the addition of feculent odor to the list of findings. Prevention of insufflation needle injury to the gastrointestinal tract is important because such measures largely eliminate the risk of more sinister trocar trauma. Gastric perforation can largely be eliminated with the selective use of preoperative oral or nasogastric suction. The surgeon should request that this can be performed if there has been difficulty with intubation or when the needle is intentionally inserted near to the stomach in the left upper quadrant.

Many have suggested that open laparoscopy is the most appropriate and effective way to reduce the incidence of intestinal injury in a patient at risk because of previous lower abdominal surgery. However, there are no studies that prove this to be the case. Indeed, there exists evidence that open laparoscopy is itself associated with intestinal injury. Consequently, many surgeons have suggested the use of left upper quadrant insertion with a properly decompressed stomach.

Although not strictly a prophylactic measure, the routine use of preoperative mechanical bowel preparation, at least in selected, high-risk cases, will diminish the need for laparotomy and/or colostomy, if large bowel entry occurs.

Management

The management of any trauma to the gastrointestinal tract depends in part upon the nature of the injury and in part upon the organ(s) involved. In general, insufflation needle punctures that have not resulted in a defect significantly larger than their diameter may be handled expectantly. Larger defects should be repaired or resected, by laparoscopic- or a laparotomy-based technique, depending upon extent of the lesion.

If, following insertion of an insufflation needle, particulate debris is identified, the needle should be left in place and an alternate insertion site identified such as the left upper quadrant. If the insufflation needle possesses a removable obturator, an arrow caliber optical fiber or laparoscope may be passed to evaluate the location of the tip and to aid in later identification of the puncture site. Immediately following successful entry into the peritoneal cavity, the site of injury is identified. Unless significant injury or bleeding is identified, the situation may be handled expectantly. If there is unexpected extension of the laceration, it should be managed similarly to a trocar injury.

Trocar Injuries

During access technique, damage caused by sharp trocar penetration is usually more serious than when needle injury occurs. Most often, the injury is created by the primary trocar because of its blind insertion. However, inadequate attention paid to the insertion of ancillary cannulas may also result in visceral injury.

Diagnosis

If a primary trocar penetrates bowel, the diagnosis is usually made when the surgeon visualizes the mucosal lining of the gastrointestinal structure following insertion of the laparoscope. If large bowel is entered, feculent odor may be noted. However, in some instances, the injury may not immediately be recognized as the cannula may not stay within or it may pass through the lumen and out the other side of the viscus. Such injuries usually occur when a single loop of bowel is adhered to the anterior abdominal wall near to the entry point. Consequently, it is important at the end of the procedure to directly view the removal of the primary cannula, either through the cannula itself or via an ancillary port. Routine direct visualization of primary port incisional closure will facilitate the accomplishment of this task. Unfortunately, the injury may go unrecognized until it presents postoperatively as peritonitis, abscess, enterocutaneous fistula, or death.

Prevention

The following measures were reported to reduce the incidence of trocar injuries:

- Disposable laparoscopes are usually sharper. They require less force to insert and, thus, there is less chance of compressing the trocar against the bowel or blood vessels
- Some manufacturers provide a plastic sheath, which springs and covers the sharp edge of the trocar after insertion. Safety shields will not prevent injury, however, in case of bowel adhesions
- The use of ultrasound to "map" the abdominal wall for safe entry area is recommended, especially when adhesions are present
- The smaller 5 mm cannula is safer as it requires less pressure to insert. Equipped with a camera, it allows safe placement of the larger cannula under vision
- Hasson described an open surgical approach to placement of the cannula, thus reducing the risk of perforation by the blind closed technique
- Before the conclusion of surgery, a thorough search for bowel injuries must be performed as delay in recognition of such injury can be catastrophic. Thus, review of the videotapes can ascertain if safety measures were taken during this critical part of the procedure.

