REVIEW

Complications and Recommended Practices for Electrosurgery in Laparoscopy

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BACKGROUND: Electrosurgery is one of the most commonly used energy systems in laparoscopic surgery. Two major categories of potential complications related to electrosurgery in laparoscopy are mechanical trauma and electrothermal injury. The latter can result from unrecognized energy transfer in the operational field or, less commonly, to unnoticed stray current outside the laparoscopic field of view. Stray current can result from insulation failure, direct coupling, or capacitive coupling.

METHODS: We reviewed the literature concerning essential biophysics of electrosurgery, including electrosurgical waveform differentiation, tissue effect, and variables that determine tissue effect. The incidence of electrosurgical injuries and possible mechanisms responsible for the injuries are discussed. Different types of injuries may result in different clinical manifestations and histopathological findings. Gross and microscopic pathological check-ups of the injury sites may distinguish between different mechanisms, and thus provide further clues postoperatively.

RESULTS: Several recommended practices are proposed to avoid electrosurgical injury laparoscopically. To achieve electrosurgical safety and to prevent electrosurgical injuries, the surgical team should have a good understanding of the biophysics of electrosurgery, the basis of equipment and general tissue effects, as well as the surgeon's spatial orientation and hand-eye coordination. Some intraoperative adjuvant procedures and newly developed safety devices have become available may aid to improve electrosurgical safety.

CONCLUSIONS: Knowledge of the biophysics of electrosurgery and the mechanisms of electrosurgical injury is important in recognizing potential complications of electrosurgery in laparoscopy. Procedures for prevention, intraoperative adjuvant maneuvers, early recognition of the injury with in-time salvage treatment, and alertness to postoperative warning signs can help reduce such complications. ***Am J Surg.*** **2000; 179:67–73. © 2000 by Excerpta Medica, Inc.**

Since the introduction of the small medical video camera in the mid 1980s, the advent of laparoscopic surgery has brought a revolution in surgical techniques with shorter hospitalization and convalescence.[1,2] The rapid increase in the use of these procedures and numerous reports of adverse outcomes have raised justifiable concern.[3] Surgeons who are skilled in open techniques need additional training to become proficient with laparoscopic techniques. The required spatial orientation, hand-eye coordination, and manipulative skills under laparoscopy are quite different.[4] All surgeons are aware of their own "learning curves," during which time complication rates may be appreciable.[5,6] In laparoscopic surgery, electrosurgery is one of the most commonly used energy systems. Potential complications specific to electrosurgery relate to unrecognized energy transfer, commonly referred to as "stray current," occurring within the operational field of view and less commonly outside the laparoscopic field beyond the notice of the laparoscopist. The potential for complications due to direct trauma also exists similar to that in traditional laparotomy.[7]

Appropriately applied, electrosurgery is safe and effective. During the 1970s and 1980s, monopolar electrosurgery was considered a contraindication in operative laparoscopy owing to its inherent characteristics.[8] The risk of surgical complications is linked to the surgeon's fundamental knowledge of the instruments, surgical technique, applicable biophysics, and relevant surgical anatomy.[9] It is therefore very important for the laparoscopists to become intimately familiar with the principles, applications, and safety aspects of the energy sources to be used during laparoscopic surgery.[10] We review the literature concerning the potential pitfalls and complications of electrosurgery in laparoscopy, and the mechanisms of electrosurgical injuries and their clinical manifestations, in order to offer guidelines for improving electrosurgical outcomes in electrosurgical laparoscopy.

