Best Practices for Minimally Invasive Procedures

BRENDA C. ULMER, RN, MN, CNOR

ABSTRACT

Techniques and instrumentation for minimally invasive surgical procedures originated in gynecologic surgery, but the benefits of surgery with small incisions or no incisions at all have prompted the expansion of these techniques into numerous specialties. Technologies such as robotic assistance, single-incision laparoscopic surgery, natural orifice transluminal endoscopic surgery, and video-assisted thoracoscopic surgery have led to the continued expansion of minimally invasive surgery into new specialties. With this expansion, perioperative nurses and other members of the surgical team are required to continue to learn about new technology and instrumentation, as well as the techniques and challenges involved in using new technology, to help ensure the safety of their patients. This article explores the development of minimally invasive procedures and offers suggestions for increasing patient safety. AORN J 91 (May 2010) 558-572. © AORN, Inc, 2010. doi: 10.1016/j.aorn.2009.12.028

Key words: minimally invasive surgery, single-incision laparoscopic surgery, electrosurgery, NOTES, VATS, SILS, SPA, OPUS.

Throughout the history of medicine and surgery, the discoveries of yesterday have served as a platform for the innovations of today. That is especially true for minimally invasive surgery (MIS). Less invasive approaches and techniques are not new. Historical references to endoscopy date back to the time of Hippocrates (460 BC to 375 BC), when a rectal examination using a speculum was described.¹ A vaginal speculum was reportedly found in the Pompeii ruins (70 AD), which indicates a long history of interest in looking at human internal organs.²

Over centuries, researchers have developed instruments and equipment to examine internal organs, creating the field that encompasses MIS today. An overview of this development demonstrates how the science and technology have progressed over time.

HISTORICAL DEVELOPMENT

Philipp Bozzini (1773–1809), a German physician, developed the first endoscope in the early 1800s. He published his work in 1806 in a paper...
entitled “Der Lichtleiter,” or “The light conductor.” Bozzini described the light conductor as an instrument used to observe internal organs and their diseases. The light conductor included a candle and a mirror to reflect light into a cavity and a lens to view the reflected image.

In 1853, French surgeon Antoine Jean Desormeaux (1815–1882) refined the Bozzini light conductor. His instrument included a system of mirrors and lenses and a lamp flame rather than a candle to provide light. It burned a mixture of alcohol and turpentine and incorporated a mirror with a central hole tilted at a 45-degree angle over the flame, which allowed direct vision of the internal organs. Desormeaux called his instrument an “endoscope”—the first use of the term—and he is considered the father of endoscopy.

In 1877, Maximilian Nitze (1848–1906), a German urologist, created the first modern optical system. His system included a heated wire for illumination at the tip of the scope and a water cooling system. He later modified Thomas Edison’s light bulb by making a miniaturized version of the filament globe, thereby creating the first electrical source of illumination of the cystoscope.

In 1901, Georg Kelling (1866–1945), a gastroenterologist and surgeon from Dresden, Germany, performed the first laparoscopic surgery on a dog at the 73rd meeting of the German Natural Scientist Society in Hamburg. He called his procedure a “celioscopy.”

This event ushered in the laparoscopic age, as other surgeons began to use minimally invasive methods and add to the body of endoscopic knowledge. In 1910, H. C. Jacobaeus of Stockholm, Sweden, used the term “laparothorakoskopi” in a report he published on laparoscopy and thoracoscopy. The first laparoscopy in the United States was performed in 1911 by Bertram M. Bernheim, MD, of Johns Hopkins University, Baltimore, Maryland. Bernheim used a proctoscope and called the procedure an “organoscopy.”

An early pioneer of endoscopy in the United States was John C. Ruddock, MD (1891–1964), an internist in the Los Angeles, California, area, who used a modified cystoscope to view inside the abdomen in a procedure he termed “peritoneoscopy.” He was a proponent of laparoscopy over laparotomy and, by 1937, published a review of 500 procedures to support his claims. During the next 20 years, Ruddock performed 5,000 abdominal procedures laparoscopically and published his results in a 1957 article. Ruddock was an early user of electrosurgery during laparoscopy, modifying an instrument so that he could apply bipolar radiofrequency current to bleeding vessels during the procedures.

Many men of medicine have contributed to the field of endoscopy and laparoscopy over the years (Table 1). From the time of Ruddock, practitioners in the specialty of gynecology in particular embraced laparoscopy as a diagnostic and therapeutic tool. Power and Barnes reported on their technique of laparoscopic sterilization in 1941. After 1941 and this report, laparoscopic procedures became commonplace among gynecologists. In 1987, laparoscopy entered the general surgery arena when Phillipe Mouret, a physician in France, removed a patient’s gallbladder laparoscopically. The first laparoscopic cholecystectomy in the United States was performed by J. Barry McKernan, MD, and William B. Saye, MD, in Marietta, Georgia, on June 22, 1988. After this, the laparoscopic revolution spread quickly across the country. The tools and technology in the field of MIS have continued to evolve and expand in surgical specialties.

