This competency assessment module has been designed for health care professionals and is intended to provide the basic knowledge and skills necessary for the safe use of electrosurgical equipment. Information will outline safety consideration for both patients and personnel, including general considerations and those related to fire and smoke plume, and minimally invasive laparoscopic surgical procedures.
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Overview and Objectives

Overview

Electrosurgery employs the passage of high frequency, oscillating electric currents through tissue between two electrodes to cut, fulgurate, or desiccate tissue. The evolution of electrosurgery has resulted in many clinical advantages, but its use is also associated with certain hazards in the clinical practice setting. As new instrumentation and surgical techniques are continually introduced in the perioperative environment, the advancements in energy modalities that enhance these techniques also continue to evolve. Therefore, it is imperative that all members of the perioperative team understand the principles of electrosurgery and demonstrate competency in the use of electrosurgery equipment. In addition, maintaining knowledge of the associated hazards, relevant safety considerations, and emerging energy modalities is vital to providing a safe environment of care for all surgical patients.

This competency assessment module has been designed for perioperative health care professionals and is intended to provide the basic knowledge and skills necessary for the safe use of electrosurgical equipment. The module presents an overview of the mechanisms of action of electrosurgical devices, including the basic principles of electricity and the effects on tissue. The role of the health care professional is discussed in detail, outlining safety considerations for both patients and personnel, including general considerations and those related to fire and surgical smoke, minimally invasive laparoscopic surgical procedures, and other energy-based modalities. After completion of the written educational activity and review questions, the participant should be able to demonstrate safe and effective use of the electrosurgical unit.

Objectives

Upon completion of this module, the participant should be able to:

1. Explain how electrosurgical devices work.
2. Define the tissue effects of electrosurgery.
3. Outline the health care professional’s role in the safe use of electrosurgical devices as related to both patient and staff safety.
4. List the hazards of surgical smoke generated during electrosurgery.
5. Discuss safety considerations of electrosurgery during minimally invasive laparoscopic surgery.
6. State the special clinical considerations applicable to the use of various advanced energy modalities.
7. Apply the principles of electrosurgery safety to specific patient care situations.
8. Demonstrate proper use of electrosurgical equipment.
Unit 1:

**Principles of Electrosurgical Devices**

Achieving optimal hemostasis and the desired tissue effects during a surgical or invasive procedure are key factors in promoting positive patient outcomes. Electrosurgery is frequently used to achieve these objectives and also to provide the best possible visualization of the operative site. In the late 18th century, it was discovered that high frequency electrical current could be passed through the human body without producing neuromuscular stimulation; the production of heat in the tissues was found to be a side effect. Electrosurgery generators were soon developed to produce radio frequency (RF) current to sever tissue and achieve hemostasis. Electrosurgery was born, and it continues to be one of the most commonly used energy modalities in the operating room (OR) today. While electrosurgery has been used for many decades in surgical and invasive procedures, new energy technologies continue to develop and impact surgical care.

Electrosurgery and other energy modalities can be used in almost any surgical or invasive procedure in which coagulation or severing of tissues is required. Electrosurgery is commonly used in dermatological, gynecological, cardiac, plastic, ocular, spine, otorhinolaryngological, orthopedic, urological, neurosurgical, and general surgical procedures.

In addition, specialty applications of electrosurgery and other energy modalities have evolved:

- **Gastrointestinal** — laparoscopic cholecystectomy, polypectomy, papillotomy, fulguration of selected malignant rectal tumors, liver resection
- **Gynecology** — laparoscopic sterilization with bipolar electrosurgery
- **Neurosurgery** — micro-bipolar electrosurgery for intracranial use
- **Orthopedic** — total hip arthroplasty, total knee arthroplasty, oncology, spine surgery
- **Urology** — transurethral resection of the prostate and bladder tumors

Despite the numerous clinical benefits of electrosurgery, its use in the clinical practice setting also presents certain hazards for both perioperative personnel and patients. Therefore, members of the perioperative team involved in the use of electrosurgery in surgical and invasive procedures must have a basic understanding of the principles of electricity to use it safely. Awareness of the clinical considerations of electrosurgery use in the OR, especially those related to electrosurgical burns, fires, and the hazards associated with surgical smoke, is vital to promoting safety in the OR. Knowledge of emerging energy technologies is critical to maximizing their clinical benefits, while using them safely.