BIOPHYSICS OF ELECTROSURGERY

Electrosurgery is a term used to describe the passage of high-frequency electrical current through tissue to create a desired clinical tissue effect.[11] During this process the tis-

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sue is heated by conduction of the electrical current, in contrast to electrocautery wherein an electrical current is used to heat the surgical instrument, and the heat of the instrument is then transferred to the tissue.[12] Electrosurgical units operating in the frequency range of 300,000 to 600,000 Hz (300 kHz to 600 kHz) typically offer the best balance of safety and performance, instead of low-frequency current, which has a "faradic effect" with possible muscular twitching, pain, even ventricular fibrillation, and cardiac arrest.[13,14]

Waveform Differentiation: Monopolar and Bipolar Electrosurgery

A pure cutting waveform (current mode) is a continuous, unmodulated, undamped waveform. A coagulation waveform is an interrupted, modulated, and damped current with an initial high waveform that quickly dissipates.[15,16] The coagulation mode produces an interrupted waveform with a duty cycle that is "on" about 6% of the time, ie, 6% on, 94% off. Blended modes are actually variations of the "cutting" current. As the duty cycle (amount of time the current is on) diminishes, the voltage must correspondingly increase, provided the power remains constant. The percentage duty cycle can vary, eg, 80% on, 20% off; 66% on, 34% off; and 50% on, 50% off, and so forth.[6] The term "blended" does not refer to a blend of currents, but rather to a blend of surgical effects. The blended mode permits the surgeon to cut and to coagulate at the same time. With cooling periods, cell wall explosion and vaporization are accompanied by slow dehydration of cellular fluid and protein.

In monopolar electrodes, radio-frequency currents flow from the generator through the active electrode, into target tissue, through the patient, the dispersive electrode, and then return to the generator.[13] With the return electrode properly placed, the desired electrosurgical effect takes place only at the active electrode, not the dispersive electrode. In bipolar electrodes, both arms of the circuit are delivered to the surgical instrument (usually gasping forceps), and no return electrode plate needs to be attached to the patient.[16] The flow of current is restricted between these two poles. Because the poles are in such close proximity to each other, lower voltages are used to achieve the tissue effect. Most modern bipolar units employ the cutting waveform, because it is a lower voltage waveform, allowing homeostasis to be established without unnecessary charring.[17] Bipolar electrosurgery has a more limited area of thermal spread compared with that of monopolar electrosurgery, and is similar to that of a laser.[12,18] For example, standard-size Kleppinger forceps (Richard Wolf Instruments, Vernon Hills, Illinois) with nonmodulated current at 17.6 W and 625 kHz frequency are used to perform electrocoagulation for 5 seconds till the current flow on the flowmeter is zero. The maximal lateral thermal spread is within 5 mm and deep-limited to the serosal layer.[18] This is not necessarily safe, however, because capacitive coupling could also produce injury.[18,19] Bipolar electrodes cannot be used effectively for a cutting effect because it is difficult for the two electrodes to be oriented in such a way as to allow efficient vaporization to occur.[10]

Variables Determining Tissue Effects

Alternating currents of different frequencies will have different effects on the cell. When a radio frequency (500 Hz to 3 MHz) alternating current is applied across the cell, these cations and anions rapidly oscillate within the cytoplasm and elevate the temperature within the cell. If the intracellular temperature reaches about 70°C to 80°C, protein denaturation occurs, initiating the process of "white coagulation." If the temperature rises quickly to 90°C, the cells lose water content (dehydration), but preserve architecture in the process termed desiccation.[10] Electrosurgical desiccation can occur using either the cutting or coagulating current modes on the generator. When the temperature quickly reaches 100°C and beyond, the intercellular water boils. Subsequently, the formation of steam and intracellular expansion results in explosive vaporization of the cell. The cutting effect (vaporization) is usually produced using a pointed or thin loop-shaped electrode held near to, but not in contact with, the tissue. This concentrates the current at its tip. The current then arcs to the tissue, rapidly elevating the local intracellular temperature and causing vaporization.[10] Finally, if the cellular temperature reaches 200°C or more, the process of carbonization (fulguration) occurs. The fulguration effect is a process in which the tissue is superficially carbonized through high-voltage electrosurgical arching,[10] ie, holding the electrode a short distance away from the tissue, the electric current is delivered by way of sparks "jumping" across the air space and contacting the tissue. The most common surgical indication for fulguration is rapid control of bleeding across a wide area, such as oozing capillary beds. To avoid charring, it is better to keep the electrode moving during the procedure.[12] For example, a monopolar electrode with coagulation current and near-contact technique can fulgurate tissue; a bipolar electrode with cutting current and both blade contact technique can desiccate tissue.[20]