**THE INCREASING PREVALENCE OF MIS**

Gynecologists popularized laparoscopy primarily in response to an increased demand from female patients who wanted the benefits of minimally invasive procedures, including smaller scars, less postoperative pain, and faster recovery times. The American Association of Gynecologic Laparoscopists, founded in 1971 by Jordan Matthew Phillips, MD, provided a framework for teaching and studying minimally invasive techniques and a forum in which ideas and innovation could
TABLE 1. Innovations in Endoscopy and Laparoscopy

<table>
<thead>
<tr>
<th>Year</th>
<th>Name and country</th>
<th>Innovation</th>
</tr>
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<tbody>
<tr>
<td>1801</td>
<td>Philipp Bozzini, Germany</td>
<td>Introduced first lighted endoscope, called “der Lichtleiter,” the light conductor.¹</td>
</tr>
<tr>
<td>1853</td>
<td>Antonin Jean Desormeaux, France</td>
<td>Modified Bozzini’s light conductor and used it on a patient.¹</td>
</tr>
<tr>
<td>1877</td>
<td>Maximilian Nitze, Germany</td>
<td>Developed the first electrically lighted endoscope.²</td>
</tr>
<tr>
<td>1901</td>
<td>Georg Kelling, Germany</td>
<td>Performed first laparoscopy on a dog using Nitze’s cystoscope.³</td>
</tr>
<tr>
<td>1910</td>
<td>Hans Christian Jacobaeus, Sweden</td>
<td>First used the term “laparoscopy.”⁴</td>
</tr>
<tr>
<td>1911</td>
<td>Betram M. Bernheim, United States</td>
<td>Performed the first laparoscopy in the United States and called his procedure an “organoscopy.”⁴</td>
</tr>
<tr>
<td>1920</td>
<td>Benjamin Orndoff, United States</td>
<td>Developed a sharp pyramid-shaped trocar.⁴</td>
</tr>
<tr>
<td>1929</td>
<td>Heinz Kalk, Germany</td>
<td>Developed the 135° lens system and founded the German School of Laparoscopy.⁵</td>
</tr>
<tr>
<td>1934</td>
<td>John C. Ruddock, United States</td>
<td>Developed a bipolar electrosurgery device.⁶</td>
</tr>
<tr>
<td>1938</td>
<td>Janos Veress, Hungary</td>
<td>Developed the first spring-loaded needle for insertion into the peritoneum.⁴</td>
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<tr>
<td>1970s</td>
<td>Kurt Semm, Germany</td>
<td>Developed thermacoagulation, laparoscopic suturing, and the automatic electronic insufflator.⁷,⁸</td>
</tr>
<tr>
<td>1987</td>
<td>Phillipe Mouret, France</td>
<td>Performed the first European laparoscopic cholecystectomy.⁹</td>
</tr>
<tr>
<td>1988</td>
<td>J. Barry McKernan, William B. Saye, United States</td>
<td>Performed the first laparoscopic cholecystectomy in the United States.⁵</td>
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Perioperative practitioners have been challenged to stay abreast of technology in a field that is a constantly changing landscape of new techniques and improved instruments and equipment. The “laparoscopic revolution” of the 1980s propelled the changes onto the fast track as practitioners in other surgical specialties devised treatments with smaller incisions.¹⁴ In 1983, the
implementation of the diagnosis-related groups prospective payment system through Medicare strongly influenced health care facilities to provide care on an ambulatory basis. The shift from inpatient to outpatient—from laparotomy to laparoscopy—is exemplified by the continuing increase in the number of minimally invasive procedures that are performed. Approximately 3 million outpatient surgical procedures were performed in 1980. By 1996, that number had increased to 20.8 million, and by 2006 the number of outpatient surgeries increased to 34.7 million. This trend is expected to continue as the tools and surgical techniques used in MIS improve and because of advances in other sciences and technology such as gene therapy and biotechnology (Figure 1).

Patient satisfaction with less invasive procedures is one reason the shift to MIS has continued. Smaller scars are just one benefit of less invasive procedures. Patients also report less pain and shorter recovery periods, which facilitate a faster return to normal activities of daily living. Smaller external scars also mean less scarring internally, which decreases the formation of adhesions. Patients often lose less blood during minimally invasive procedures, which also promotes faster recovery. Members of the Society of Gynecologic Oncology were surveyed twice during a three-year period to determine the reasons surgeons perform laparoscopic surgeries. Results from surveys in 2004 and 2007 revealed that surgeons perform laparoscopic surgery for some of the same reasons that patients prefer it, including decreased length of hospital stay (74% and 85% for 2004 and 2007, respectively), improved quality of life for patients (57% and 74%), and improved cosmesis (46% and 59%).

**ADVANCEMENTS IN MINIMALLY INVASIVE PROCEDURES**

Recent decades have seen an accelerated advancement in medical technology. In MIS, some of the major advancements include robotics, single-incision laparoscopic surgery (SILSTM), natural...
orifice transluminal endoscopic surgery (NOTES®), and video-assisted thoracoscopic surgery (VATS).

