ULTRASONICS
IN SURGERY
A Look Back — Current Innovations
Self-Study Guide
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Ulmer served on local and national committees for the Association of periOperative Registered Nurses (AORN) since 1977. She served three terms as a member of the national AORN Board of Directors, one term as President–Elect, and as AORN National President 2000–2001. Since 1995, Ulmer worked with AORN, OSHA, NIOSH, ANA, physicians and nurses to facilitate the publication of workplace safety guidelines from OSHA on smoke evacuation. She also developed a program on Fire Safety in the Operating Room in 1998 and presented it to nurses and surgeons across the country. From 2003 to 2006, Ms. Ulmer served as Chair of AORN’s International Resource Committee, which launched AORN’s first Latin American conference in Panama City, Panama, in 2004.

At AORN Congress in 2006, Ms. Ulmer was awarded AORN’s highest honor, the Award for Excellence in Perioperative Nursing.

From 1989 to 1994, Ulmer was a member of the Certification Board Perioperative Nursing. She served as president 1990–1991 and 1993–1994. During her tenure the Board published its first CNOR Study Guide and started an RN First Assistant certification exam (CRNFA).

Ms. Ulmer presented numerous programs on nursing issues throughout the world, including Argentina, Australia, Austria, Brazil, Canada, China, Colombia, Costa Rica, England, Finland, France, Georgia, Germany, Guatemala, Honduras, Hong Kong, Indonesia, Japan, Korea, Malaysia, Mexico, New Zealand, Panama, Russia, Singapore, Spain and Taiwan.


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Mark L. Phippen, RN, MN, CNOR, was a Global Senior Clinical Educator for Covidien. He received his Bachelor of Science in Nursing from California State University, Long Beach, in 1973, and his Masters in Nursing from the University of Los Angeles, Los Angeles, California, in 1981. Mark was a certified operating room nurse since 1985. He has held a variety of perioperative nursing positions, including staff nurse, head nurse, operating room educator, manager and director. Mark completed twenty years of enlisted and commissioned military service as a United States Air Force military policeman and United States Army Nurse Corps officer. He retired in 1989 with the rank of Major.

Mark was the senior editor for the Competency and Credentialing Institute’s publication *Competency for Safe Patient Care During Operative and Invasive Procedures* (2009); and the W.B. Saunders publications *Patient Care During Operative and Invasive Procedures* (1999), *Perioperative Nursing Practice* (1993) and *Perioperative Nursing Handbook* (1994). He was the second editor for *Review of Perioperative Nursing* (1999). He authored 15 chapters in perioperative nursing books and 33 articles in the *AORN Journal* and *Seminars in Perioperative Nursing*. From 1992 to 1993, Mark served as the editor of *Seminars in Perioperative Nursing*, a W.B. Saunders quarterly publication.

During his career, he made numerous professional presentations on various healthcare topics to nurse and physician audiences throughout the United States, Canada, the United Kingdom, France, Germany, Austria, Japan, Australia, Singapore, Malaysia, Taiwan, Hong Kong and the Republic of Korea. As a Covidien clinical educator, he presented to approximately 75,000 perioperative nurses, surgical technologists and surgeons.

Intended Audience:
Surgeons, perioperative nurses and other healthcare team members who provide patient care during operative or invasive procedures.

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OBJECTIVES
Upon completion of this activity the participant will be able to:

- Recognize the importance of the historical development of ultrasonics
- Discuss the principles of ultrasonic technology
- Describe the tissue effects of ultrasonic scalpel technology
- Identify the surgical applications of ultrasonic devices
- Distinguish the benefits of ultrasonic technology for surgeons and patients

OVERVIEW
Ultrasonic technology as used in energy-based devices is an essential tool to support today’s advanced surgical techniques. It is widely used across multiple surgical specialties because of its clinical benefits for patients and surgeons. The use of ultrasonic energy dates back to the 1880s when the Curie brothers discovered the piezoelectric effect. Since the 1800s, the evolution of ultrasonic technology has led to the development and incremental improvements of the ultrasonic scalpel. The ultrasonic scalpel can provide hemostasis while minimizing the tissue injury that is sometimes associated with the use of energy. To maximize patient benefits, it is necessary for perioperative professionals to understand the principles of ultrasonic technology as well as its tissue effects and applications. It is equally important that personnel demonstrate competency in the use of ultrasonics in order to provide safe patient care. This study guide outlines the historical evolution of ultrasonics and the basic principles of ultrasonic energy. The ultrasonic scalpel is reviewed, including its mechanisms of action; tissue effects; advantages and disadvantages in comparison to electrosurgery and vessel fusion; surgical applications; and clinical benefits for surgeons and patients. Competencies for safe patient care during the use of ultrasonics are included.
INTRODUCTION
Throughout the practice of surgery, ongoing technological advancements in operative techniques and instrumentation continue to provide exciting new treatment options for patients. The evolution of surgical devices that enhance newer techniques parallels these developments. Ultrasonic technology as used in energy-based devices supports today’s advanced surgical techniques. It is widely used across multiple surgical specialties due to its clinical benefits for surgeons and patients.

HISTORICAL DEVELOPMENT OF ULTRASONIC TECHNOLOGY
To fully appreciate and maximize the clinical benefits of ultrasonic technology, it is helpful to review historical development, basic principles and technological advancements over time. As one discovery builds on another, at times serendipitously, events unfold to reveal newer techniques and improved devices.

Piezoelectric Effect
The historical development of ultrasonics dates back to 1880, when Jacques and Pierre Curie discovered the piezoelectric effect (from the Greek word piezein, meaning “to press”) (Figure 1). The translation, quite literally, means pressing electricity. The Curie brothers found that the application of pressure on certain classes of crystals — tourmaline, topaz, quartz, Rochelle salt and cane sugar — caused a potential difference (an electrical charge) to be generated between two conducting surfaces that were in contact with the crystals. Within a year, based on mathematical deductions from thermodynamic principles, Gabriel Lippman, Ph.D., physicist and inventor, predicted the inverse piezoelectric effect, in which an applied alternating electric field results in a change in the crystal dimensions: the electric charge causes the crystals to vibrate. This was subsequently verified by the Curie brothers. In essence, they discovered that the motor action of piezoelectric ceramics or crystals converts electrical energy into mechanical energy. This was a breakthrough discovery in the 1880s, leading to numerous piezoelectric devices that are used commonly today. Watches use the piezoelectric effect to help us tell time, and the voice recognition system in cell phones allows us to make hands-free contact.

Cavitational Effect
An important concept in the historical progression of ultrasonics is the cavitational effect. In the 18th century, Daniel Bernoulli (1700 – 1782), a Swiss physician and geometer, studied fluid dynamics. He developed what is now called Bernoulli’s law, which states that when a high-velocity water stream is generated, pressure within the stream falls so low that the water vaporizes; the rapid formation and collapse of vapor pockets became known as cavitation. Bernoulli’s law was at the foundation of Lord Rayleigh’s (John William Strutt) discovery of the cavitation effect (Figure 2). While studying the structural damage to a ship’s propellers in 1916, Rayleigh deduced that a small jet stream of water was created by the collapse of the bubbles that was strong enough to cause the damage. Based on this principle, high-speed mechanical waves can be used in nonelastic media (e.g., water) to create a cavitation effect. When used in tissues that are high in water content (e.g., the liver), the final effect is destruction of the water-rich cells and sparing of structures that are low in water but high in collagen (e.g., blood vessels and nerves).