With electrosurgery, we can achieve tissue effects such as cutting (also called vaporization), fulguration (also called superficial coagulation or spray coagulation), and desiccation (also called deep coagulation). With monopolar electrosurgery, we can cut, fulgurate, or desiccate tissue depending upon how it is used.[21] Primary factors that determine tissue effects of electrosurgery include generator power output (watts), the alternating current waveform, the current density, and surgical techniques. Generator power output is most often indicated via a digital readout on the face of the generator. Others may have a logarithmic scale from 1 (lowest) to 10 (highest), making exact settings and adjustments more difficult.[10,11,22] Surgeons should understand what kind of generator they use and in what scale the power is presented. Alternating current waveforms include cutting current (continuous, nonmodulated, undamped), blended current (different percentage duty cycle), and coagulation current (interrupted, modulated, damped). These current modes are each used for different surgical aims.[10,11,22] Current density depends on the area of surface contact and on the shape or size of the electrode.[10,11] When the contact area is decreased by a factor of 10 (eg, 2.5 cm^2 to 0.25 cm^2), the current density increases by a factor of 100 (eg, 0.01 amp/cm^2 to

1 amp/cm^2), and the resulting final temperature increases from 37°C to 77°C. Thus, a small contact area produces high-enough temperatures to cut.[12] Surgical techniques include hand-eye coordination, speed of procedure, proximity between the electrode and the tissue, and dwell time.[10,11,22] Efficient use of electrosurgery with high current density has been recommended. For example, 70 to 90 watts of pure cutting current or 50 watts of coagulation current passed down 3-mm scissors has been recommended.[21] Larger diameter scissors will require a higher power setting and will have a bigger footprint on the tissue, which will reduce the current density and result in a greater degree of coagulation than is desirable. Considerable difficulties are encountered by most surgeons in acquiring radically new operative skills that involve working in a two-dimensional environment with their hands generally disassociated from their eyes.[3] Surgeons should learn to operate via traditional laparotomy before progressing to laparoscopy. In order to minimize complications, trainees need to become proficient at converting to laparotomy when the procedure cannot be completed laparoscopically.[3,23]

MECHANISMS AND CLINICAL MANIFESTATIONS OF ELECTROSURGICAL INJURIES

Background

The incidence of complications related to laparoscopic electrosurgery has been reported to be 2.3 per 1,000 electrosurgical procedures in the 1970s[24] and 2 to 5 per 1000 in 1990s.[23,25] In 1997, Meikle et al[26] reported a bowel injury rate of 4 per 1,000 in a laparoscopic-assisted vaginal hysterectomy group. Bile duct injury is the most important complication in the laparoscopic cholecystectomy group and has been reported to be 2 to 3.5 per 1,000.[23,27,28] Inadvertent instrumental perforation of the bowel is estimated to have an incidence of approximately 0.6 to 3 per 1,000.[29,30] However, the exact incidence of laparoscopic electrosurgical complications is very hard to ascertain. Many complications are treated with the exact cause never determined.[31] As for surgeons' experience, the survey of American College of Surgeons in 1993 demonstrated that a large number of physicians (18%) have personally experienced a complication attributable to electrosurgery or know of a surgeon who has experienced such a complication (54%). Gynecologists have experienced more personal misadventures (33.3%) than have other subspecialists (eg, general and thoracic surgeons). These data also indicate that once surgeons have performed approximately 60 procedures, their electrosurgical complication rate plateaus at a minimum.[32] With regard to bowel injury, the small intestine is the most commonly involved area (75%) followed by the large intestine (25%).[33] Bowel injury, although not commonly seen, is one of the most serious complications, especially when not detected in time and managed properly.[8] Electrothermal injuries may also result in late stricture in biliary tracts, ureteral narrowing, hydroureter, or fistula formations in the urinary tract.[19,23,34]