**Robotics**
Advances in computer capabilities make it possible for surgeons to perform procedures without even touching their patients. With robotic-assisted technology, a surgeon could perform a procedure on a patient in Asia from a facility in New York. The evidence to support the use of robotics is increasing as more facilities implement robotic assistance in surgery. From the surgeon’s perspective, the advantages of robotic assistance include three-dimensional vision, hand tremor reduction, increased intra-abdominal articulation, and motion scaling. The benefits to patients of robotic assistance include smaller incisions, decreased postoperative pain, shorter hospital stays, better cosmesis, reduced blood loss, reduced tissue loss, and a faster return to work.

Currently, robotic-assisted surgeries are performed in the specialties of cardiac, genitourinary, gynecologic, and general surgery. As robotic-assisted surgery becomes more prevalent in the surgical setting, facilities may realize the need to employ a perioperative robotics nurse specialist. The role of the robotics specialist will be dynamic and multi-faceted and may include responsibilities such as:

- ensuring instrument availability and care,
- assisting intraoperatively with all robotic procedures,
- providing patient and staff member education, and
- assisting with research efforts.

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**Advances in Invasive Surgery**

Science and technology are advancing at an incredible pace, in some cases reducing the need for surgery by moving patients out of the OR and into endoscopy units and radiology suites. Biotechnology and gene therapy help to further reduce the need for invasive surgery and replace it with minimally invasive procedures. There are, however, innovations in various stages of development that will keep patients seeking surgical care as well:

- Bioengineering scientists at the University of Pittsburgh in Pennsylvania are developing valves to replace human heart valves. Japanese researchers have successfully created an autologous heart valve by growing it in the body of a rabbit. The valve has the potential to be a prosthetic human heart valve replacement.  
- Researchers at Wake Forest University, Winston-Salem, North Carolina, have engineered bladders grown in the laboratory from a patient’s own cells and then implanted the bladder into the patient.  
- Tengion, a US-based biotechnology firm, is conducting research to use healthy cells from patients to engineer organs, such as bladders and kidneys, as well as vessels to be implanted.  
- Researchers from several US and European universities are investigating the use of a combination of biodegradable polymers and mesenchymal stem cells to generate vascularized bone for reconstructive surgery.

An aging population and biomedical engineering of body tissue and organs will fuel the continued need for, and the advancement of, both surgery and minimally invasive procedures.

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The high cost of a robotic system—more than $1 million—and the learning curve required to run a program support the need for a perioperative robotics nurse specialist. In May 2009, the increased number of nurses working with robotics prompted AORN’s Minimally Invasive Surgery and Lasers Specialty Assembly to expand to encompass robotics. The Specialty Assembly is now known as the Minimally Invasive Surgery/Lasers/Robotics Specialty Assembly.

SILS
Surgery performed through a single umbilical incision is not new. Gynecologists used the approach in the 1970s for laparoscopic tubal ligations and diagnostic laparoscopy. The single-entry approach is new for the more complex procedures developed by general surgeons and surgeons in other specialties because as laparoscopic procedures became more complex, the number of entry sites into the abdominal cavity increased. Single-port access (SPA) is known by several different acronyms, including SILS and one-port umbilical surgery (OPUS).

Single-incision laparoscopic surgery was pioneered at Drexel University College of Medicine in Philadelphia, Pennsylvania, in May 2007, when Paul G. Curcillo, MD, removed the gallbladder of a 28-year-old woman through a single umbilical incision. Single-port access is an advanced minimally invasive technique in which all instrumentation must pass through a single entry point at the navel. Comparatively, traditional minimally invasive procedures may involve two or more ports inserted into the abdominal cavity. An MIS cholecystectomy, for example, requires several incisions (Figure 2). In single-incision procedures, the scope and instruments are inserted through a 1.5-cm to 2-cm incision in the navel.

An advantage of the single-incision method is that standard laparoscopic instruments can be used. Single-incision procedures are currently performed with standard MIS instrumentation, including 2-mm and 3-mm ports and endo-roticular graspers, dissectors, and shears. During single-port access procedures, a trocar with multiple instrument ports and bendable, articulating instruments are needed to compensate for the space restriction and limited range of motion. Newer devices and equipment currently in development will assist the surgeon by increasing dexterity and helping maintain the pneumoperitoneum (Figure 3).