Despite the widespread use of retractable trocars or safety sheaths, injury to bowel or other structures may occur. As stated above, many employ, routinely or selectively, the concept of "open" laparoscopy, where the peritoneal cavity is entered directly via an infra- or intraumbilical incision. Despite the apparent virtues of this approach, bowel entry may still occur. An alternative approach, especially when entering an abdomen with previous laparotomy scars, is the insertion of an arrow caliber cannula in the left upper quadrant following decompression of the stomach. It is unusual for a patient to have had previous surgery in this location. Following placement of the cannula, usually just below the costal margin in the midclavicular line, an arrow diameter laparoscope may be passed, allowing a direct view of the abdominal wall under the umbilicus or other planned site of insertion. If necessary, the small laparoscope may be used to direct the dissection of intestine from under the insertion site. This approach gains additional value with the introduction of a fiber laparoscope small enough to fit through the lumen of an insufflation needle.

Stomach injuries most frequently occur when there has been difficulty in intubation and may be more common following left upper quadrant insertion if the stomach has not previously been decompressed. Consequently, liberal use of oral or nasogastric decompression will likely reduce the incidence of trocar injury to the stomach.

Most common cause of bowel injuries usually is when the intestine is adherent to the abdominal wall under the site of trocar insertion. Adherence is usually secondary to previous surgery. Consequently, in such patients, open laparoscopy or left upper quadrant entry may be used. Preoperative mechanical bowel preparation should be employed in high-risk patients to facilitate repair of colonic defects without the need to perform a laparotomy.

Management

Trocar injuries to small bowel require repair. If it can be ascertained that the injury is isolated and if the operator is capable, the lesion may be sutured under laparoscopic guidance with a double layer of running 2-0 or 3-0 synthetic absorbable suture. Extensive lesions may require resection and reanastomosis. In well-trained and experienced hand, this may be performed under laparoscopic direction. However, in most instances, laparotomy will be required. Regardless of the method of repair, copious irrigation should be employed and the patient admitted for postoperative observation. The patient is kept without oral intake and nasogastric decompression should be liberally used at the discretion of the surgeon.

If the injury is to the sigmoid colon, primary repair may be attempted if the bowel has been mechanically prepared preoperatively. Otherwise, colostomy should be considered, with the possible exception of ascending colon lesions. If uncertainty exists regarding the extent of injury, laparotomy is always indicated.

INJURY TO BLADDER

Laparoscopy-associated damage to the bladder or ureter may occur secondary to mechanical or thermal trauma. Vesical injury is often secondary to a trocar entering the undrained bladder, but may also occur during dissection of the bladder, either from other adhered structures or from the anterior aspect of the uterus. The proliferation of laparoscopically-directed retropubic suspension for urinary incontinence will likely be associated with bladder injury. Ureteric injury is more commonly encountered secondary to thermal damage. However, more recently, there have been descriptions of ureteric trauma secondary to other causes such as mechanical dissection or the use of linear stapling devices.

Diagnosis

If urinary bladder is injured, intraoperative identification of the injury is the most important aspect of management. The surgeon may be cognizant of entering a hollow viscus or may note the presence of urine in the operative field. If an indwelling catheter is in place, hematuria or pneumaturia (CO_2 in the indwelling drainage system) may be noted. Existence of a bladder laceration may be confirmed with the injection of sterile milk or a dilute methylene blue solution via a catheter. Thermal injury to the bladder may not be initially apparent, presenting later in the patient's postoperative course.

Unfortunately, although intraoperative recognition of ureteric injury has been described, diagnosis is usually delayed until sometime following the procedure. Ureteric lacerations may be proven intraoperatively with the injection of indigo carmine. Thermal injury will present, 24 hours to 14 days, following surgery with one or a combination of fever, abdominal or flank pain, and the clinical findings of peritonitis. A leukocytosis may be present and an intravenous pyelogram (IVP) will demonstrate extravasation of urine or urinoma. Intraoperative recognition of mechanical obstruction, with staples or a suture, will be made only by direct visualization. Not surprisingly, cases of laparoscopy-associated ureteric obstruction seem to present at a time similar to those that follow laparotomy-based procedures a few days to a week following the operation. These patients present with flank pain and may have fever. The diagnosis may be suggested by abdominal ultrasound, but an IVP can be more precise at identifying the site and completeness of the obstruction.

Uretero- or vesicovaginal fistula will present in a delayed fashion with incontinence or discharge. Confirmation of bladder fistula will be by direct visualization and/or the leakage of instilled methylene blue onto a tampon. Ureterovaginal fistula will not pass the methylene blue from the bladder, but will be demonstrated with the intravenous injection of indigo carmine.