Mechanisms of Injury

Injuries during laparoscopic electrosurgical procedure can be attributed to misidentification of anatomic structures, mechanical trauma, and electrothermal complications.[24,28] Misidentification and mechanical trauma can occur laparoscopically, just as in laparotomy.[31] Moreover, surgical skills become more difficult when the surgeon's spatial orientation and hand-eye coordination have not been well established. To decrease the risk of inadvertent instrumental perforation of the bowel during the introduction of the Veress needle or trocar, the use of a patented, radially expandable sleeve with a tapered blunt dilator and cannula has been proposed for potentially safer laparoscopic trocar access.[36,37] Open laparoscopic method through an infraumbilical minilaparotomy, in which the abdomen is entered under direct visualization by sharp dissection, has been presented as an alternative to a blind closed approach.[38,39] Umbilical axis assessment and alignment may also provide another protective maneuver for laparoscopic entry in the obese patient.[40] The trocar-cannula systems with safety apparatus do not necessarily guarantee safety during entrance of the abdominal wall because the relatively thick plastic shields need extra effort push the shield through the transveralis fascia and peritoneum.[34,41]

Electrothermal injury may result from the following situations: direct application, insulation failure, direct coupling, and capacitive coupling, and so forth. Direct application may be due to unintended activation of the electrosurgical probe, eg, moving from the intended operating area to an iliac artery or vein on the pelvic sidewall, or operating on a moving ovarian cyst.[23] A common equipment defect is a break in the insulation. The risk of a break may be increased when using a 5-mm insulated instrument through a 10-mm sleeve, or by repeated use of disposable equipment. Direct coupling comes from unintended contact of an noninsulated instrument (eg, laparoscope, metal grasper forceps) within the abdomen. Electric current will flow from the active electrode into the secondary conductor and energize it.[11,12,16] Capacitive coupling occurs when electric current is transferred from one conductor (the active electrode) through intact insulation and into adjacent conductive materials (eg, bowel, etc) without direct contact.[42] For example, in a hybrid trocar sleeve a non-conductive (plastic) locking anchor is placed over a conductive (metal) sleeve. The plastic anchor will stop the transmission into the abdominal wall over a large surface and allow capacitive coupling to adjacent bowel resulting in bowel burns.[12]

Alternative site burn can occur if the dispersive pad does not make sufficient contact with the patient's skin. The primary purpose of the dispersive pad is to provide a grounding path from the patient back to the generator and ensure an area of low current density.[43] Should this ground path be compromised in quantity or quality of the pad/patient interface, the electrical circuit can be completed via other grounded contact points thus producing high current densities and causing a burn. Examples of such contact points include electrocardiogram (EKG) leads, towel clips, intravenous stands or stirrups, and neurosurgical head frames.[12,34,43] The electrosurgical dispersive pad should be placed on an area of clean, dry skin over a large muscle mass, avoiding bony protuberance, scar tissue, and so forth.[12,43]

The surgeon is also susceptible to electrothermal burns during electrosurgical procedures, even while wearing surgical gloves. Surgical gloves can pass radio frequency current by three mechanisms: hydration (low resistance conduction), capacitive coupling (induced charge from the hemostat to the sweating conductive skin of the surgeon), and high-voltage dielectric breakdown (eg, holes in glove).[12,44] Consequently, during the course of long procedures that expose gloves to large amounts of blood or fluid, surgeons should consider replacing gloves before reactivating electrosurgery.[44]

Clinicopathologic Findings

The mechanical damage of bowel may be perforating or nonperforating, and may be recognized at the time of surgery or become apparent some time postoperatively.[45] Inadvertent instrumental perforation of the bowel is a well-recognized potential complication of laparoscopy. Patients who have had previous abdominal surgery are at a higher risk for these injuries because of the increased likelihood of bowel adhesions to the abdominal wound.[46,47] The other form of complication relates to the electrothermal burn. Most electrothermal injuries to the bowel (approximately 75%) are unrecognized at the time of occurrence.[31] The result of an unrecognized bowel injury is usually serious, often leading to long-term complications. The small bowel, especially the ileum, is most frequently involved, and the injury may not cause clear-cut or rapid symptoms and abnormal laboratory values.[48] Generally speaking, symptoms of bowel perforation following electrothermal injury are usually seen 4 to 10 days after the procedure. With direct traumatic perforation, symptoms usually occur within 12 to 36 hours, although their occurrence up to 11 days later has been reported.[35,49] The time delay from burn to perforation would appear to be related to the severity of the coagulation necrosis.[50] Different types of injury result in different clinical manifestations.