Ultrasonics in Dentistry
A significant step in the evolution of ultrasonic technology was its use in dentistry. In 1953, Dr. Matthew C. Catuna was the first to use ultrasonic energy for the preparation of cavities and reported it as a good alternative method for this purpose (Figure 3). By 1955, D.D. Zinner had introduced the ultrasonic scaler for periodontal procedures. Seven years after the original publications on ultrasonic scalers, the benefits of using ultrasonic debridement during patient care were described. The benefits included improved visualization as well as a reduction in patient fatigue and discomfort while undergoing ultrasonic debridement (Figure 4).
Phacoemulsifier

In 1967, phacoemulsification, introduced by ophthalmologist Dr. Charles Kelman, moved ophthalmic surgery into the minimally invasive arena and cataract removal into the modern era. Dr. Kelman had been working since 1962 on ways to remove cataracts through smaller incisions. While having a dental procedure in 1966 with a Cavitron Dental Scaler, he made the intuitive leap that the ultrasonic dental device could be used to break up cataracts. He used the dental device in his lab and developed it to be used in ophthalmology. He called his new procedure phacoemulsification — the breakup and removal of the lens with a cavitational ultrasonic aspiration device. By 1967, Kelman was using the device on patients (Figure 5). He patented his machine and partnered with Cavitron to produce the Kelman phacoemulsification unit. Phacoemulsification is accomplished through a small ultrasonic tip, whose vibrations break up the mass of the cataractous lens within its capsule; the remains are then suctioned out through a small needle in the tip. This technique transformed cataract extraction. Prior to Kelman’s development of phacoemulsification, cataract surgery was a difficult procedure that required patients to be immobilized in the hospital for over a week; this was followed by weeks of recovery and the wearing of thick, image-distorting glasses the remainder of their lives. Further advances in surgical techniques and equipment led to a dramatic increase in the popularity of phacoemulsification, with increased safety and efficiency. Viscoelastic agents, which were developed simultaneously with modern phacoemulsification techniques, played an essential role in the success of this technology.

Cavitational Ultrasonic Surgical Aspirator

The cavitational ultrasonic surgical aspirator was the next generation of the phacoemulsifier. By 1973, Kelman had performed more than 500 procedures using the ultrasonic phacoemulsifier. He not only published his results, but his success was noted in the broadcast media as well. By 1976, neurosurgeons in New York, learning of Kelman’s success, had become interested in using the ultrasonic device for the removal of brain tumors. Dr. Eugene S. Flamm and Dr. Joseph Ransohoff, of New York University, tried to use the phacoemulsifier but found it inadequate for use in the brain and nervous system. Modifications to the phacoemulsifier were subsequently made, and a more powerful version of the device proved successful for the removal of central nervous system tumors (Figure 6). During the late 1970s and 1980s, doctors from other surgical specialties began using the cavitational ultrasonic surgical aspirator in a variety of procedures. Dr. W.J. Hodgson and colleagues used the device in general surgery procedures such as the fulguration of a rectal cancer, the removal of a villous adenoma and the transection of the pancreas during a Whipple procedure. Oncology surgeons used it to remove cancerous implants off the diaphragm and other delicate structures. The ultrasonic device’s selectivity and precise removal of tumor tissue made it a favorite of surgeons. In addition, the device’s ability to skeletonize structures such as the liver allowed for excellent blood control (Figure 7).

The cavitational ultrasonic surgical aspirator simultaneously fragments, irrigates and aspirates tissue. The motor action of piezoelectric ceramics or crystals converts electrical energy into mechanical energy. Ultrasonic waves are produced by applying electromagnetic energy to the piezoelectric transducer, which creates mechanical vibration in response to the electric field. The piezoelectric effect is the elastic vibration of the quartz crystal induced by resonance with the applied electric field. (Resonance is the phenomenon that occurs when a driving force near that...
the natural frequency of a crystal is applied to it, causing the crystal to vibrate with a larger amplitude at the same frequency.) Without resonance, the oscillations would gradually subside, because the motion of the crystals would be stopped by dissipation of energy and the resistance of air to motion. Thus, when ultrasonic waves are applied at low power levels, no tissue effect occurs, as is the case with diagnostic ultrasonic imaging. Conversely, the application of higher power levels and densities can be used to produce tissue dissection as well as surgical cutting and coagulation. The ultrasonic surgical aspirator harnesses ultrasonic energy for cavitational fragmentation of tissue. The ultrasonic scalpel uses ultrasonic energy without aspiration to cut and coagulate tissue. An ultrasonic surgical aspirator system consists of a hand piece, a function control console and a foot switch; the hand piece and the console are connected by a cable. The console regulates the solution delivered to the sterile field and controls the suction of tissue through the hand piece; the console also controls tip vibration. The connection of the hand piece and cables back to the console can sometimes cause surgeon fatigue due to the weight of the cables. Positioning the console close enough to the sterile field can, at times, be a challenge to the perioperative team.

To achieve tissue cavitation, the device produces ultrasonic waves in the range of 23,000 Hz to 55,000 Hz (i.e., 23,000 to 55,000 cycles per second); the mechanical energy is delivered through the hollow tip, which also fragments tissue at the cellular level (Figure 8). As the tip moves rapidly, it creates a pulsating cavitational effect within the cells, whereby cavities are formed. When the surface tension of the cavity can no longer withstand the pulsating effect, the cavity implodes, resulting in cell destruction. During fragmentation, sterile fluid is delivered through the hand piece to suspend the tissue particles; the tissue debris is then aspirated through the suction tip. Cavitation ultrasonic aspirators enable surgeons to remove tumors that are high in water content or moderately calcified, while sparing tissues that are high in collagen, such as blood vessels and nerves.

Decades after Kelman’s successful use of cavitational ultrasonic surgical aspiration in ophthalmology, advancements in this technology have led to its application across multiple surgical specialties. Neurosurgeons adopted the Kelman phacoemulsification technique for use in dissecting tumors from delicate brain and spinal cord tissue, because it simultaneously breaks up and evacuates firm tumors while protecting vital neural and vascular structures. The cavitational ultrasonic surgical aspirator has also been used successfully in laparoscopic general and gynecological procedures, including laparoscopic cholecystectomy, the treatment of endometriosis and advanced gynecologic endoscopic procedures such as presacral neurectomy and laparoscopically assisted vaginal hysterectomy. Its demonstrated clinical benefits include reductions in both blood loss and tissue injury, as well as improved visualization.

**Ultrasonic Scalpel**

A more recent advance in ultrasound technology in surgery is the ultrasonic scalpel. In the late 1980s, Tom Davison, Ph.D., Dr. Joseph Amaral and colleagues began investigating the feasibility of an ultrasonically activated scalpel. By the mid–1990s, ultrasonic shear technology used ultrasonic waves for cutting and coagulation without the need for electrical current. With the rapid and ongoing advancements in minimally invasive surgery (MIS) techniques, the need for dissection...
without blood loss took on greater significance. For example, thick and/or adipose structures with numerous blood vessels (e.g., greater omentum, mesentery of the large and small intestines, regional lymph drainage areas) have especially poor accessibility for hemostasis in MIS procedures. Therefore, safe video-endoscopic divisions of these anatomic structures may exceed the capacity of both high-frequency currents and MIS suturing techniques. As a result, ultrasonic dissection technology was developed to provide an alternative dissection technique. Table 1 summarizes the evolution of ultrasonic technology:

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>1880s</td>
<td>Jacques and Pierre Curie discovered the piezoelectric effect.</td>
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<tr>
<td></td>
<td>Littman predicted the inverse piezoelectric effect; this was subsequently verified by the Curie brothers.</td>
</tr>
<tr>
<td>1916</td>
<td>Lord Rayleigh discovered the cavitational effect.</td>
</tr>
<tr>
<td>1950s</td>
<td>The ultrasonic dental scaler emerged.</td>
</tr>
<tr>
<td>1967</td>
<td>Phacoemulsification was introduced by ophthalmologist Dr. Charles Kelman.</td>
</tr>
<tr>
<td>1970s</td>
<td>The cavitational ultrasonic surgical aspirator was developed for use in neurosurgery by Drs. Flamm and Ransohoff.</td>
</tr>
<tr>
<td>1980s</td>
<td>The ultrasonic scalpel was introduced by Drs. Davison and Amaral.</td>
</tr>
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**ULTRASONIC SCALPEL: MECHANISMS OF ACTION**

The production of ultrasonic energy begins with an electrical current that generates a signal sent through a co-axial cable to a transducer in a hand piece (Figure 9).\(^{21,22}\) The transducer then converts the electrical energy into mechanical motion through the contraction and expansion of the ceramic elements. A longitudinal vibratory response is produced that moves the distal end of the blade up to 84 μm peak-to-peak at up to 55,500 Hz, depending on the manufacturer of the device (Figure 10). As the power increases, the frequency remains the same, but the longitudinal excursion of the tip becomes longer. When the tip of the ultrasonic scalpel is in contact with tissue, the mechanical motion causes tissue proteins to become denatured as hydrogen bonds are broken; as a result, the protein molecules become disorganized and form a sticky coagulum, which welds and coagulates the smaller bleeding vessels.
Ultrasonic devices have four mechanisms of action, depending on the manufacturer of the device:

- **Cutting** — The ultrasonic scalpel uses a combination of tension and pressure to rapidly stretch tissue; when the tissue reaches its elastic limit, the blade cuts through it easily (Figure 11).