Prevention

Before start of surgery, patient should void urine. Trocar-related cystotomies are generally preventable with routine preoperative bladder drainage. Additional caution must be exercised in the patient previously exposed to abdominal or pelvic surgery, where there is a tendency for the bladder to be pulled above the level of the symphysis pubis. The urachus, although rarely present, should be avoided, if possible. It is likely that the placement of an indwelling catheter, at least for prolonged or difficult cases, will reduce the incidence of injury resulting from dissection. Surgical 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.

If the surgeon cannot, with assurance, steer a wide path from its course, the ureter must be directly visualized. This is especially true when laser, electrosurgical, or stapling techniques are employed. Frequently, the ureter can be seen through the peritoneum of the pelvic sidewall between the pelvic brim and the attachment of the broad ligament. However, because of patient variation or the presence of pathology, the location of the ureter can become obscured. In such instances, the ureter can usually be visualized through the peritoneum at the pelvic brim, although the maneuver is slightly more difficult on the left because of the location of the sigmoid mesentery. If CO_2 laser energy is to be employed, fluid injected at an appropriate location between the peritoneal surface and the ureter can provide a degree of protection from thermal injury.

If entry into the retroperitoneal space is required for exposure, there should be no hesitation to undertake such dissection. The surface of the peritoneum should be breached with scissors at the closest level proximal, and anterior, to the most distal site of planned dissection where the location of the ureter is known or anticipated. If the ureter is seen through the peritoneum, it may be grasped with a Babcock forceps to minimize trauma while the peritoneum is incised. Careful sharp and blunt dissection then may be applied to provide adequate exposure in the operative field. If the ureter cannot be seen through the peritoneal surface, a fine, toothed forceps should be employed to grasp and elevate the peritoneum allowing careful entry into the retroperitoneal space.

The techniques used for retroperitoneal dissection are also important in reducing the risk of ureteric injury. Blunt dissection can be facilitated with the instillation of fluid into the retroperitoneal space under pressure. Others have advocated the selective preoperative placement of ureteric stents including those that are illuminated to provide additional safety. We prefer instead the use of mechanical (sharp or blunt) dissection with sharp-curved scissors and a narrow, pointed grasping forceps attached to an electrosurgical generator. The assistant is provided with a narrow, pointed, and toothed grasping forceps as well as a suction irrigation system to use, as requested, through an ancillary cannula. Dissection proceeds, respecting the blood supply of the ureter, by minimizing direct manipulation and by preserving the integrity of its sheath. If electrical energy is used, it must be applied judiciously at safe distances from the ureter and its blood supply. The narrow, pointed grasping forceps facilitate precise and safe desiccation of small caliber blood vessels.

Treatment

Most of the injury of the bladder can be managed conservatively. Small caliber injuries to the bladder (1–2 mm) may be treated expectantly, with prolonged catheterization for 7–14 days. However, in such cases, the duration of catheterization can be reduced or eliminated if repair is undertaken intraoperatively. When a more significant injury to the bladder is identified, it may often be repaired under laparoscopic direction, provided the presence of adequate surgical skill and a location that is amenable to laparoscopic technique. Further evaluation of the location and extent of the laceration may be provided by direct laparoscopic examination of the mucosal surface of the bladder. Should the laceration be near to or involve the trigone, open repair may be preferable. In making this evaluation, the mechanism of injury should be considered, as desiccation resulting from electrical energy may extend beyond the visible limits of the lesion.

A purse string closure may be fashioned using any of a number of synthetic absorbable sutures of 2-0 to 3-0 caliber, tying the knot either intra- or extracorporeally. For linear lacerations, the defect is preferably closed in two layers. If there is significant thermal injury, it may be valuable to excise the coagulated segment. Postoperative catheterization with either a large caliber urethral or suprapubic catheter should be maintained for 5–7 days for simple fundal lacerations and for 2 weeks for those closer to the trigone, the vaginal vault, or those that may be associated with significant thermal injury.

During minimal access surgery, intraoperative diagnosis of ureteric injury provides the opportunity for intraoperative management. If damage is less, it may respond adequately to the passage of a ureteric stent for about 10–20 days. However, in most instances, repair is indicated. The principles should follow those previously established for open cases. While laparoscopically-directed repair of ureteric lacerations and transections have been described, such maneuvers should be practiced only by those with exceptional surgical skill and experience. Even in these cases, it is advisable to consult intraoperatively with a specialist in urology.