At surgery for delayed bowel perforation, the gross appearances of traumatic and electrothermal injuries are the same: the perforation with a surrounding white area of necrosis. However, microscopic examination reveals completely different characteristics. The puncture injuries are characterized by (1) limited, noncoagulative-type cell necrosis, more severe in the muscle coat than the mucosa; (2) rapid and abundant capillary ingrowth with rapid white-cell infiltration; (3) rapid fibrin deposition at the injury site followed by fibroblastic proliferation; and (4) significant reconstitution of the injured muscle coat by 96 hours.

Features of electrical injuries are distinguished by an area of coagulative necrosis, absence of capillary in-growth or fibroblastic muscle coat reconstruction, and absence of white cell infiltration, except in focal areas at the viable borders of injury.[35,49] The reports of histopathologic findings have been reported to have significant influence on the verdict of medical-legal claims.[48]

PREVENTION AND MANAGEMENT OF ELECTROSURGICAL INJURIES

Electrothermal burns during laparoscopy can be prevented or at least minimized with thorough preparation and training of the operating room staff, and regular equipment maintenance. The surgeon's hand-eye coordination using these instruments during laparoscopy is the most obvious and crucial factor. It is also important, however, that the rest of the surgical team, including the perioperative nurses, biomedical engineer, anesthesiologists, and assistants have a thorough knowledge of the biophysics of the equipment being used so they understand how it is to be handled and the inherent risks associated with its use.

We recommend the following steps for preventing electrosurgical injuries in laparoscopy:

1. A thorough understanding of the biophysical principles of radiofrequency electrical energy is essential.[7,10] For example, when the generator output cannot accomplish tissue effects as expected, it should be suspected first that there is a defect in the ground plate or its connection, or that an alternative pathway for the current has been established.[43]

2. Bowel preparation is important if it is anticipated that the large bowel is at risk.[23,45] Also, the use of an orogastric tube is recommended to diminish the possibility of a trocar entry into the stomach.

3. Choose the proper current waveform mode. In monopolar electrosurgery, either the cutting or coagulation waveform can be used to achieve a cutting effect or fulguration effect. Others have recommended using high current density, eg, 70 to 90 watts of pure cutting current or 50 watts of coagulation current passing down 3-mm scissors.[21] Larger diameter scissors will require a higher power setting and will have a bigger footprint on the tissue. However, these authors also advise to proceed with caution when using coagulation waveform mode because the coagulation waveform is intermittent, being "off" more than it is "on." This necessitates higher voltage than that needed to achieve a comparable power in cutting current mode, and predisposes to the potential arcing to nontarget tissue.[22,34,42]

4. Improve dexterity and hand-eye coordination through sequential phases of training, ie, didactic phase, laboratory experience, observation and/or assistance, and preceptorship.[3] The chances of direct trauma are greater during laparoscopic surgery because surgeons are limited to visualization in only two dimensions, with their hands generally dissociated from their eyes, especially when operating on mobile organs.[23,48] In order to minimize the chances of direct trauma; activate the electrode only when whole tissue is in the field of vision.[12]

5. Avoid hybrid trocar sleeves. The use of completely metal trocar cannulas can reduce the risk of capacitive coupling.[16,20] Activating the electrode in the air when not in use will create an "open" circuit, which can also result in a capacitive current effect. Capacitive coupling is increased by open circuits, use of 5-mm cannulas (versus 10 mm), and higher generator voltages.[7] This situation can be avoided by using multiple, short activation times that allow normal tissue to remain cool.[31]