- **Coaptation** — The vibration of the ultrasonic device disrupts the hydrogen bonds in tissue, causing collagen molecules to collapse and adhere to one another at a low temperature. In this process, the tissue is subsequently transformed into a sticky coaptate (Figure 12).

- **Coagulation** — When ultrasonic energy is applied to tissue for a few seconds longer than it takes to achieve coaptation, a rise in temperature will lead to the release of water and vapor and then to coagulation.

- **Cavitation** — A side effect of the ultrasonic energy that is used to cut, coaptate or coagulate occurs when the vibration of the device is transmitted to the surrounding tissue, causing rapid volume changes of the tissue and cellular fluid. Cavitation facilitates tissue plane dissection and improves visibility of the operative field.

The advantages of using ultrasonic energy have been well documented in the decades since the first device was developed.

The advancements that have been made with ultrasonics are without question — better dental procedures, vastly improved removal of cataracts and brain tumors, and an efficient and efficacious device to dissect and coagulate tissue. It is noteworthy, however, that until recently every ultrasonic device used in surgery also came with at least one cable that attached to an operating console. As innovations continue to improve patient care, an innovative battery-powered ultrasonic scalpel can now be added to the tools available to surgeons.

**ULTRASONIC SCALPEL INNOVATION: A CORDLESS, BATTERY-POWERED DEVICE**

Ultrasonic dissection devices, as documented in the literature (Table 2), enable fast dissection and vessel occlusion, and facilitate safe and efficient surgical procedures. Historically, these devices were available only in models that used a cord to connect the device on the sterile field to a generator outside the sterile field. Complaints associated with the use of corded (tethered) devices include the cumbersome weight and drag of the cords/cables and difficulty managing cords on the sterile field. A new, innovative cordless ultrasonic dissecting device is now available that offers the documented advantage of ultrasonics while reducing some of the concerns associated with corded models.

The cordless ultrasonic dissection device provides hemostasis on vessels up to 5 mm in diameter, with hand-activation dissection capabilities.

The device uses a miniaturized generator component containing a ceramic stack that produces the piezoelectric effect. The generator attaches to the disposable device along with a battery that gives the operator a self-contained system with all controls delivered onto the sterile field.
The pistol-style handle design is 5 mm in diameter with a 39-cm-long shaft linking the jaws to the handle. The device can be activated with the instrument jaws open for finer dissection using just the active blade, or with the jaws closed around tissue for optimal hemostasis. The dual-mode power activation button provides tactile guidance for the surgeon to differentiate between the minimum and maximum power modes. Depressing the button to the first position provides displacement at the distal end of the blade (approx. 64 μm); depressing the button completely provides displacement at the distal end of the blade (approx. 84 μm). Minimum power is intentionally slower to allow for better hemostasis and burst pressure. Maximum power is intentionally faster to provide faster dissection. The activation button allows the surgeon to focus on the procedure by providing a single-finger position for activation. The active blade and clamping jaw are both straight on the cordless ultrasonic dissection device (Figure 13).

The cordless ultrasonic dissection device can be used to transect, dissect and coagulate tissue. It can be used in open and laparoscopic general, urologic, gynecologic, pediatric, thoracic, plastic and non-bone orthopedic procedures where blood control with minimal thermal injury to tissue is necessary.

The cordless ultrasonic device uses a lithium-ion polymer battery pack, which provides electrical power (DC) to the generator when charged. The advantage of the lithium-ion battery is that the power output does not degrade as the battery is depleted; the power remains strong until the battery is depleted; the last application is as strong as the first. There is a warning given at 20% capacity remaining and again prior to total battery depletion.

The device contains two microprocessors (containing software): one is in the battery, and one is in the generator. A serial data-link between the processors allows communication and coordination of their operation. A signal is delivered from the battery to the piezoelectric ceramic stack inside the generator. Ultrasonic waves are created and are amplified as they travel from the blade extender to the tip of the instrument. The mechanical vibrations drive the 14.5-mm-long active blade of the device. With the combination of the vibration at 55,500 cycles per second and the pressure applied by closing the instrument, tissue is dissected and hemostasis achieved. Coaptation disrupts the positive hydrogen bonds in tissues, causing collagen molecules to collapse and form a sticky coagulum, which forms a hemostatic vessel occlusion as time, pressure and temperature continue. This allows the instrument to simultaneously cut and coagulate tissue.

This is the first battery-powered, cordless ultrasonic scalpel device to be developed for use in surgery. The cordless design increases freedom of movement and promotes more natural surgeon movement, which may result in less surgeon fatigue. The cordless design makes it easier to pass the device on the sterile field and to move it from room to room. Set up is greatly simplified and takes place completely on the sterile field.

**EVOLUTION OF ADOPTION OF BATTERY POWERED DEVICES IN SURGERY**

“The history of powered instruments has paralleled their need in surgery.”

Instruments and devices used during surgery were developed over time by users who were in search of better ways to provide patient care. One of the first powered devices used in the United States was a bone drill created in 1850 by Dr. Daniel Brainard of Chicago’s Rush Medical College. Dentistry’s need for powered instruments helped to fuel the development and advancement of additional drills. In 1871, James Beall Morrison created a foot-driven dental drill (Figure 14), which was used by the United States Navy into the Korean War era. Such early instruments were crude, but...
they helped the user accomplish tasks more easily than did muscle-powered instruments. The advent of electric power instruments came in 1906 when Dr. Fred Albee of Boston developed the Albee Bone Mill (Figure 15). Although innovative, the device was cumbersome to use.

Pneumatic-powered devices were developed in the mid-1920s by Dr. Horace C. Pitkin in Boston and Dr. W.H. Ogilvie at Guy’s Hospital in London. Ogilvie’s device had the advantage of eliminating the sparks that could be produced by electric motors, which could lead to explosions in the operating room. It was not until the 1950s, however, that the need for more precise and controlled power tools promoted further developments. Powered instruments of many varieties became more widely used. The 1960s saw an increase in the use of power tools in neurosurgery when the Codman company marketed the first cranial drill. The company was founded by Dr. Harvey Cushing, who is also considered to be the father of neurosurgery and electrosurgery. The early devices were all bulky and difficult to handle, but they helped surgeons to improve surgical care of patients.23

Over the decades, pneumatic devices were replaced by others that used nitrogen as the power source. These devices required connection to a large nitrogen tank, which had to be pulled into the operating room and positioned close to the sterile field. Nitrogen-powered devices developed into air-turbine-driven motors, and the hand-held devices became smaller and more compact.23

The first battery-powered surgical instruments were introduced by the Mira corporation in the 1960s. The early battery-powered instruments and equipment were large, bulky and heavy. As with early motorized instruments, operator fatigue was not uncommon and battery life could be an issue. It was not until the 1980s, however, that battery-powered devices came into wider use through the efforts of companies such as Stryker, Aesculap, Black and Decker and others, which worked to revise, update and improve battery-powered instruments. As battery performance and life have continued to improve, the number and type of these devices used in hospitals have increased. An important advantage of using battery power is the absence of a cord that must be connected to an external power source, which then must be connected to a wall electrical outlet. Floor space is at a premium in most surgical suites. Reducing the amount of equipment that must be positioned around the sterile field is an obvious benefit to patients and staff alike. A reduction in operator fatigue is an additional advantage of using battery-powered devices. The weight or drag created by a cord or power line may seem imperceptible, but over time it can produce a tiring effect for the operator. Just as tiresome for the entire surgical team is the effort to keep cords from becoming entangled, and keeping them on the sterile field. As with most innovative solutions, keeping a device simple and compact while allowing the operator to accomplish the task at hand produces the greatest benefit. Use of battery power simplifies the device.23

TISSUE EFFECTS OF ULTRASONIC SCALPEL TECHNOLOGY: COMPARISON TO ELECTROSURGERY AND VESSEL FUSION TECHNOLOGY

To help ensure the effective and prudent use of ultrasonic technology during surgical and/or invasive procedures, it is useful to compare it to monopolar and bipolar electrosurgery, and vessel sealing. Doing so can outline the advantages and disadvantages of each energy device and help the operator to select the best device for the job.
Monopolar and Bipolar Electrosurgery

Electrosurgery generators produce electrical current that is in the radio frequency range (above 100,000 Hz). A variety of waveforms can be produced as monopolar or bipolar current, each with a specific tissue effect. Electrosurgery is very useful in the hemostatic control of small vessels and has been the backbone of hemostatic devices for decades. Because it produces high heat, it should be applied accurately and with care, as excessive use or misuse in attempts to control bleeding can result in unintended tissue effects. Unintended thermal injury is a consideration when using high-frequency electrosurgery in both the bipolar and monopolar modes. This is a greater concern with older electrosurgery generators that do not have tissue response capabilities. The degree of thermal spread is dependent on other factors as well, including user techniques such as dwell time, the wave form selected and the power setting chosen.