When the diagnosis of ureteral injury is delayed until following surgery, the imperative is to establish drainage. Some obstructions or lacerations, if incomplete or small, may be successfully treated with either the retrograde or anterograde passage of a ureteral stent. Urinomas may be drained percutaneously. If a stent cannot be successfully manipulated across the lesion, a percutaneous nephrostomy should be created and plans should be made for operative repair.

NEUROLOGIC INJURY

The incidence of nerve injury associated with laparoscopy is more common in obese patient, but has been estimated at 0.5 per 1,000 cases. Peripheral neurologic injury is usually related either to inappropriate positioning of the patient or occurs secondary to pressure exerted by the surgeon or assistants. During laparoscopy, nerve injury may happen rarely as a result of the surgical dissection.

In the lower extremity, the trauma may be direct such as compression of the perineal nerve against stirrups. Alternatively, the femoral nerve or the sciatic nerve or its branches may be overstretched and damaged by inappropriate positioning of the hip or the knee joint.

Brachial plexus injuries may occur secondary to the surgeon or assistants leaning against the abducted arm during the procedure. Alternatively, if the patient is placed in steep Trendelenburg position, the brachial plexus may be damaged because of the pressure exerted on the shoulder joint.

Diagnosis

If nerve is damaged in most instances, the patient is found to have sensory and/or motor deficit as they emerge from the effects of the anesthesia. The diagnosis can usually be suspected by clinical examination. Injuries to the perineal nerve will be reflected by loss of sensation in the lateral aspect of the leg and foot together with a foot drop. Brachial plexus injuries may be variable, but usually involve damage to the C5-C6 roots manifesting in loss of flexion of the elbow and adduction of the shoulder. Electromyography can be used to further define the extent and location of the lesion by testing nerve conduction and recording the electrical potential for various muscles. This evaluation should be delayed for 3 weeks to allow for complete degeneration of injured nerves.

Prevention

During laparoscopic procedure, if nerve injury has to be prevented, then surgeon should must achieve a good ergonomics of patient. The incidence of brachial plexus injury can be reduced by placing the arms in an adducted position, which also facilitates the performance of pelvic surgery by allowing the surgeon to stand in a more comfortable position. Should it be necessary to leave the arm in an abducted position, adequate padding and support of the arms and shoulders are necessary and can be facilitated with the use of shoulder supports, preventing the slippage of the patient up the table when placed in Trendelenburg position. Furthermore, in such a position, the surgeon may not lean on the patient's arm.

Sciatic and perineal nerve injury is minimized with the use of appropriate stirrups and careful positioning protocols. Those stirrups that combine both knee and foot support are probably best. Additional measures include simultaneous raising and lowering of the legs, flexion of the knees before flexion of the hips, and limitation of external rotation of the hip. Assistants should be admonished to avoid placing undue pressure on the inner thighs.

Injury to the obturator and genitofemoral nerves is uncommon, but will likely increase as greater numbers of retroperitoneal dissections are performed. In such cases, it will be important to clearly understand the anatomy, maintain hemostasis, and to exert the utmost care in performing the dissections, carefully identifying the neural structures as they are encountered.

Management

Most injuries to peripheral nerves recover spontaneously. The time to recovery depends upon the site and severity of the lesion. For most peripheral injuries, full sensorineural recovery occurs in 3–6 months. Recovery may be facilitated with physical therapy, appropriate braces, and electrical stimulation of the affected muscles. Transection of major intrapelvic nerves will require open microsurgical repair.

DISSECTION AND THERMAL INJURY

Recognition

Diagnosis of injury to the bowel incurred during the course of dissection may be more straightforward. Any length of dissected bowel should be carefully examined prior to proceeding further with the procedure. This is, if anything, more important during laparoscopic operations in comparison to those performed via laparotomy, for comprehensive "running" of the bowel near the end of the case is far more difficult under endoscopic guidance.

There has been confusion in the past regarding the frequency of thermal injury to bowel following the use of electrical energy. Formerly, many injuries actually caused by mechanical trauma were erroneously attributed to electrosurgical accidents.