6. Use electrosurgical accessory safety equipment when possible. A return electrode monitoring system is a dual-padded patient return electrode system designed to monitor irregular separation of the ground pad.[12] It can actively monitor tissue impedance (resistance) at the contact between the patient's body and the patient return electrode, and interrupts the power if the quality and/or quantity are compromised.[51] Active electrode monitoring is a tech-

nique of placing a sleeve around the electrode to detect stray energy generated by insulation failure or capacitive coupling.[12] When in place, this system continuously monitors and actively shields against stray current. It can be effectively minimize the potential hazards for the patient.[20,42,52] Tissue response technology uses a computer-controlled tissue feedback system that automatically senses resistance of the tissue and adjusts the output voltage to maintain a consistent effect across different tissue density, to achieve a consistent tissue effect.[51] Newer design generators constantly monitor impedance to maintain the present wattage over a broad range of impedance, avoiding unnecessary higher wattage with potential hazards.[23,53] Smoke evacuation through a scavenger system can significantly improve visualization in the operational field. It also protects patients and surgical staff from the exposure of smoke and the byproducts during laparoscopic procedures.[54–56]

7. Organize a laparoscopic team that includes a biomedical engineer, perioperative nurses, and other operation room personnel. Promote extended education activities and participation in medical conferences.[12]

Intraoperative Adjuvant Protective Maneuvers, Early Recognition of Injuries, and In-Time Salvage Procedures

Intraoperative adjuvant protective maneuvers and early recognition of injuries (while the patient is still in the operating room if possible), followed by immediate implementation of appropriate treatments, are crucial to reduce catastrophic consequences.[57] If left undetected or untreated, injuries may require more extensive and complex corrective procedures. During laparoscopic cholecystectomy, for example, the use of intraoperative cholangiography has been reported to provide a protective effect.[27] In biliary surgery, if the recognized injuries were not repaired or were repaired in a suboptimal manner, 95% of laparoscopic injuries resulted in a need for at least one additional surgical procedure.[34] The treatment of bowel injuries depends upon the extent of damage. If the Veress needle has been inserted into a hollow viscus without tearing, no further therapy is indicated since its small diameter leaves no defect and the muscular wall will close over this puncture spontaneously.[46] When extensive adhesions surrounding the umbilical puncture are suspected, eg, a history of multiple laparotomies, prior ruptured appendicitis, previous pelvic inflammatory disease, and so forth, pneumoperitoneum can be established through an alternative insertion site, eg, the left costal margin in the midclavicular line.[49] However, when the insertion of the trocar into a small intestine leaves a large defect, eg, one half the diameter of the lumen, a segment resection and anastomosis should be performed through laparotomy. Both open technique and the use of a radially expandable trocar sleeve with a tapered blunt dilator (to avoid blind puncture) have been proposed to minimize the risk of laparoscopic trocar trauma.[36–39] If the perforation has occurred, it may be beneficial to leave the trocar in situ to serve to identify the site of laceration.[49] In small bowel or prepared colon, direct suture repair under laparoscopic guidance is recommended. In selected cases with trocar-induced penetrating injuries of the bowel, institution of drainage and antibiotics can allow possible medical management of the problem, and thereby preclude conversion to laparotomy.[46] Percutaneous endoscopic cecostomy has been proposed as a safe nonsurgical approach to decompressing nonobstructive colonic dilation, using intentional colonic perforation to place the cecostomy.[46,58]

Trocar injuries to the colon occur most commonly in the transverse and sigmoid colon. The spillage of foul-smelling gas through the insufflation needle is a helpful diagnostic sign. The needle should be discarded, because it is probably contaminated.[49] Superficial lesions can be treated with a laparoscopic purse-string suture placed beyond the margins of the thermally affected tissue or by postoperative observation alone.[23] Defects involving the full thickness of the bowel wall require direct surgical repair via laparoscopy or open laparotomy.[49] Contraindications include the need for blood transfusion over 4 units, more than two associated injuries, significant contamination, and increasing colon injury severity scores. Primary closure of the perforation trauma was reported to be a safe method, with a failure rate varying from 1.2% to 2.4%, as an alternative to traditional colostomy.[59–61] A laparoscopic suture closure followed by copious irrigation until the effluent becomes clear might also be satisfactory.[62] Full-thickness penetration of the rectum can occur during the excision of rectal endometriosis. After excision of the nodule of the rectosigmoid colon, a single- or double-layered repaired can be done by a laparoscopy-assisted transvaginal approach or total laparoscopic intracorporeal technique.[63,64] Concerning the unprepared bowel, traditional colostomy is still advised for severe contaminated colon injuries. The decision whether to repair such injuries under laparoscopic guidance depends on the amount of fecal spillage present. If a large amount of fecal contamination occurs, laparotomy followed by repair and colostomy should be considered. In the emergent situation, primary anastomosis in the unprepared left colon has been reported to produce a good outcome.[65]