**Basic Electricity**

The fundamental principles of electricity must first be understood in order to comprehend how electrosurgery works. Electricity involves the motion of subatomic particles that behave in a consistent and predictable manner. Electrons are negatively charged and orbit the nucleus of an atom. As the electrons jump from one atom into the orbit of another atom, an electrical current is generated. There are three important terms that describe the properties of electricity:

- **Current** — the flow of electrons, measured in amperes (amps)
- **Voltage** — the force or push that moves the electrons from one atom to another, measured in volts; and
- **Impedance** (also called resistance) — the opposition to the flow of the current (i.e., electrons), measured in ohms. Impedance converts electrical energy into heat, similar to the way mechanical friction results in heat. Ohm’s law applies to electrical circuits; it states that the current through a conductor between two points is directly proportional to the potential difference or voltage across the two points, and inversely proportional to the resistance between them.

Another important term in describing the properties of electricity is frequency. Frequency, which is measured in hertz (Hz) or cycles per second, is the number of waves
Unit 2:  
Clinical Considerations for Electrosurgery Safety

**Recommended Practices**

All members of the perioperative team play an integral role in the safe and effective use of electrosurgery in the clinical practice setting. Clinical considerations focus on safety measures to minimize the potential for electrical and other hazards during the use of electrosurgery. While all ESUs are not alike, the principles of electrosurgery are the same; therefore, appropriate safety measures should be applied for all clinical applications. The Recommended Practices for Electrosurgery promulgated by the Association of periOperative Registered Nurses (AORN) outline practices for proper care and handling of electrosurgical equipment that are essential for patient and personnel safety. Policies and procedures for electrosurgery should be developed, reviewed periodically, revised as necessary, and readily available in the practice setting. Policies and procedures assist in the development of quality assessment and improvement activities and should be included in both the orientation and ongoing education of personnel to assist in the development of the required knowledge, skills, and attitudes that affect patient outcomes. These policies and procedures should include, but are not limited to:

- required safety features on ESUs;
- equipment maintenance programs;
- required supplemental safety monitors;
- equipment checks prior to initial use;
- reporting and impounding malfunctioning equipment;
- preoperative, intraoperative, and postoperative patient assessments;
- precautions during use;
- injury reporting;
- ESU sanitation; and
- documentation.

In addition, all policies and procedures must be in compliance with the Safe Medical Devices Act of 1990; if equipment failures or patient or personnel injuries occur, the ESU and both the active and dispersive electrodes should be handled in accordance with this act.

These recommended practices state that personnel involved in the selection of ESU and accessories for purchase or use should make decisions based on safety features to minimize the risks to both patients and personnel. Equipment selected should include technology to detect stray current and be designed to minimize the risk of alternate site and capacitive coupling injuries, as well as unintentional activation. Accessories should be compatible with equipment and other accessories. Personnel should remain aware of evolving electrosurgery technology and its impact on patient care and safety. Personnel also should demonstrate competency in the use of ESUs and accessories and use the ESU and accessories according to the manufacturer’s written instructions.

Recommendations specific to ESU systems state that the system should be used in a manner that minimizes the potential for injuries. The ESU should be mounted securely on a shelf or tip-resistant cart. The ESU electrical cord should be of adequate length and flexibility to reach the electrical outlet without stress or the use of an extension cord. The ESU should be tested before initial use, inspected periodically, and receive preventive maintenance by a designated person responsible for equipment maintenance (e.g., bioengineering personnel). Personnel should visually inspect the ESU and test the return electrode contact monitor before each use (i.e., attempt to activate the device with the dispersive electrode not connected). The manufacturer’s written precautions should be followed for the safety of both the patient and the personnel involved in the procedure.

An ESU that is damaged or not working properly should be removed from service immediately and reported to the designated person responsible for equipment maintenance. Each ESU should be assigned an identification or serial number that allows designated personnel to track function problems and document the maintenance performed.
Unit 3:

Fire Safety

Fire is one of the electrical hazards inherent in the OR environment. Although it is a rare occurrence, a surgical fire is a frightening and devastating experience for everyone involved. In 2003, The Joint Commission issued a sentinel alert on surgical fires after two cases of OR fires, which had been reported for review under the Sentinel Event Policy, resulted in serious injury to the patients.10 Fires can result from the use of electrosurgery, particularly in an oxygen-enriched environment or in the presence of flammable liquids. Fires that occur in the OR usually ignite on or in the patient.

The Fire Triangle

The risk of a surgical fire may be present whenever and wherever surgery or invasive procedures are performed (e.g., hospital ORs, ambulatory surgery centers, physicians’ offices, endoscopy centers, interventional and diagnostic radiology centers) and in any setting where the elements of a surgical fire are present. For any fire to occur, the three elements of the fire triangle must be present in proper proportion — an oxidizer or oxygen source; a fuel source; and an ignition mechanism (Figure 4). All of these factors are abundantly present in the OR.