Thermal injury to bowel may be more difficult to diagnose intraoperatively, particularly if created with electrical or laser energy, a feature that makes careful adherence to safety protocols a surgeon's imperative. Even if thermal injury is recognized, it is difficult to estimate the extent of the damage by visual inspection, as the zone of desiccation may exceed the area of visual damage. An understanding of the differing impacts of the various types of electrical current is essential for estimation of the extent of injury. In some instances, diagnosis is delayed until the development of peritonitis and fever, usually a few days later, but occasionally not for several weeks.

Prevention

Total prevention of dissection or thermal injury is impossible, but the incidence of penetrating or energy-based enteric complications may be reduced with patience, prudence, and meticulous technique. A sound understanding of the principles of electrosurgery is critical to reducing the incidence of electrical trauma.

When dissecting, exposure of the operative field must be accomplished with a combination of good visualization and adequate traction and, if necessary, countertraction applied by forceps. In many instances, it will be necessary to enlist the aid of a competent assistant. Dissection close to bowel should be performed mechanically, using sharp scissors, not with electrical or laser energy sources. Occlusion of blood vessels near to bowel is preferably accomplished with clips, but may be performed with bipolar current provided that there is an adequate margin of tissue, a circumstance that usually requires skeletonization of the vessel.

There is no certainty about the proper distance to maintain between the electrode and the bowel serosa. Animal histological studies, using the rather large caliber Kleppinger forceps, have demonstrated that desiccation injury begins to affect bowel serosa and muscularis between 5 and 10 mm away. It is likely that the zone of safety is less for instruments that compress tissue well or that use electrodes with a smaller surface area. Regardless, if the difficulty of the dissection makes the surgeon uncomfortable, alternative methods for hemostasis should be used. If this is not feasible, the aid of more experienced colleagues should be sought the procedure abandoned or converted into an open case.

Management

The treatment of mechanical bowel trauma recognized during the dissection follows the principles described above for trocar injury. If the diagnosis is delayed until the postoperative recognition of peritonitis, surgical consultation should be obtained and laparotomy arranged.

Thermal injury may be handled expectantly, if the lesion is superficial and confined. It is possible to estimate the degree of tissue injury, if the nature of the current and other parameters is known, such as the wattage, current density, and duration of contact with tissue. For example, fulguration current, arcing to bowel, is unlikely to cause thermal injury >1 mm deep, even with rather prolonged exposure. On the other hand, the high power density provided by a sharp electrode will quickly cause penetrating injury of the bowel. Such lesions will have relatively little collateral thermal injury and may be repaired as if they were created by mechanical means. This is a circumstance vastly different from that occurring when there is direct and even relatively short, duration of contact (seconds) with a low power density electrode. The significant thermal injury that results will often mandate wide excision of the lesion or local resection of the injured segment of bowel.

INCISIONAL HERNIA

It is not that the incidence of laparoscopic incisional hernia is unknown, it is clear that the complication has been underreported. Recent reports of incisional hernia after laparoscopy have stressed the relationship of this complication with the use of ports 10 mm in diameter or larger. In our opinion, this can probably be attributed to increased operating times which result in excessive manipulation of the port site, thereby widening the fascial and peritoneal defects.

While no incision is immune to the risk of herniation, those defects that are 10 mm or more in diameter are particularly vulnerable. The increasing number and size of the incisions, ID combination with the surgeon's variable propensity to close them, will likely further contribute to the increasing incidence. Another important contributing factor may be the use of cannula anchoring devices that effectively increase the diameter of the incision by 2–3 mm.

Diagnosis

After laparoscopy, the most common hernia appears to occur in the immediate postoperative period where bowel or omentum passes through the unopposed or inadequately repaired defect. The patient may be symptomatic or can present with any or a combination of pain, fever, periumbilical mass, obvious evisceration, and the symptoms and signs of mechanical bowel obstruction, often within hours and usually within the first postoperative week. Consequently, the surgeon should take care not to casually disregard the patients who talk about symptoms consistent with herniation.

Because Richter's hernias contain only a portion of the circumference of the bowel wall in the defect, the diagnosis is often delayed. It is likely that such lesions most commonly occur in incisions that are made away from the midline. The initial presenting symptom is usually pain, since the incomplete obstruction and still allows the passage of intestinal content. Fever can present if incarceration occurs and peritonitis may result from the subsequent perforation. The diagnosis is difficult to make and requires a high index of suspicion. Ultrasound or CT scanning may be useful in confirming the diagnosis.