In laparoscopic biliary surgery, most of the gastrointestinal injuries were puncture wounds, except for the duodenum, which was usually thermally injured and was not recognized during the original procedure.[34] The sigmoid colon is especially vulnerable because of its close proximity to the uterus and ovaries. Colon injury caused by bipolar electrosurgery can be readily identified by viewing the area of blanch on the surface of the colon, as compared with injury due to monopolar electrosurgery, which is more difficult to detect and evaluate.[23] Superficial thermal injuries to the bowel may be treated prophylactically with a laparoscopy-guided pursestring suture placed beyond the thermally affected tissue.[49] The spread of electrothermal injuries is greater than the initial area of branching and can create a large area of necrosis. Thus, the depth of injury is difficult to assess even if it is noticed intraoperatively. The injury of a viscous or bile duct typically occurs several days postoperatively.[34] Excision of a generous segment up to 5 cm on each side of the margin of the injury site, to include this area of coagulation necrosis (rather than simple closure of the perforation), is required to prevent subsequent reperforation.[45,50] Currently, the best way to treat bowel injury during laparoscopic surgery is by traditional laparotomy. However, as laparoscopists become more experienced in laparoscopic surgery, laparoscopic suture repair will become another management option.[66] The efficiency and accuracy of laparoscopic bowel suturing techniques have been evaluated.[67] In the Reich[49] series, there are few indications for colostomy during the repair of bowel injuries noted during the course of a laparoscopic procedure.

Postoperative Warning Signs

During the postoperative observation period, which may last 3 to 5 days, the laparoscopist and physicians on duty for coverage should be highly alert to the early manifestations of peritonitis. The degree of peritonitis depends upon the amount of spillage and the length of time between perforation and exploration.[66] However, the warning signs may be insidious and imply the importance of possibly early intervention. Abnormal laboratory and imaging tests are helpful in confirming the diagnosis although normal test results do not necessarily rule out complications. Increasing abdominal pain after laparoscopic surgery demands an expedient evaluation, even if it requires a repeated laparoscopy with a negative finding.[48] A patient's inability to void may be an early manifestation of bowel injury.[9] Atypical manifestations also warrant attention. For example, lower gastrointestinal bleeding can be a possible indication of thermal injury to the lower gastrointestinal tract.[19]

CONCLUSIONS

The risk of injury to patients and/or operating room personnel during electrosurgical laparoscopy can be minimized by thoroughly training operating room staff, regularly maintaining equipment, and following adjuvant guidelines. Staff should understand the biophysics of electrosurgery, the characteristics of their own equipment, desired tissue effects, types of potential injury, and the possible clinical manifestations of such injuries. We recommend that surgeons master laparoscopic surgical dexterity and hand-eye coordination through sequential phases of training. We also recommend that a laparoscopic surgical term be organized that includes surgeons, perioperative nurses, biomedical engineers, and operation room personnel. Recognizing injuries early and immediately implementing salvage procedures can minimize complications. Particular attention should be paid to placement of the first port, more liberal use of open laparoscopy or other adjuvant instruments, placement of all other ports under direct vision, elimination of intraoperative anatomical uncertainty, and programmed inspection of the abdomen before withdrawing the laparoscope.[34] Postoperative warning signs can include obvious signs of peritonitis or abdominal pain and/or atypical signs such as lower gastrointestinal bleeding.

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