Oxidizers

Most fuels burn only in the gaseous state and ignite only when sufficient vapors have mixed with oxygen. Although oxygen from the air combines with fuels during a fire, the OR has other sources of oxygen, usually related to administration of anesthesia. Anesthesia often requires the delivery of oxygen-enriched mixtures above the 21% of room air oxygen to ensure proper oxygenation of the patient. This additional oxygen is supplied from the anesthesia machine, ventilator, or gas cylinder via nasal cannulae, face mask, or endotracheal tube. Nitrous oxide also is considered an oxidizer. When heat is applied to nitrous oxide, it breaks down and releases oxygen, further contributing to the oxygen-rich environment. Because oxygen is heavier than air, it collects in low-lying areas, such as within drape folds or an open chest cavity. Some drape fabrics absorb and retain oxygen. With the increased oxygen, it is not only easier for a fire to ignite, it will burn faster and hotter and is more difficult to extinguish.

Fuels

By definition, a fuel is anything that can burn. In the OR, this includes almost everything that comes in contact with the patient, including the patient him/herself. The most obvious sources of fuel in the OR include paper and cloth drapes; skin prep solutions, especially those with an alcohol base; endotracheal tubes made of silicone, plastic, or rubber; blankets; stockinettes; flexible endoscopes; and blood pressure and tourniquet cuffs.

Ignition Sources

Ignition sources are anything that produces heat. Heat, from many sources, increases the oxidation rate of a fuel-oxygen mixture until combustion occurs. There are several potential ignition sources in the OR, the most frequent one being electrosurgery, including both monopolar and bipolar. Other sources include lasers, overhead and fiberoptic lights, drills, defibrillators, and argon beam coagulators. These sources are capable of producing temperatures from several hundred to a few thousand degrees Fahrenheit, which is enough to ignite most fuels, including surgical drapes. In addition to the heat generated by these devices, other ignition sources must be considered, such as incandescent sparks produced by electrosurgical accessories during normal operation that result from the use of certain modes and surgical techniques; damaged laser fibers; and glowing embers from charred tissue. Sparks can produce enough initial heat to ignite some fuels. These types of events are
During surgical procedures that use an electrosurgical unit or a laser, the thermal destruction of tissue creates a smoke by-product. It is estimated that 500,000 health care workers, including surgeons, nurses, anesthesia providers, and surgical technologists, are exposed to electrosurgical or laser smoke every year. Since the mid-1970s, the body of evidence documenting the hazardous components of surgical smoke has continued to grow.

Surgical smoke has been found to contain toxic gases and vapors, as well as bioaerosols and viruses; in high concentrations, this smoke can cause adverse health conditions. Therefore, perioperative personnel must remain aware of the hazards of surgical smoke and the need to minimize the exposure to it in clinical practice settings where electrosurgery is used.

**Components of Surgical Smoke**

Electrosurgical units are the most common heat-producing devices used to achieve a desired tissue effect during surgical procedures. The heat produced by electrosurgical devices causes pyrolysis; this combustion or mechanical disruption of tissue causes bioaerosol to form. This surgical smoke is comprised of 95% water or steam and 5% cellular debris in the form of particulate matter; the particulate matter is composed of chemicals, blood and tissue particles, viruses, and bacteria. ESUs produce particles with a mean aerodynamic size of 0.07 micrometers; this is important to note, because the smaller the particle size, the farther it can travel to affect members of the surgical team. Particles that remain airborne are smaller than 100 micrometers in diameter; particles that are 5 micrometers or larger are deposited on the walls of the nose, pharynx, trachea, and bronchus; those that are smaller than 2 micrometers are deposited in the bronchioles and alveoli. See Table 5 for the particle size produced by various heat-producing devices in the OR.

The gaseous component of smoke generated by electrosurgery produces a noxious odor. This smoke also can contain chemical by-products similar to other smoke plumes, including benzene, carbon monoxide, formaldehyde, hydrogen cyanide, methane, phenol, styrene, and toluene. These by-products also are known to have mutagenic potential and be carcinogenic, as some of them are also found in cigarette smoke. The concentration of these by-products produced during pyrolysis depends on the type of tissue, power density, and length of time the energy is used on the tissue. Table 6 lists the toxic chemicals created during the decomposition of tissue protein and lipids that are present in surgical smoke.