While many defects likely remain asymptomatic, late presentation may occur if bowel or omentum becomes trapped. The symptoms and findings are similar to that described for earlier presentations.

Prevention

The underlying fascia and peritoneum should be closed not only when using trocars of 10 mm and larger as previously suggested, but also when extensive manipulation is performed through a 5-mm trocar port, causing extension of the incision.

There are a number of unproven but seemingly logical preemptive strategies. First, it is desirable to use the smallest possible cannula whenever possible recognizing that hernia has even been reported in conjunction with the use of 5 mm trocars. Second, the "Z-track" insertion method, particularly applied, in the umbilicus, may be of value. This approach offsets the skin and fascial incisions by entering the subcutaneous tissue, then sliding the conically-tipped trocar along the fascia for a short distance prior to penetrating it. Such a track is purported to close like a curtain, reducing the incidence of hernia. Third, all ancillary cannula should be removed under direct vision to ensure that bowel is not drawn into the incision. Insertion of an obturator (or a laparoscope) into the cannula may further prevent suction from drawing bowel or omentum into the incision. Fourth, at least those incisions 10 mm or greater in diameter should undergo fascial closure under direct laparoscopic vision, thereby preventing incorporation of bowel. This may be accomplished by using a small caliber diameter laparoscope through one of the narrow cannula to direct incisional closure. A narrow diameter, three-quarter round, needle (Ethicon UR-6) facilitates such a closure, as does the use of one of the newer devices. Finally, the laparoscope cannula should be removed with the laparoscope in position, preventing accidental incorporation of bowel.

If the final incision is of sufficiently large diameter to require closure, blind insertion of needles may be avoided by prepositioning sutures. They are placed when the laparoscope is in another location and tied following removal of the final cannula. The sutures should be used to elevate the abdominal wall as the laparoscope and cannula are simultaneously removed, looking down the endoscope to ensure that bowel or omentum are not inadvertently drawn into the wound.

Management

Management of postoperative development of incisional hernia after laparoscopy is same as that of open surgery. Management of laparoscopic incisional defects depends upon the timing of the presentation and the presence or absence of entrapped bowel and its condition. Evisceration will always require surgical intervention. If the diagnosis is made in the recovery room, the patient may be returned to the operating room, the bowel or omentum replaced in the peritoneal cavity (provided there is no evidence of necrosis or suture incorporation), and the incision repaired, usually under laparoscopic guidance. However, if the diagnosis is delayed, it is likely that the bowel is incarcerated and at risk for perforation. In such circumstances, resection will likely be necessary, usually via laparotomy. Most gynecologic surgeons should request general surgical consultation.

INFECTION

Wound infection following laparoscopy is less but not rare. Even a case of postoperative wound infection due to *Mycobacterium chelonae* also has been reported. A 35-year-old woman presented with multiple erythematous nodules, plaques, and discharging sinuses over the abdomen, 45 days after she had undergone laparoscopic ovarian cystectomy. The seropurulent discharge from the wound showed acid-fast bacilli on Ziehl–Neelsen stain and culture yielded *Mycobacterium chelonae*. The patient responded to clarithromycin and doxycycline. The source of infection was probably contaminated water or disinfectant solution used for sterilization of laparoscopic instruments. In the urologic and general surgical wound infection, rates seem to range from 5 to 6 per 1,000 cases. While the vast majority of wound infections are handled successfully with expectant management, drainage, or antibiotics, severe necrotizing fasciitis has been reported.

Many other types of postlaparoscopy infection have been reported including bladder infection, pelvic cellulitis, and pelvic abscess. While bacteremia has been described, there have been no reports of disseminated infection following laparoscopic surgery.

This is true that the risk of infection associated with laparoscopy is low, much lower than that associated with open abdominal or vaginal surgery. Nevertheless, until clinical studies dictate otherwise, it is prudent to continue to practice strict sterile technique and to offer appropriate prophylactic antibiotics to selected patients. These could include those with enhanced risk for bacterial endocarditis as well as those who are to undergo procedures (e.g., laparoscopic hysterectomy), suspected of increasing the chance of wound, or vault infection. Patients should be instructed to routinely take their temperature following discharge and to immediately report fever of 38°C or more.

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