One benefit of single-port procedures is that making a single incision reduces scarring and produces a better cosmetic effect, which has captured the attention of the public and health care providers alike. Procedures currently being performed through a single incision include...
The natural body orifice approaches that can be used for NOTES procedures are the transgastric, transvaginal, transvesical, and transcolonic. The first reported NOTES procedure was a kidney removed transvaginally in a porcine model described by Gettman and colleagues in 2002.23 In 2004, Kalloo et al reported using the transgastric approach to access the peritoneum.24

As an example, a transgastric cholecystectomy would involve inserting an endoscope down the esophagus, placing an incision in the stomach or digestive tract to access the abdominal cavity, and removing the gallbladder through the mouth.25 In addition to cholecystectomy, additional NOTES procedures include

- appendectomy,
- gastrojejunostomy,
- liver biopsy,
- oophorectomy,
- splenectomy, and
- tubal ligation.26

There are challenges that must be addressed to ensure that NOTES procedures have lower morbidity and mortality rates and are better for patients than traditional approaches. In 2005, to address concerns about procedures through natural orifices, the Society of American Gastrointestinal and Endoscopic Surgeons and the American Society for Gastrointestinal Endoscopy formed a working group called Natural Orifice Surgery Consortium for Assessment and Research (NOSCAR).27 The group was convened to identify obstacles to using the NOTES approach. Some of the obstacles they cited related to

- access,
- closure,
- infection,
- suturing technology,
- orientation,
- physiology,
- complications,
- training, and
- platform development.27
Challenges to NOTES are the matter of developing the instruments needed to perform the procedures and training practitioners to ensure that they have the advanced skills and the knowledge to perform the procedures safely. Research indicates that NOTES procedures can be successfully performed, so continued collaboration in developing a safe and effective practice model will dictate future development.

**VATS**

Thoracic surgery is another specialty in which the number of minimally invasive procedures has increased. Techniques that do not require rib spreading are beneficial to patients because there is less postoperative pain and shorter hospitalizations. Thoracic procedures that can be performed with the VATS method include pulmonary and esophageal resection, thymectomy, and sympathectomy. Technology development and increased skill and knowledge can result in benefits to both patients and the health care facility.

**INSTRUMENTATION THAT FACILITATES MIS PROCEDURES**

With the continued expansion of MIS, the instrumentation used to perform these increasingly intricate procedures also has become more specialized. The goal of increased instrument specialization is to reduce risk and increase patient safety. The development of instruments for minimally invasive procedures has resulted from surgeons, nurses, engineers, and medical manufacturers working together to produce the best possible equipment. Instruments used during MIS procedures mimic the actions of those used during open procedures. The surgeon must have the ability to grasp, retract, clamp, dissect, and cut tissue. The types of laparoscopic instruments available to surgeons are as varied and specialized as those for open procedures.

**Laparoscopes**

A laparoscope is a type of endoscope used to view organs and tissues in the abdominal cavity. Scopes can be rigid or flexible with optical systems that provide light, a field of view, magnification, and high resolution. Laparoscopes are available as diagnostic systems that have no operating channels or as operating scopes that have channels and connectors for instruments, suction, and irrigation. They are available in a variety of sizes and configurations.

**Trocar/Cannula Systems**

The trocar/cannula system allows access into the patient’s body after the pneumoperitoneum is established, typically with a Veress needle. Available systems are reusable, reposable, or disposable.

**Reusable.** Reusable trocar/cannula systems are generally made of metal that can be steam sterilized. The metal trocar must be sharpened frequently to facilitate peritoneal access. The stopcock and valves in the cannula must be cleaned to be sure no bioburden is passed between patients. They should be inspected before, during, and after use to ensure they are in proper working order.

**Reposable.** Trocar/cannula systems that are available as multiple-use items are referred to as reposable. They are typically plastic and must be cleaned and inspected before, during, and after each use to ensure proper function. Reusable systems provide some cost savings to the health care facility but should not be used beyond the life of the instrument, as indicated in the manufacturer’s instructions.

**Disposable.** Disposable trocar/cannula systems are designed to be used once and then discarded. They are made of plastic and have safety features that are not available in the metal systems. Although they may be bladed, nonbladed systems decrease the risk of internal injury. Some systems are translucent to allow for greater visualization during the use of x-ray or fluoroscopy. Radially expanding systems can be used on patients who have adhesions from previous surgeries or on pediatric patients. With the radially expanding, disposable system, the muscles are not cut; rather,
they are spread, decreasing possible damage to abdominal organs and vessels and adhesion formation. Optical trocars have a blunt, clear window at the distal end to allow for visualization.30

**Sutures and Staples**

Perhaps the greatest specialization and adaptation to minimally invasive procedures has occurred with sutures and staples. Sutures, needle holders, and closing devices have been developed to facilitate tissue approximation in the body cavity. Some suture carriers are designed to pass the needle endoscopically from one side of the holder to the other.

Specially designed endoscopic staples and clip appliers provide hemostasis. Staplers and clip appliers come in a variety of lengths, diameters, and sizes. They are disposable or reusable, offering the surgeon a wide choice of handling characteristics for ease of use.

**MIS SAFETY CONSIDERATIONS**

There is increasing emphasis on safe surgery around the world. There are an estimated 234 million surgeries performed worldwide annually, and “at least half” of all surgical complications are preventable.31(p491) Perioperative professionals are aware that teamwork is very important in the OR. As with any surgery, during minimally invasive procedures, the surgeon depends on team members and requires the complex equipment to function efficiently and effectively. Identifying safety concerns and building safety into technology and perioperative team culture can reduce adverse outcomes. To help promote patient safety during minimally invasive procedures, perioperative nurses should have an understanding of

- the categories of patient injuries associated with MIS instrumentation,
- electrosurgical considerations (eg, the variables in electrosurgical tissue effect, innovations, patient return electrodes, tissue density feedback),
- vessel fusion and closed-loop coagulation,
- the potential hazards that may occur with the use of electrosurgery, and
- electrosurgical technologies.