**Possible Health Effects of Surgical Smoke**

Exposure to surgical smoke poses potential health risks for both patients and perioperative staff. As far back as 1996, the National Institute for Occupational Safety and Health (NIOSH) recognized the hazards of surgical smoke when it released a hazard control report stating that at high concentrations, smoke generated by a laser or electrosurgical unit causes ocular and upper respiratory tract irritation in health care personnel, and creates visual problems for the surgeon; further, the smoke has unpleasant odors and has been shown to have mutagenic potential. While a large amount of information and various recommendations exist, a specific link between exposure to surgical smoke and adverse health effects to perioperative personnel has not been established. Table 7 lists potential risks associated with surgical smoke.

Early studies indicate that the toxic effects of surgical smoke pose potential health risks for both patients and perioperative staff.

<table>
<thead>
<tr>
<th>Table 5: Particle Sizes for Heat-producing Devices in the OR</th>
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</thead>
<tbody>
<tr>
<td><strong>Device</strong></td>
</tr>
<tr>
<td>Electrosurgical unit</td>
</tr>
<tr>
<td>Laser</td>
</tr>
<tr>
<td>Ultrasonic scalpel</td>
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</tbody>
</table>

Whenever electrosurgery is used in the OR, all members of the perioperative team must consider the potential for its interaction with other electrical equipment or conductive materials. These considerations are especially crucial during endoscopic minimally invasive procedures. Surgeons and endoscopists use various types of electrosurgical equipment when performing these procedures because they can cut, coagulate, and grasp tissue for easier dissection. Equipment used in endoscopic minimally invasive procedures includes:

- endoscopes, which are inserted directly into a hollow organ, such as the bowel, bladder, or stomach;
- laparoscopes, which are inserted through the abdominal wall through a trocar cannula;
- video systems, which include light sources, monitors, cameras, video cassette recorders (VCRs), and DVD technology;
- insufflators; and
- a variety of trocars, scissors, dissectors, and graspers.

**Risks of Monopolar Electrosurgery During Endoscopic Minimally Invasive Surgery**

The combination of monopolar electrosurgery and endoscopic minimally invasive surgery is quite popular, versatile, and cost-effective. The combination does have some inherent risk factors, however, which often are not fully appreciated by the perioperative team. These dangers can jeopardize patient safety, cause severe complications, and have significant medical effects on the patient. The two primary potential dangers in these cases are:

- direct thermal injury — when the tip of an active electrode is accidentally applied to a nontargeted tissue; and
- stray energy burns — when stray electrical energy escapes from monopolar instruments, resulting in serious burns and tissue damage.

The complications and injuries associated with these dangers may include vessel and organ hemorrhage, organ perforation, contamination of the abdominal cavity, and peritonitis. Any of these conditions can lead to morbidity and even death if not detected early. In addition to user-caused burns, electrosurgical injuries during minimally invasive procedures that can potentially cause thermal burns to nontargeted tissues resulting from stray electrical current are caused by:

- insulation failure,
- direct coupling, and
- capacitive coupling.

**Insulation Failure**

Insulation failure can occur when the coating, or special layer of insulation covering the surface of an endoscopic instrument or active electrode, has been compromised. This compromise may be a crack or break in the insulation along the shaft of the instrument. This can occur increasingly over time, during a surgical procedure, or during cleaning and sterilization processes. When this occurs, electrical energy can escape at the point of the defect and burn untargeted tissue. If the defect occurs along the shaft of the instrument, it may be outside of the practitioner’s limited field of vision. Therefore, it is not always possible to detect the insulation failure. The integrity of the insulation must be inspected every time a reusable endoscopic active electrode or electrosurgical tool is used.

**Direct Coupling**

Direct coupling occurs as electrical energy flows from the active electrode and comes in direct contact with a nonin-
Summary

When using electrosurgery during open or endoscopic minimally invasive surgical procedures, the safety of the patient is the primary consideration for the entire surgical team. All members of the perioperative team are responsible for protecting the patient from the hazards associated with electrosurgery use in the OR environment. As technological advancements in surgical techniques, electrosurgery, and other energy modalities continue to evolve, it is even more important that perioperative personnel remain aware of these advancements and implement the appropriate safety precautions to minimize the associated risks and reduce potential complications.

**Staff Education and Training**

Initial education and training on all electrosurgical and laparoscopic instrumentation and equipment is a vital component of the orientation process. Furthermore, ongoing education on surgical techniques and outcomes, new equipment, or equipment that is used infrequently is a key component in maintaining clinical competency. Return demonstration of proper equipment operation is essential in the education process.

In addition to providing inservice training on the appropriate use of products and equipment, many manufacturers offer continuing education (CE) activities, usually at no cost to the facility, as a value-added service. These activities provide staff members an opportunity to learn more about the theory behind the technology, as well as the clinical considerations related to the use of the equipment.

**Equipment Check Protocols**

Protocols for equipment checks should be instituted for all equipment and instrumentation. Protocols should include the following.