Monopolar Electrosurgery

When monopolar electrosurgery is used, the electrical current originates in the generator and is delivered to patient tissues by an active electrode tip. The current then travels through the patient tissue, where it achieves the desired tissue effect, and is then collected by the patient-return electrode and returned to the generator (Figure 16). This is the intended pathway for the electrical current. Monopolar electrosurgery must be used in a way that restricts current flow to the intended pathway and prevents any stray current flow.

Tissue Density Feedback Electrosurgery

The progression of computer capabilities led to great strides in patient safety in 1995 when computer-controlled feedback generators were introduced. This technology uses a computer-controlled, instant-response system that senses tissue density. The feedback system provides consistent clinical effect through all tissue types. The generator rapidly senses tissue resistance and automatically adjusts the output voltage to maintain consistent tissue effect. This is referred to as an adjustment mode, or effect mode. This feedback mode reduces the need to adjust power settings for different types of tissue. It also gives improved performance at lower voltages, which helps to reduce the risk of patient injury. The instant response to changing patient conditions translates into improved performance over conventional generators and was a tremendous advance in patient safety. This safety system, however, was only available in the cut or vaporization mode when it was introduced and coagulation continued to be the primary mode used in the operating room.

Closed-loop Coagulation

An engineering breakthrough in electrosurgery occurred in 2006 with the introduction of increased tissue-sensing generator capabilities with a closed-loop coagulation mode. The technology builds on, and then improves, the best tissue-sensing engineering developments of the last 25 years. Closed-loop coagulation is a computer-controlled system that senses tissue resistance and adjusts output voltage, current and generator power in microseconds. This provides a consistent electrosurgical effect across different patient tissues. This technology is the first time that tissue sensing has been available to the surgeon in the coagulation mode. The difference between conventional coagulation and closed-loop coagulation can be seen by comparing wave-form printouts of the generator output (Figure 17). The tissue-sensing technology communicates information about the patient’s tissues back to the generator, making each surgical procedure custom and specific to each patient.

Figure 16. Monopolar electrosurgery circuit.

Figure 17. Comparison of electrosurgery generator waveforms.
**Bipolar Electrosurgery**

While monopolar is the most frequently used electrosurgical modality, bipolar electrosurgery is often selected when the surgeon needs to limit thermal spread, such as when working with delicate tissues or on small anatomical structures. It can be considered a safer alternative to monopolar electrosurgery in patients who present the potential for electromagnetic interference with implanted devices because of the low voltages used to deliver the current. Additionally, bipolar electrosurgery results in less collateral thermal damage; however, it may be of limited benefit other than in the control of bleeding from very small blood vessels.

With bipolar electrosurgery, the electrical energy flows from one tine (or prong or blade) of the bipolar instrument to the other tine as it passes through the tissue located between these tines (Figure 18). The flow of electricity is stopped if a certain impedance level is reached; frequently, this is 100 ohms but may vary for the different types of bipolar generators available today.

**Tissue Effects**

Electrosurgical generators are capable of producing various electrical waveforms. As the waveform changes, so does the tissue effect (Figure 19).

The electrosurgical mode referred to as cut is a continuous sinusoidal waveform. Because the delivery of the current from the generator is continuous, lower voltage is needed to achieve tissue vaporization. The correct method to achieve the cutting effect in tissue is to hold the tip of the active electrode in close proximity to, but not touching, patient tissue. When used in this manner, the current creates higher tissue temperatures in a shorter time, leading to rapid expansion of intracellular fluids and cell explosion or vaporization. This type of cell vaporization provides a clean tissue division. The cut mode is also a good choice for coagulation of tissue through desiccation.

The electrosurgical mode referred to as coagulation or coag is an interrupted or dampened method of current delivery. When using this mode, current is being delivered to tissue only about 6% of the time. This is referred to as the duty cycle. The coagulation current produces spikes of voltage as high as 9,000 to 10,000 volts peak to peak. As the waveform spikes, the tissue heats and then cools down between voltage spikes, thus producing coagulation of the cell during the 94% off cycle of the waveform. The practitioner should hold the active electrode tip slightly above the target tissue.

Electrosurgical generators also offer a blend mode of current delivery. Blend modes are a function of the cut waveform (typically the yellow side of the generator) whereby current delivery is modified producing varying degrees of cutting and hemostasis. Generators can produce several blend waveforms that provide varying degrees of coagulation and cutting-current delivery by modifying the duty (on/off) cycle. Examples of blend waveforms available in electrosurgery generators are:

- **Blend 1** = 50% on/50% off
- **Blend 2** = 40% on/60% off
- **Blend 3** = 25% on/75% off

Variations of cut-to-coagulation blends may vary among manufacturers. Generally, however, a higher blend number means a higher degree of coagulation.

**Vessel Fusion**

Comparisons are often made between the ultrasonic scalpel and the vessel fusion device. While both have a place in the surgeon’s armamentarium, they have very different tissue interactions. A vessel fusion device is an advanced electrosurgical technology in which the intimal layers of the vessel wall are fused and a permanent seal is formed.
In contrast to other energy-based ligation methods, which shrink the vessel walls and rely on the proximal thrombus for occlusion and thus hemostasis, the lumen of the vessel is obliterated with this ligation method through the optimization of the combination of pressure and energy (Figure 20). The unique combination of pressure and energy used in this technology melts the collagen and elastin in the vessel walls, reforming it into a permanent, plastic-like seal.

Vessel fusion technology significantly reduces thermal spread in comparison to existing bipolar instruments because the effects are confined to the target tissue or vessel with virtually no charring and therefore, with minimal thermal spread to adjacent tissue. The vessel fusion device also uses much less voltage when delivering the therapeutic current, which also reduces thermal spread. The use of vessel fusion provides the following advantages:

- Permanently fuses vessels up to and including 7 mm in diameter
- Seals all the tissue bundles without dissection and isolation
- Causes minimal thermal spread, precisely confining its effect to the target tissue
- Results in virtually no sticking
- Reduces sticking and charring
- Reduces need for multiple applications
- Has no dislodged clip
- Leaves no foreign material in the patient

**Figure 20. A vessel sealed using a vessel fusion device (a, b), compared to one sealed using bipolar electrosurgery (c).**

**Comparison of Ultrasonic Technology to Electrosurgery and Vessel Fusion**

**Ultrasound Energy**

Unlike electrosurgery, ultrasonic energy is mechanical in nature and works at lower temperatures. Both monopolar and bipolar electrosurgical devices coagulate by heating tissues (i.e., coagulation) to temperatures ranging from 150°C to 400°C. Blood and tissue are desiccated and oxidized (i.e., charred), forming an eschar that covers and seals the bleeding area. Rebleeding can occur when the blades being removed during electrosurgery adhere to tissue and disrupt the eschar. Conversely, an ultrasonic scalpel controls bleeding by coaptive coagulation at temperatures, ranging from 50°C to 300°C (proteins begin to denature at temperatures above 60°C). The vessels are coapted or tamponaded and sealed by this sticky protein coagulum. Coagulation occurs by means of protein denaturation when the blade, vibrating at 55,000 Hz, produces heat and denatures the protein, and a coagulum is formed that seals small, coapted vessels. When the effect is prolonged, secondary heat is produced that subsequently seals larger vessels.