**Categories of Patient Injuries**

The two major categories of patient injuries that occur during minimally invasive procedures are classified as mechanical trauma and thermal injuries.32,33 Both types of complications have been identified in the literature and include bleeding, perforations, lacerations, infections, dehiscences, and occlusions. “Never events” in surgery are those complications or injuries that should never happen because they are preventable. Never events in surgery are retained foreign objects, wrong site surgery, fires and burns, neuropathies from improper positioning, pressure ischemia, and well-leg compartment syndrome.33 Equipment failure can contribute to or cause some of these complications.

**Mechanical.** Perforation of vital structures is the most common complication during laparoscopic surgery because of the “blind” placement of the Veress needle and the first laparoscopic port.33 Studies of perforation injuries indicate that the most likely time that an injury will occur is on establishment of the primary port when the internal structures cannot be visualized.34 During the five-year period from January 1, 1997, to June 30, 2002, 1,353 serious injuries and 31 fatal injuries related to laparoscopic surgery complications were reported to the US Food and Drug Administration.33,35 In one study, researchers analyzed 629 trocar injuries that were reported from 1993 to 1996.33,36 The report showed that most of these injuries were perforations of the bowel or the vascular system.36 Since these reports, trocar systems have improved; however, it is important to note that of 41 suspected trocar malfunctions, only one trocar was found to be defective.36 Equipment failures can be especially hazardous during minimally invasive procedures because the complexity and sophistication of the equipment...
increases the possibility of failures. A French study examined equipment failure and determined that most fell into one of four categories:

1. failure of electrical equipment,
2. failure of imaging systems,
3. failure of accessory equipment (e.g., fluid, light, gas devices), or
4. failure of surgical instruments.

Equipment failures can adversely affect the quality of the surgical intervention. Completion of the procedure could be delayed, but the consequences also could be more serious. Findings from the French study indicate that many of the failure events were preventable. The French researchers developed a laparoscopy checklist as part of the study in an effort to reduce the possibility of human error. Implementing the checklist reduced the number of equipment failures in the study facility. Using checklists to reduce human error is supported by the World Health Organization’s Safe Surgery Saves Lives campaign.

Failure of surgical instruments is a hazard that can have dire consequences for patients, especially if it involves the use of electrosurgery. Montero et al at the University of Colorado Denver School of Medicine conducted a study of electrosurgical complications to determine the incidence of insulation failure with active electrodes and to compare the incidence of insulation failure in reusable and disposable instruments. They found that one in five reusable instruments had an insulation failure, and this finding was not affected even when the instruments were routinely checked for insulation defects. Disposable instruments also had insulation failures, but to a lesser degree. An interesting finding was that insulation failure most often occurred in the distal third of the instrument.

Thermal. John R. Clarke, MD, professor of surgery at Drexel University and clinical director of the Pennsylvania Patient Safety Reporting System, made three important points about thermal injuries. First, most thermal injuries involving MIS result from electrosurgery. Second, many of the complications from electrosurgery arise from practitioners’ bad habits or lack of awareness of risky behavior. Finally, the necessity of electrosurgery makes education about best electrosurgical practices important.

Electrosurgery MIS Safety

Minimally invasive procedures have expanded beyond the OR and outpatient surgery suites into radiology departments, endoscopy suites, and physicians’ offices. Laparoscopic cholecystectomy leads the way, with an estimated 700,000 procedures performed yearly in the United States. Electrosurgical units are the most commonly used hemostatic devices because they are versatile and economical. Minimally invasive procedures require the vigilance of perioperative professionals to prevent consequences from practices that could result in patient injury. Some of the concerns related to the endoscopic use of electrosurgery are:

- insulation failure,
- direct coupling,
- capacitive coupling,
- residual heat, and
- endosurgical smoke plume.

Each of these can cause adverse patient outcomes that could result in injury. Perioperative practitioners should be aware of how and when the conditions could occur and take steps to reduce risks to patients.

To determine the root cause of potential hazards, it is useful to divide the active electrode and cannula system into four zones (Figure 4):

- Zone 1—the small area at the tip of the active electrode; the only area that is in direct view of the surgeon.
- Zone 2—the area just beyond the active electrode tip to the distal end of the cannula, outside the view of the surgeon.
- Zone 3—the area of the active electrode covered by the cannula system, outside the view of the surgeon.
- Zone 4—the portion of the active electrode and cannula system outside the patient’s body.
The greatest concern and possible hazard to the patient is the incidence of stray radiofrequency current in zones 2 and 3, which are outside the surgeon’s view. The stray current could be caused by insulation failure, direct coupling, or capacitive coupling.40

**Insulation failure.** Insulation failure occurs when the insulating coating on the active electrode is compromised. This can happen in multiple ways, including instrument damage from rough handling or defects resulting from high-voltage electrosurgical current, such as coagulation. Insulation damage can occur during instrument cleaning, but it also can develop during surgery from repeated insertions into and removals from the cannula system. High-voltage radiofrequency current can be powerful enough to compromise intact active electrode insulation if the surgeon activates the active electrode when it is not in close proximity to target tissue. This is referred to as open-circuit activation, which increases generator voltage output. Depending on the electrosurgery generator being used, coagulation voltages can be as high as 8,000 to 10,000 volts of electricity. Reusable active electrodes have thicker insulation than disposable active electrodes. Insulation failure that occurs in zones 2 or 3 could escape detection by the surgeon and cause injury to adjacent body structures, because the current is likely to be delivered in a more concentrated manner.