- Biomedical engineering personnel perform a check of all equipment prior to its use in the OR.
- The circulating nurse and scrub assistant also should check all equipment and instrumentation before use on a specific procedure.
- The scrub assistant should thoroughly inspect the instrumentation as it is being prepared on the sterile field.
- If there is any doubt regarding the integrity of the insulation or any damage to the instrument whatsoever, it should be taken out of service for repair and replaced on the field immediately.
- Annual preventive maintenance checks on all equipment must be conducted according to manufacturers’ written recommendations.

**Equipment Standardization**

Standardization of equipment and instrumentation facilitates safe operation of all equipment used during surgical or invasive procedures and also allows for uniform safety precautions to be developed and implemented. The perioperative team must remain informed of current trends in electrosurgery and other energy modalities to work collaboratively with surgeons and administrators in obtaining equipment that will promote the best possible patient outcomes.

**Patient Education**

For patients undergoing minimally invasive procedures, routine discharge teaching should include instructions to report immediately if they experience any signs or symptoms of infection (e.g., abdominal pain, fever above 101° F), excessive pain, bleeding, or the inability to void that may be indicative of a laparoscopic electrosurgical injury. Symptoms of such an electrosurgical injury can occur days after discharge from the perioperative practice setting.

**Medico-Legal Issues**

There are certainly medico-legal aspects regarding the use of electrosurgery today. Patient injuries resulting from the use of electrosurgery have potentially enormous medico-legal consequences for clinicians, as well as health care facilities. Using all available safety measures in electrosurgery monitoring is essential in today’s practice arena.
Unit 7:

Case Studies

The following case studies allow the learner to synthesize and apply the concepts discussed in the previous units to patient care scenarios. Read the scenarios carefully, integrating the patient data and information regarding electro-surgery and safety considerations, to discuss the key points. Focus on the appropriate perioperative safety interventions based on the patient assessment factors and planned surgical intervention.

CASE STUDY 1 — Ms. SC

Ms. SC is a 44-year-old woman admitted to an outpatient surgery center for laparoscopic tubal ligation. She is 5’4” tall and weighs 135 pounds. She has a history of Crohn’s disease, for which she was treated with steroids. This caused severe osteoarthritis, and Ms. SC underwent a right total hip arthroplasty two years ago. She has limited range of motion in her right hip as a result of the surgery.

Points to Consider:
What are the key patient assessment factors for Ms. SC?
What are the expected outcomes?
What are the appropriate intraoperative interventions?

CASE STUDY 2 — Mr. RO

Mr. RO is a 62-year-old male with a history of cardiac arrhythmias due to coronary artery disease. He is 6’ tall and weighs 140 pounds. He had an automatic implantable cardiac defibrillator (AICD) implanted six months ago. He also has a history of hypertension and malignant melanoma, and has had several sites excised on both of his legs. He is experiencing pain in his left lower quadrant and is being admitted for an urgent open repair of a left incarcerated inguinal hernia.

Points to Consider:
What are the key patient assessment factors for Mr. RO?
What are the expected outcomes?
What are the appropriate intraoperative interventions?

CASE STUDY 3 — Ms. MR

Ms. MR is a 35-year-old female admitted for a laparoscopic cholecystectomy with exploration of the common bile duct. She is 5’4” tall and weighs 260 pounds. She has a history of diabetes for which she self-administers insulin on a sliding scale. In the preoperative holding area, she appears very anxious, and tells you that she had a friend who had this same surgery and experienced a “bad burn in her stomach.”

Points to Consider:
What are the key patient assessment factors for Ms. MR?
What are the expected outcomes?
What are the appropriate intraoperative interventions?

CASE STUDY 4 — THE SURGICAL TEAM

Ms. NM, the circulating nurse, and Mr. VC, the surgical technologist, are assigned to OR #1. Their first case is a left nephrectomy that has started late because the previous case ran over. After a smooth induction of anesthesia, the anesthesia provider has given Ms. NM the sign to proceed with patient preparation. Ms. NM places the dispersive electrode on the patient. While she is doing that, Mr. VC inadvertently drops the safety holster for the active electrode on the floor and kicks it out of the way so that no one will trip on it. He then folds a sterile towel and places the active electrode in it. He also places a dry sponge in the folded towel to clean the electrode tip during the case. Dr. BJ then enters the OR, and the team positions the patient. Because they are running behind, Ms. NM hurriedly preps the patient, after which Mr. VC immediately begins draping the patient with the first assistant.

Points to Consider:
What actions taken by Ms. NM and Mr. VC were inappropriate?
What should Ms. NM and Mr. VC have done differently?
References


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