To maximize tissue effects and also enhance safety, an ultrasonic hand piece has an active, stable jaw for the transmission of energy as well as a movable jaw that is used for tissue clamping. The ultrasonic wave produced by the generator is transferred to the active vibrating blade that is used to grasp tissue against a nonvibrating blade. The vibration denatures hydrogen bonds in tissue and vessel proteins, forming the coagulum, which seals the vessel lumen. Energy is not transmitted to the movable part; therefore, it can be used as a barrier against thermal transmission. Because the device does not operate through the use of electrical energy, no electricity passes to or through the patient; furthermore, the thermal energy produced is relatively low when compared to electrosurgery, thereby causing minimal thermal damage and tissue trauma.

Compared to electrosurgery, the lower temperatures associated with the use of ultrasonic devices have the potential for less charring and lateral thermal tissue damage. Because electricity is not transmitted through the patient, due to the rapid mechanical motion of an ultrasonic device, the risk for stray-energy injuries is reduced, and dissection near vital structures is safer. However, heat is produced. Additional advantages associated with ultrasonic energy include no nerve or muscle stimulation and the provision of tactile feedback. In minimally invasive procedures, the clinical advantages of ultrasonic energy include the elimination of direct coupling, capacitive coupling, insulation failure, pad-site burns and stray electrical energy, while allowing for precise cutting and controlled coagulation. One of the major disadvantages of ultrasonic technology has been the inability to coapt larger vessels. However, it has been
noted that with proper technique of “milking the vessels” (i.e., gently squeezing the vessel in one direction, e.g., proximally or distally), larger vessels can be sealed; in addition, several factors, including the generator setting, tension on the tissue, grip force and shape of the instrument can yield varied effects. Furthermore, advances have been made in the instrumentation (e.g., hand activation) and also in the generator capabilities that may allow for better management of larger vessels.

**Literature Review: Advantages and Disadvantages of Ultrasonic Energy**

A review of the literature yields numerous studies that have examined clinical outcomes with the use of the ultrasonic scalpel in comparison to conventional electrosurgery and vessel fusion technology across various surgical specialties. A brief synopsis of several relevant studies is presented below.

- **Comparison of ultrasonic energy and electrosurgery:**
  - Two studies examined the benefits of the ultrasonic scalpel with regard to postoperative morbidity in patients undergoing tonsillectomy. These studies demonstrated that, while there was no clinically significant difference between the groups with respect to the amount of operating time, postanesthetic recovery room time, pain scale scores, postoperative admissions and postoperative morbidities, the patients who had undergone ultrasonic scalpel tonsillectomy experienced significantly less intraoperative and postoperative bleeding than those who had conventional electrosurgery.
  - The ultrasonic scalpel has demonstrated advantages over electrosurgery in obtaining a quality radial artery graft conduit in coronary artery bypass grafting. Vasospasm is the primary obstacle to the widespread adoption of using the radial artery as a conduit; because the radial artery is prone to spasm, its successful use as a graft is dependent on techniques involving the management of vasospasm during surgery. An early study investigated the vasoreactivity of the radial artery harvested with either an ultrasonic scalpel or electrosurgery and also examined the possible effects of these techniques on endothelial integrity. With regard to the influence of the harvesting technique on the vasoreactivity of radial artery, this study showed that radial arteries harvested either by an ultrasonic scalpel or by electrosurgery did not differ in their response to various vasoconstrictor and vasodilator agonists. However, the ultrasonic scalpel did not affect the contractile properties or endothelium-dependent or -independent relaxations of the radial arteries of the patients undergoing coronary artery bypass grafting, compared with those harvested by electrosurgery. More recently, a study was undertaken to measure the degree of radial artery spasm induced by means of harvest with electrosurgery or an ultrasonic scalpel in patients undergoing coronary artery bypass grafting. This study showed that the mean luminal volume, a measure of vasospasm, decreased significantly less after harvesting with the ultrasonic scalpel (9% ± 7%) than with electrosurgery (35% ± 6%). Completely intact intima was present in 11 of 15 (73%) radial arteries harvested with the ultrasonic scalpel, compared to 9 of 29 (31%) arteries harvested with electrosurgery.
  - The safety and efficacy of the ultrasonic scalpel in both experimental and clinical thoracic surgery have been evaluated. Cutting and hemostasis of pulmonary parenchyma can be achieved with minimal tissue damage using the ultrasonic scalpel, compared to electric coagulation; further, the ultrasonic scalpel minimized tissue charring and dissection, and eliminated thermal injury in thoracic surgery procedures.
  - Because meticulous hemostasis is essential to successful thyroidectomy and using electrosurgery to achieve hemostasis carries the risk of injury due to lateral dispersion of heat, a study was conducted to compare the procedure parameters and complications of thyroidectomies performed using an ultrasonic scalpel with those using electrosurgery. Operating time was 25 minutes less in the ultrasonic scalpel group than in the electrosurgery group (96 minutes ± 23 versus 121 minutes ± 34, respectively). The median number of ligatures in the ultrasonic scalpel group was 1 (range 0–7) versus 17 (range 6–28) in the electrosurgery group. Mean blood loss, estimated by gauze weight, was less in the ultrasonic scalpel group (35 ± 27 mL versus 54 ± 51 mL in the electrosurgery group). Drainage during the first 24 postoperative hours and pain intensity during the first postoperative week were similar in both groups. There were no episodes of persistent nerve palsy or hypoparathyroidism in either group. These authors concluded that the use of an ultrasonic scalpel in thyroidectomies requires less operative time than does electrosurgery.

- **Comparison of ultrasonic energy and vessel fusion technology:**
  - The advantages and disadvantages of the ultrasonic scalpel in comparison to vessel fusion technology in gynecological procedures have been reported. Recently, a study was conducted to compare the use of an electrothermal bipolar vessel sealer (EBVS) with an ultrasonic scalpel during total laparoscopic hysterectomy, looking at operating time, estimated blood loss and related complications. In this study, both the average procedure time and estimated blood loss were significantly less in the EBVS group; the change in hemoglobin and hematocrit values was found to be more significant in the ultrasonic scalpel group. The authors concluded that EBVS was less time-consuming and caused less bleeding, compared to the ultrasonic scalpel. In a study of the surgical outcomes of women undergoing laparoscopic radical hysterectomy for cervical cancer using a vessel sealing device compared with an ultrasonic surgical device, the results demonstrated that both devices provided...
equivalent surgical outcomes; the data further suggested that use of either instrument is safe and effective and instrument choice should be based on surgeon comfort and training.36

— A study comparing the efficacy and safety of laparoscopic colorectal surgery performed using a vessel sealing system versus an ultrasonic scalpel was undertaken in patients eligible for elective laparoscopic right or left hemicolectomy or anterior resection of the rectum.37 The primary end point was intraoperative reduction of blood loss; secondary end points included intraoperative and postoperative morbidity and operative time. Blood loss, complication rate and operative time were similar between the two groups. These results demonstrated that both devices were useful instruments for laparoscopic colorectal surgery, with no significant difference in terms of intraoperative or postoperative morbidity and operative time. The choice of which technique to use should be according to the surgeon’s preference.

— A prospective study comparing vessel sealing system tonsillectomy (VSST), ultrasonic scalpel tonsillectomy (UST) and cold knife tonsillectomy (CKT) assessed intraoperative bleeding, operative time, postoperative pain and complication rates.38 Intraoperative bleeding was significantly lower in the VSST group, with no measurable bleeding in any of the cases. Bleeding in the UST group was significantly lower than in the CKT group. Operative time and postoperative pain were significantly lower in both the VSST and UST groups. One primary hemorrhage occurred in the UST group, and one occurred in the CKT group. Secondary hemorrhage occurred in one, two and one patients in the VSST, UST and CKT groups, respectively. The authors concluded that VSST and UST showed comparable results regarding intraoperative blood loss, postoperative hemorrhage and pain. Compared with CKT, both were associated with less intraoperative blood loss and pain.