**Direct coupling.** Direct coupling occurs when the active electrode is activated in close proximity or in direct contact with other conductive instruments in the abdominal cavity. Direct coupling can occur in zones 1, 2, or 3. If direct coupling occurs outside the field of the surgeon’s view and the current is sufficiently concentrated, injury to the patient may occur. The surgeon should only activate the active electrode when he or she is confident that only the target tissue will be affected and that no other conductive instruments are close enough to be energized.

**Capacitive coupling.** Capacitive coupling is the most difficult concept to understand as a potential endoscopic electrosurgery phenomenon. The definition of a capacitor is two conductors separated by an insulator. Laparoscopically, a capacitor is created by inserting an active electrode, surrounded by insulation, into a conductive metal cannula system. When the electrode is activated, capacitively coupled electrical current can be induced to flow from the active electrode, through intact insulation, and into the conductive metal cannula. Should the cannula then come into contact with body structures, the current could be discharged, causing injury to the tissue.41 During use of an all-metal cannula, any electrical energy stored in the cannula will tend to disperse into the patient through the relatively large contact area between the cannula and the muscular abdominal wall. The large area of contact serves to disperse the electrical energy, which is far less dangerous than areas of higher concentration. For this reason, it is not recommended to use plastic anchors to secure the cannula because the plastic anchor isolates the electrical current from the abdominal wall and increases the likelihood that it could
accumulate on the cannula and discharge into body tissues. This is referred to as a hybrid system—the cannula is conductive, but the anchor is not. Capacitive coupling can be avoided by using conductive systems that allow energy to dissipate over a larger surface area.

Residual heat. Radiofrequency electrosurgical devices produce heat instantaneously to achieve quick hemostasis. After use, however, the active electrode tips do not cool down instantaneously. There is enough heat remaining in a recently deactivated electrode tip to produce a tissue effect. As a result of the residual heat, surgeons must be aware of the position of a deactivated tip in relation to the tissue or to other metal devices in the abdomen to avoid unintended tissue effect.

To reduce the risk of injury to the patient during laparoscopic use of electrosurgery, the members of the surgical team should

- inspect insulation carefully,
- ensure the active electrode tip is clean,
- use the lowest possible power setting,
- use the lower voltage (cut) or blend modes,
- use brief intermittent activations versus prolonged activations of the active electrode,
- not activate the active electrode in an open-circuit method,
- not activate the electrode in close proximity or in direct contact with metal or conductive objects in the abdomen,
- use bipolar electrosurgery whenever possible,
- select a conductive trocar cannula system to reduce electrical buildup on the cannula in the active electrode operative channel, and
- avoid using hybrid systems (e.g., metal cannula/plastic anchor).

Electrosurgical smoke plume. Surgical smoke can represent a risk for patients during laparoscopic surgery. Smoke can reduce visibility in the abdomen, impeding procedural progress, and the patient can experience dangerous side effects, such as unrecognized hypoxia and port site metastases. Weld and colleagues studied smoke produced by various energy sources in 2007 and determined that monopolar electrosurgery produces particle distributions that degrade visibility the most, illustrating the need to effectively evacuate and filter smoke in the abdominal cavity.

A study conducted at the University of Minnesota, Minneapolis, involved measuring levels of carbon monoxide inside the peritoneal cavity during laparoscopic cholecystectomy. The study showed that five minutes after the use of electrosurgery, carbon monoxide was present in the abdomen at a median concentration of 345 ppm. By the end of the procedure, the median concentration had risen to 475 ppm. This was in excess of the 35 ppm upper limit for a one-hour exposure set by the Environmental Protection Agency.

The danger of smoke inside the abdomen also has been documented at the Mercer University School of Engineering, Macon, Georgia, by Ott. This study found that as smoke is produced inside the abdomen, it is absorbed through the peritoneal membrane. The subsequent result in the patient’s bloodstream is an increase in methemoglobin and carboxyhemoglobin concentrations, which reduces the oxygen-carrying capacity of red blood cells. The potential hazard for the patient is falsely elevated pulse oximeter readings, which are compromised in the presence of dyshemoglobinemia—both carboxyhemoglobin and methemoglobin are dyshemoglobinemias—and give a falsely elevated oxygen reading, which could result in unrecognized patient hypoxia.