— In a retrospective study comparing the outcomes of total thyroidectomies, patients were divided into three groups: group SL patients underwent total thyroidectomy with the classic suture ligation technique; group L patients were treated using the electrothermal bipolar vessel sealer; and group U patients were treated using the ultrasonic scalpel.39 The primary outcomes measured were operative and hospitalization time, intraoperative and postoperative bleeding, postoperative hypocalcemia, and superior and inferior laryngeal nerve injuries. All three groups were similar in terms of demographics, thyroid gland weight and pathology, perioperative complications and hospital stay. Compared with the classic technique, surgical time was reduced significantly (by approximately 20%) when the bipolar vessel sealer or ultrasonic scalpel was used. The authors concluded that both the bipolar vessel sealer and ultrasonic scalpel were safe, useful and time-saving alternatives to the traditional suture ligation technique for thyroid surgery. Because no differences were observed regarding the two devices, the choice should be made based on the surgeon’s preferences and experience.

• Comparison of ultrasonic energy, electrosurgery and vessel sealing technology:

— Two recent studies compared the advantages and disadvantages of ultrasonic energy, electrosurgery and vessel sealing technology. One study investigated lateral thermal spread following ex vivo application of monopolar electrosurgery, bipolar electrosurgery, ultrasonic energy and vessel fusion technology on animal muscle. The results showed that while the degree of lateral thermal spread varied with the instrument type, power setting and application time, monopolar electrosurgery was associated with the highest temperatures and the greatest degree of lateral thermal spread.40 Although there was little difference between the other three devices, the vessel fusion device seemed to produce the least rise in temperature. Another study compared the efficiency, safety and cost of the three different methods (ultrasonic energy, electrosurgery and vessel sealing technology) for achieving hemostasis in thyroid surgery. It demonstrated that while the operative safety was similar for all three instruments, total thyroidectomy using the ultrasonic scalpel was the fastest procedure because it was bloodless, and hemostasis and sectioning were controlled with a single instrument; therefore, it was the least expensive procedure because of the reduction of operative time and staff cost.41

SURGICAL APPLICATIONS FOR ULTRASONICS AS AN ADDITIONAL ENERGY-BASED TECHNOLOGY

The ultrasonic scalpel can effectively seal vessels up to a diameter of 5 mm.3 Because ultrasonic energy does not produce the high temperatures that are generated with electrosurgery (i.e., the thermal change is gradual), it is less reliable for deep-tissue coagulation.41 Ultrasonic energy is indicated for soft tissue incision when bleeding control and minimal thermal injury are desired; it is contraindicated for incising bone and contraceptive tubal ligation.21 This technology has been used in many open as well as laparoscopic procedures across multiple surgical specialties, as evidenced in the literature.

Applications in Open Surgical Procedures

Although initially popularized in laparoscopic procedures, the ultrasonic scalpel has recently been shown to be useful in open procedures as well.44 Its use in open procedures for rectal villos adenomas, local or extensive oral lesions, and pancreas and liver dissection procedures has been reported. The ultrasonic scalpel tends to be especially useful in open procedures in which the surgeon is working in a narrow operative field. A recent study compared two techniques of skeletonizing the internal mammary artery (IMA) in coronary artery bypass surgery, in a prospective randomized trial.41 In coronary artery bypass procedures, selective
skeletonization of the IMA without adjacent vasculo-muscular structures reduces trauma to the chest wall, results in elongated grafts, makes ideal graft positioning possible and eliminates the need to implant a dissected or hypoplastic graft with direct visual control of the vessel. In this study, 51 IMAs were randomly harvested and divided into two groups according to the technique of skeletonization. In group I, IMAs were harvested in a skeletonized fashion with an ultrasonic scalpel; in group II, they were harvested using scissors and hemostatic clips. The investigators compared arterial wall histology, harvesting time, spasm frequency and the use of hemostatic clips between the two groups. The results showed no significant morphological differences in the arterial wall in the two groups. The use of an ultrasonically activated scalpel reduced the IMA harvesting time, the frequency of spasm and the use of hemostatic clips. The authors concluded that ultrasonic harvesting of a skeletonized IMA is a nontraumatic preparatory technique that reduces the costs of surgical clips and can be performed safely and quickly.

A prospective study of patients undergoing hemorrhoidectomy with the use of an ultrasonic scalpel was conducted to evaluate the incidence of postoperative complications and to identify any predisposing factors leading to postoperative complications; the postoperative complications were recorded and any predisposing factors were evaluated. In this cohort of 187 consecutive patients undergoing hemorrhoidectomy, the authors reported no significant differences in the incidence of postoperative complications between the ultrasonic scalpel and the control groups. The authors concluded that the ultrasonic scalpel is a safe surgical modality, and postoperative complication rates compare favorably with previously published studies.

Applications in Laparoscopic Surgical Procedures

As noted, the majority of the advantages and disadvantages associated with the ultrasonic scalpel have been studied in the realm of its use in laparoscopic surgical procedures. It has been shown to reduce operative time, complications and costs compared to electro surgery or suture ligation in laparoscopic Nissen procedures and laparoscopic hysterectomies. In laparoscopic cholecystectomies, the ultrasonic scalpel demonstrated a lower gallbladder perforation rate and reduced operative time, compared to electro surgery. In addition to laparoscopic procedures, the ultrasonic scalpel has been used effectively in many video-assisted procedures; technical advantages of the ultrasonic device include the absence of problems associated with coagulated tissue sticking to the instrument, and reduced risk of electrical injury to both the patient and surgeon. Additionally, it does not produce interference with pulse-oximeter machines, arterial catheter transducers or electrocardiograms.

The efficiency and safety of laparoscopic cholecystectomy carried out using an ultrasonic scalpel as an outpatient surgical procedure were prospectively studied on 100 patients presenting for same-day laparoscopic cholecystectomy; the ultrasonic scalpel was used with retrograde dissection. All patients were considered for discharge the same day, unless medically contraindicated. The major complications reported included conversion to open procedure (1%); common bile duct injury (1%); and bile leak from the cystic duct stump (1%). The same-day discharge rate was 65%; age over 65 years was the only independent predictor of overnight admission. The authors concluded that laparoscopic cholecystectomy using the ultrasonic scalpel is associated with a low complication rate and a high same-day discharge rate when performed as an outpatient surgical procedure.

Another study compared a traditional method of laparoscopic cholecystectomy (LC) versus LC using an ultrasonic scalpel, looking at factors related to safety and efficacy. Patients were assigned to one of two groups. In group A, LC was conducted using the traditional method (TM): clipping both cystic duct and artery and dissection of the gallbladder from the liver bed by diathermy. In group B, LC was conducted using ultrasonic scalpel closure and division of both cystic duct and artery, and dissection of the gallbladder from the liver bed by ultrasonic scalpel. The intraoperative and postoperative parameters collected included duration of operation, postoperative pain and complications. The use of the ultrasonic scalpel resulted in a shorter operative duration than TM (33.21 minutes versus 51.7 minutes, respectively), with a significantly reduced incidence of gallbladder perforation (7.1% versus 18.6%), and a reduced rate of conversion to open cholecystectomy. The amount of postoperative drainage was also significantly less in the ultrasonic scalpel patients (29 mL versus 47.7 mL). Postoperative bile leak did not occur in the ultrasonic scalpel patients but did occur in 2.9% of patients in the TM group. The investigators concluded that the ultrasonic scalpel provided a complete hemobiliary stasis and is a safe alternative to standard clipping of the cystic duct and artery; it provided a shorter operative time, less incidence of gallbladder perforation, less postoperative pain and a reduced rate of conversion to open cholecystectomy.

The feasibility and reliability of the use of the ultrasonic scalpel in laparoscopic colorectal surgery were studied in a nonrandomized prospective study of 34 consecutive patients undergoing laparoscopic colorectal surgery for benign disease or colorectal cancer. The authors concluded that coagulation and division of both minor and major vascular pedicles in laparoscopic colorectal surgery with an ultrasonic scalpel are technically easy, feasible and reliable. In an examination of the use of an ultrasonic scalpel in a prospective study of 16 consecutive patients undergoing liver surgery, the ease...
of parenchymal dissection and the hemostatic effect of the ultrasonically vibrating blade were assessed in each procedure. The authors concluded that the ultrasonic scalpel permits efficient resection of liver parenchyma, precise dissection of intrahepatic structures and good hemostasis of small intrahepatic vessels.

**SURGEON BENEFITS**

Use of ultrasonic technology affords the surgeon the benefits of precise cutting and controlled coagulation and the provision of tactile feedback. There are certain strategies that can be used to maximize tissue effects as well as minimize potential adverse effects.

**Strategies to Maximize Tissue Effects**

In comparison to standard cutting and electrosurgical systems, an ultrasonic scalpel offers precise control of tissue ablation due to the controlled ultrasonic field generated; this precise control allows the surgeon to perform atraumatic transection and coagulation with minimal disturbance to surrounding tissue structures. By adjusting the power level, tissue tension and the blade edge and pressure, the surgeon is afforded control and precision in coagulation and cutting. To obtain optimal tissue response, counter traction must be applied to the structure being treated; however, a shear-grasper that holds the tissue between a blade and tissue pad can be used to eliminate the need for counter traction.

**Strategies to Minimize Potential Adverse Effects**

There are several strategies that can be used to minimize the potential adverse effects associated with use of ultrasonic energy. With prolonged activation, the ultrasonic scalpel generates residual heat. This has led to unintended burning of adjacent tissue, skin and drapes, as well as minor burn injuries to a surgical assistant and operating room staff. In one instance, prolonged contact with a surgical hemostat caused the fracture of an instrument. A fracture can happen if the device comes into contact with any metal object, so care should be taken to maintain a safe distance from other metal objects within the abdomen. One method for avoiding these complications and improving the safety of the device is the use of a moist sterile towel fastened to the surgical field, with placement of the device tip into the towel immediately following each use.

The ultrasonic scalpel transfers less energy to tissues, which can reduce the potential for lateral thermal damage and deep penetration because lower temperatures are reached when compared to electrosurgery. A study designed to determine the effects of varying durations of ultrasonic scalpel application demonstrated that tissue lateral thermal damage after application of the ultrasonic scalpel at standard output power is greater when a longer sustained period of application is used. Lateral thermal damage also is greater when the application time is continuous, compared to the same total duration with a brief midpoint interruption. Shorter application times, or the brief interruption of a longer application period, may avoid the excessive lateral thermal damage associated with the use of an ultrasonic scalpel. The newer generations of ultrasonic scalpel devices may be more effective in tissue dissection, but they can be associated with higher peak temperatures and longer blade-hyperthermia periods, compared to the older generation ultrasonic scalps. The increased temperatures are greater after longer periods of activation and may have more potential than earlier devices for collateral damage, particularly to nerves and bowel. During the application of an ultrasonic scalpel, keeping a safety margin of at least 3 mm from sensitive structures in order to prevent tissue damage is a conservative limit to ensure safe use of the ultrasonic scalpel.

**PATIENT BENEFITS**

Patient benefits associated with the use of ultrasonic technology, including reduction in postoperative pain and improved overall outcomes, are well-documented. Three studies demonstrated that the use of ultrasonic technology during surgery reduces postoperative pain due to the avoidance of lateral thermal injury. Early studies concluded that in hemorrhoidectomy patients, the use of an ultrasonic scalpel significantly reduced postoperative pain, compared to electrosurgery; the diminished postoperative pain likely resulted from the avoidance of lateral thermal injury. One study also reported that ultrasonic scalpel hemorrhoidectomy is not only as good as bipolar-scissors hemorrhoidectomy in terms of reduced blood loss; it is superior because it is associated with less postoperative pain and therefore, better patient satisfaction. More recently, a single-blind randomized controlled trial evaluated the efficacy of using an ultrasonic scalpel in reducing the incidence of postoperative complications following hemorrhoidectomy; it demonstrated significantly reduced postoperative pain after hemorrhoidectomy and less analgesic requirement with the use of an ultrasonic scalpel, compared to bipolar electrosurgery. Again, this was most likely due to the avoidance of excessive lateral thermal injury caused by the use of bipolar electrosurgery.

The safety and usefulness of the ultrasonic scalpel in redo cardiac surgery compared with traditional electrosurgery have also been studied. Although mortality and major postoperative morbidity were comparable in the two groups, the ultrasonic scalpel patients presented markedly reduced postoperative bleeding, as well as lower incidences of minor complications, cardiac injuries, major arrhythmias and the need for transfusions. Additionally, both the operative time and mean length of stay in the intensive care unit were shorter. Therefore, this data suggest that the ultrasonic scalpel is safe and is associated with better in-hospital outcomes and lower postoperative blood loss in redo cardiac surgery.
The cost-effectiveness of the ultrasonic scalpel has also been reported. While the use of the ultrasonic scalpel has been shown to reduce surgical time, it does increase the cost of the procedure; however, when examining the total cost, the time saved and the reduction in human resources needed, the use of the ultrasonic scalpel proves to be economical.\textsuperscript{30,31}

**COMPETENCIES FOR SAFE PATIENT CARE DURING THE USE OF ULTRASONIC DEVICES**

**Recommended Practices for Safe Use of Ultrasonic Devices**

Ultrasonic devices should be used in a manner that minimizes the potential for injuries. When using an ultrasonic device, a dispersive electrode should not be used; since no electrical current enters the tissue, the current does not need to be returned to the generator by a dispersive electrode.\textsuperscript{32}

Ultrasonic devices produce a “vapor” rather than the smoke associated with the use of electrosurgical devices; this process has been described as low-temperature vaporization.\textsuperscript{61} The bio-aerosols that are included in the vapor pose a risk to patients and perioperative personnel because they can contain odorless toxic gases; viruses; and dead and live cellular debris, including blood fragments. These airborne contaminants can pose respiratory, ocular, dermatological and other health-related risks, including risks of mutagenic and carcinogenic potential. As a result, inhalation of aerosols generated by an ultrasonic device should be minimized by implementing control measures including, but not limited to, smoke evacuation systems and wall suction with an in-line ultra-low-penetration air (ULPA) filter. Wall suction with an in-line ULPA filter is only appropriate for a minimal amount of aerosol (i.e., aerosols generated using ultrasonic devices are within the respirable range and include blood, blood by-products and tissue).\textsuperscript{51,32}

**Competencies for Safe Patient Care**

Competency assessment within the operating suite is a method to determine if nurses, surgical technologists and other personnel are proficient and have demonstrated the knowledge, cognitive skills and psychomotor skills required to provide safe patient care relevant to their role function.\textsuperscript{64} See the Appendix for a sample competency documentation form for safe patient care during the use of the ultrasonic scalpel in surgery.

**CONCLUSION**

The evolution of ultrasonic technology has significantly enhanced advanced surgical techniques across multiple surgical specialties; furthermore, it has brought new concepts and alternatives to tissue dissection and hemostasis. Today, ultrasonic technology is widely used in both open and minimally invasive surgical procedures. The use of ultrasonic dissection is especially beneficial in minimally invasive procedures, because it eliminates the risks associated with monopolar electrosurgery, such as capacitive coupling and tissue damage. It also has demonstrated numerous clinical benefits for both the surgeon and the patient. Through awareness of the principles of ultrasonic energy and demonstrating competence in its safe use, members of the perioperative team can maximize its benefits and ultimately promote positive patient outcomes.
GLOSSARY

Cavitation
The side effect with some ultrasonic devices that occurs when the vibration of the device is transmitted to the surrounding tissue, causing rapid volume changes of the tissue and cellular fluid.

Coagulation
The formation of a clot.

Coaptation
The adherence of tissue achieved by the disruption of hydrogen bonds.

Electrosurgery
The cutting and coagulation of body tissue with high-frequency (i.e., radio-frequency) current.

Eschar
Charred tissue residue.

Frequency
The number of waves passing through a given point over a specified time; it is measured in hertz (Hz) or cycles per second.

Piezein
Greek word meaning "to press."

Piezoelectric effect
The ability of some materials (e.g., crystals and certain ceramics) to generate an electric field or electric potential in response to applied mechanical stress.

Ultrasonic scalpel
A cutting/coagulation device that converts electrical energy into mechanical energy, providing a rapid ultrasonic motion.
REFERENCES (CONT’D.)