An additional risk to the patient resulting from the production of surgical smoke inside the abdomen is port site metastases. If malignant tissue is cauterized and aerosolized inside the abdomen, the cancerous cells can seed at another site. A study conducted by Fletcher and colleagues in Canada showed that when electrosurgery was used on melanoma cells, they were released into the plume. The researchers concluded that the cells were viable and could be grown in culture.
This could explain port metastases at sites that were not in direct contact with the tumor.\textsuperscript{46} Evacuation and appropriate filtration of endosurgical smoke is of benefit to patients and can be done with a variety of devices designed specifically for use during laparoscopy.

**Electrosurgery Technologies**

During laparoscopic minimally invasive electrosurgery, it is critical to take advantage of improvements in technology because advancements in surgical devices and instrumentation often solve the technical problems that are present in older models. Technology improvements make surgery safer for patients and practitioners alike.

There are many electrosurgery technology improvements available today. Tissue response generators, for example, reduce capacitive coupling in the low-voltage (cut) waveform, and newer tissue-sensing generators reduce capacitive coupling across all electrosurgery modes—cut, blend, and coagulate. In addition, vessel fusion electrosurgery generators, ultrasonic devices, and active-electrode monitoring are technological advances with known patient safety benefits.

**Vessel fusion electrosurgery generators.**

Vessel fusion electrosurgery generators offer the safety of bipolar generators with the ability to fuse vessels and tissue bundles up to 7 mm in size. A study by Lamberton et al on vessel fusion concluded that vessel fusion technology “had the best overall performance with the highest burst pressure, fast sealing time, low thermal spread, and low smoke production.”\textsuperscript{47(p5)}

There is a difference between traditional bipolar electrosurgery and vessel fusion technology. Traditional bipolar electrosurgery merely collapses vessel walls together and relies on the formation of a proximal thrombus to impede blood flow. Comparatively, vessel fusion technology combined with specially designed forceps changes the nature of the collagen, creating a seal that is permanent.

**Ultrasound devices.** Vessel fusion devices are often compared with ultrasonic devices, but they are two very different technologies. Ultrasound dissection interacts with tissue by rapid mechanical action and does not produce sound waves. It is called ultrasonic because the vibrations, which occur from 23 kHz to 55 kHz, are above the range of human hearing.\textsuperscript{48} Ultrasonic devices have gained popularity as dissection and hemostasis tools.

Ultrasonic scalpels are solid tips or blades. When the tips vibrate, thermal heat is produced at the edge of the blade. This technology allows surgeons to coagulate and divide tissue. The tip vibrates at a frequency of 55,000 times per second, stimulating collagen molecules to denature and form a coagulum.\textsuperscript{49} The motion of the tip produces a vapor that, because of lower tip temperatures, could carry infectious aerosols.\textsuperscript{50} Even though the ultrasonic scalpel tip produces less heat than monopolar electrosurgery, heat is produced and there is thermal spread to adjacent tissues.\textsuperscript{51} Surgeons must be aware of heat production and the potential of transfer of the heat to unintended structures.

**Active electrode monitoring.** Active electrode monitoring can minimize concerns about insulation failure and capacitive coupling. This type of system monitors and shields against stray electrosurgical current.

**CONCLUSION**

Minimally invasive procedures have progressed in recent years; as the tools continue to improve, so too will the procedures. It is of utmost importance that procedures and systems be designed with patients’ safety in mind. Creating a culture of safety is the responsibility of every surgical team member. The recommendations of Clarke\textsuperscript{33} and others who specialize in promoting safe systems can improve overall team function:

- Ensure that equipment works and that team members are trained to use it.
- Use checklists because this can reduce errors.
- Standardize around best practice and equipment.
- Improve electrosurgical safety.
- Practice teamwork.
- Critique care and register problems.
- Continue to improve equipment.

Best practices during minimally invasive procedures should be evidence based and supported by professional standards. Organizations such as AORN publish recommended practices that, when followed, contribute to positive patient outcomes.52

Editor’s note: SILS is a trademark of Covidien, Mansfield, MA. NOTES is a registered trademark of the Natural Orifice Surgery Consortium for Assessment and Research.

References

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As an employee of Covidien Energy-based Devices, Ms Ulmer has declared an affiliation that could be perceived as posing a potential conflict of interest in the publication of this article.
Best Practices for Minimally Invasive Procedures

PURPOSE/GOAL

To educate perioperative nurses about best practices for minimally invasive procedures.

OBJECTIVES

1. Describe new technologies that are being used to perform minimally invasive surgery (MIS).
2. Discuss the benefits of these technologies compared with those used in more invasive procedures.
3. Identify procedures that can be performed using the various types of MIS technology.
4. Discuss complications that may be encountered during MIS.

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QUESTIONS

1. Reasons for the increasing shift from invasive surgery to MIS include
   1. less blood loss during surgery.
   2. smaller external scars, less internal scarring, and decreased formation of adhesions.
   3. increased patient satisfaction and decreased pain.
   4. shorter recovery periods postoperatively.
      a. 1 and 2  b. 2 and 4
      c. 1, 2, and 3  d. 1, 2, 3, and 4

2. Advantages of robotic-assisted surgery for the surgeon include
   1. increased intra-abdominal articulation.
   2. three-dimensional vision.
   3. reduced hand tremors.
   4. a smaller learning curve.

   a. 1, 2, and 3  b. 1, 3, and 4
   c. 2, 3, and 4  d. 1, 2, 3, and 4

3. Responsibilities of a perioperative robotics nurse specialist may include
   1. assisting intraoperatively with all robotic procedures.
   2. assisting with research efforts.
   3. ensuring instrument availability and care.
   4. providing patient and staff member education.
      a. 1 and 2  b. 2 and 3
      c. 1, 2, and 3  d. 1, 2, 3, and 4

4. For single-port procedures,
   a. standard MIS instrumentation cannot be used.
   b. all instrumentation must pass through a single entry point at the navel.
c. all instrumentation must pass through a single entry point that can be located in one of three positions.
d. a trocar with a single instrument port is used to compensate for the space restriction and limited range of motion.

5. The rationale for using natural orifice transluminal endoscopic surgery (NOTES) to gain access to the abdominal cavity through natural body openings is to
1. decrease the risk of infection.
2. reduce postoperative pain and wound and pulmonary complications.
3. improve cosmesis.
4. promote early ambulation.
   a. 2 and 4  
   b. 1, 2, and 3
   c. 2, 3, and 4  
   d. 1, 2, 3, and 4

6. A NOTES procedure may be performed
1. transcolonically.
2. transgastrically.
3. transvaginally.
4. transvesically.
   a. 1 and 2  
   b. 2, 3, and 4
   c. 1, 2, and 4  
   d. 1, 2, 3, and 4

7. Thoracic procedures that can be performed with the video-assisted thoracoscopic surgery include
1. thymectomy.
2. aortic valve replacement.
3. pulmonary and esophageal resection.
4. sympathectomy.
   a. 1 and 2  
   b. 1, 3, and 4
   c. 2, 3, and 4  
   d. 1, 2, 3, and 4

8. Perforation of vital structures is the most common complication during laparoscopic surgery because of the “blind” placement of the Veress needle and the first laparoscopic port.
a. true  
   b. false

9. Capacitive coupling during electrosurgery can be avoided by
a. using conductive systems that allow energy to dissipate over a large surface area.
b. isolating the electrical current from the abdominal wall so it can accumulate on the cannula and discharge into body tissues.
c. activating the active electrode only when it is near conductive instruments.
d. using open-circuit activation.

10. To reduce the risk of patient injury during laparoscopic use of electrosurgery, members of the surgical team should
1. ensure that the active electrode tip is clean.
2. inspect the insulation carefully.
3. avoid using hybrid systems made of metal and plastic.
4. use prolonged activations of the active electrode.
   a. 1 and 2  
   b. 2 and 3
   c. 1, 2, and 3  
   d. 1, 2, 3, and 4

The behavioral objectives and examination for this program were prepared by Kimberly Retzlaff, editor, with consultation from Rebecca Holm, RN, MSN, CNOR, clinical editor, and Susan Bakewell, RN, MS, BC, director, Center for Perioperative Education. Ms Retzlaff, Ms Holm, and Ms Bakewell have no declared affiliations that could be perceived as posing potential conflicts of interest in the publication of this article.
This evaluation is used to determine the extent to which this continuing education program met your learning needs. Rate the items as described below.

OBJECTIVES
To what extent were the following objectives of this continuing education program achieved?

1. Describe new technologies that are being used to perform minimally invasive surgery (MIS).
   Low 1. 2. 3. 4. 5. High
2. Discuss the benefits of these technologies compared with those used in more invasive procedures. Low 1. 2. 3. 4. 5. High
3. Identify procedures that can be performed using the various types of MIS technology. Low 1. 2. 3. 4. 5. High
4. Discuss complications that may be encountered during MIS. Low 1. 2. 3. 4. 5. High

CONTENT
5. To what extent did this article increase your knowledge of the subject matter? Low 1. 2. 3. 4. 5. High
6. To what extent were your individual objectives met? Low 1. 2. 3. 4. 5. High
7. Will you be able to use the information from this article in your work setting? 1. Yes 2. No

8. Will you change your practice as a result of reading this article? (If yes, answer question #8A. If no, answer question #8B.)
8A. How will you change your practice? (Select all that apply)
   1. I will provide education to my team regarding why change is needed.
   2. I will work with management to change/implement a policy and procedure.
   3. I will plan an informational meeting with physicians to seek their input and acceptance of the need for change.
   4. I will implement change and evaluate the effect of the change at regular intervals until the change is incorporated as best practice.
   5. Other: ______________________

8B. If you will not change your practice as a result of reading this article, why? (Select all that apply)
   1. The content of the article is not relevant to my practice.
   2. I do not have enough time to teach others about the purpose of the needed change.
   3. I do not have management support to make a change.
   4. Other: ______________________

9. Our accrediting body requires that we verify the time you needed to complete the 3.3 continuing education contact hour (198-minute) program: ___