<table>
<thead>
<tr>
<th>Performance Criteria</th>
<th>Type of Validation</th>
<th>Orientation</th>
<th>Annual</th>
<th>Self-Assessment by Employee</th>
<th>Validation of Competency</th>
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<td>Operates the ultrasonic scalpel in a safe manner.</td>
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<tr>
<td>1. Verifies that all equipment is in good working condition prior to use.</td>
<td>Never Done</td>
<td>Needs Review</td>
<td>Competent</td>
<td>Method of Instruction¹</td>
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<td>2. Inspects the packaging of sterile components before transferring to the sterile field.</td>
<td>Never Done</td>
<td>Needs Review</td>
<td>Competent</td>
<td>Method of Instruction¹</td>
<td>Met</td>
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<tr>
<td>3. Places the generator on a movable stand that will not tip.</td>
<td>Never Done</td>
<td>Needs Review</td>
<td>Competent</td>
<td>Method of Instruction¹</td>
<td>Met</td>
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<tr>
<td>4. Encases the footswitch in a clean, clear, impervious cover when there is a potential for fluid spills.</td>
<td>Never Done</td>
<td>Needs Review</td>
<td>Competent</td>
<td>Method of Instruction¹</td>
<td>Met</td>
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<td>5. Positions cords in a manner to prevent tripping.</td>
<td>Never Done</td>
<td>Needs Review</td>
<td>Competent</td>
<td>Method of Instruction¹</td>
<td>Met</td>
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<tr>
<td>6. Attaches cables to the appropriate receptacle on the generator.</td>
<td>Never Done</td>
<td>Needs Review</td>
<td>Competent</td>
<td>Method of Instruction¹</td>
<td>Met</td>
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<tr>
<td>7. Sets generator power settings per manufacturer’s recommendations and surgeon’s verbal instructions, and verbalizes safe setting ranges.</td>
<td>Never Done</td>
<td>Needs Review</td>
<td>Competent</td>
<td>Method of Instruction¹</td>
<td>Met</td>
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<td>8. Describes the alarm systems and monitoring parameters.</td>
<td>Never Done</td>
<td>Needs Review</td>
<td>Competent</td>
<td>Method of Instruction¹</td>
<td>Met</td>
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<tr>
<td>9. Demonstrates proper removal and disassembly of equipment and instrumentation.</td>
<td>Never Done</td>
<td>Needs Review</td>
<td>Competent</td>
<td>Method of Instruction¹</td>
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<td>10. Describes proper care, cleaning and sterilization procedures.</td>
<td>Never Done</td>
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<td>11. Describes proper procedure to follow for equipment malfunctions.</td>
<td>Never Done</td>
<td>Needs Review</td>
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<td>12. Describes proper procedure to follow in case of patient injury.</td>
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<td>13. Demonstrates correct set-up and operation of a smoke evacuation system.</td>
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<td>14. Describes proper troubleshooting procedures.</td>
<td>Never Done</td>
<td>Needs Review</td>
<td>Competent</td>
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</table>

**Employee’s Signature**

**Date**

**Validator’s Name (print)**

**Validator’s Signature**

¹Method of Instruction (check all that apply) : [ ] Policy/Procedure Review, [ ] Didactic Session, [ ] Independent Study Activity, [ ] Clinical Practice, [ ] Demonstration

¹Method of Validation (check all that apply) : [ ] Verbal Review, [ ] Return Demonstration, [ ] Observation in Clinical Area
**ULTRASONIC SCALPEL WITH CONNECTOR CABLE**

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<th>Not Met</th>
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<td>2. Inspects the packaging of sterile components before transferring to the sterile field.</td>
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<tr>
<td>3. Demonstrates proper assembly of instrument, transducer and cable.</td>
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<td>4. Verbalizes proper procedures for cleaning instrument tips during the procedure.</td>
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<td>5. Verbalizes importance of avoiding contact with other metal instruments during device activation.</td>
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<td>6. Verbalizes the importance of keeping cables (e.g., ultrasonic scalpel and electrosurgery) from becoming intertwined on the sterile field.</td>
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<td>7. Describes the alarm systems and monitoring parameters.</td>
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<td>8. Demonstrates proper removal and disassembly of equipment and instrumentation.</td>
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<td>9. Describes proper care, cleaning and sterilization procedures</td>
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<td>10. Describes proper procedure to follow for instrument malfunctions.</td>
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<td>11. Describes proper procedure to follow in case of patient injury.</td>
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<td>12. Demonstrates correct set-up and operation of a smoke evacuation system on the sterile field.</td>
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**Employee’s Signature**

**Date**

**Validator’s Name (print)**

**Validator’s Signature**

¹Method of Instruction (check all that apply)  
- Policy/Procedure Review
- Didactic Session
- Independent Study Activity
- Clinical Practice
- Demonstration

²Method of Validation (check all that apply)  
- Verbal Review
- Return Demonstration
- Observation in Clinical Area
ULTRASONICS IN SURGERY: A LOOK BACK — CURRENT INNOVATIONS POST TEST

Multiple Choice/True or False. Please choose the letter corresponding to the word or phrase that best completes the following statements.

1. The motor action of piezoelectric ceramics converts:
   a. Electrical energy into mechanical energy
   b. Mechanical energy into electrical energy
   c. Sound waves into electrical energy
   d. Sound waves into radio frequency current

2. The vibrating motion of an ultrasonic scalpel causes tissue protein to become denatured as the hydrogen bonds are broken because:
   a. The tip is in contact with the tissue
   b. The tip is not in direct contact with the tissue
   c. Ultrasonic energy is flowing through the tissue
   d. Ultrasonic energy operates at a high temperature

3. __________ is the adherence of tissue achieved by disruption of the hydrogen bonds.
   a. Cavitation
   b. Coagulation
   c. Coaptation
   d. Vessel fusion

4. Unlike electrosurgery, ultrasonic energy is mechanical in nature and works at lower temperatures than electrosurgery.
   a. True
   b. False

5. The advantages of ultrasonic energy in comparison to electrosurgery include:
   1. Controlled coagulation
   2. No nerve stimulation
   3. Precise cutting
   4. Provision of tactile feedback
   a. 1, 2, 3
   b. 1, 3, 4
   c. 2, 3, 4
   d. All of the above

6. The ultrasonic scalpel is especially useful in laparoscopic procedures in which the surgeon is working in a narrow operative field.
   a. True
   b. False

7. In laparoscopic and video-assisted procedures, the benefits of the ultrasonic scalpel include:
   a. No interference with electrocardiogram devices
   b. No interference with pulse oximeters
   c. Reduced risk of electrical injury for the patient and surgeon
   d. All of the above

8. An ultrasonic scalpel offers the surgeon precise control of tissue ablation due to the:
   a. Absence of electrical energy
   b. Controlled ultrasonic field generated
   c. Reduced tissue temperature
   d. Reduction in charring

9. Postoperative pain is reduced with the use of ultrasonic technology during surgery due to the avoidance of:
   a. Capacitive coupling
   b. Direct coupling
   c. Lateral thermal injury
   d. Stray energy burns

10. Because no electrical current enters the patient when using an ultrasonic device, which of the following is not needed?
    a. Active electrode
    b. Dispersive electrode
    c. Return electrode monitoring device
    d. Smoke evacuator
TEST KEY

1. a  6. a
2. a  7. d
3. c  8. b
4. a  9. c
5. d  10. b
EVALUATION FORM

Mail this form to:
Professional Education Department A50
Medtronic
5920 Longbow Drive
Boulder, CO 80301-3299, USA

Please type or print legibly

Name                     RN ☐   LPN/LVN ☐   Other ☐

Institution/Affiliation

Business Address

City                              State    ZIP

Business Phone

Home Address

City                              State    ZIP

We appreciate your comments and evaluation of this offering, which will assist us in planning future educational programs.

1. Did the activity meet the stated objectives? Yes No
   • Recognize the importance of the historical development of ultrasonics.
   • Discuss the principles of ultrasonic technology.
   • Describe the tissue effects of ultrasonic scalpel technology.
   • Identify the surgical applications of ultrasonic devices.
   • Distinguish the benefits of ultrasonic technology for surgeons and patients.

2. Did the activity meet your personal learning objectives? Yes No

3. Do you plan on changing any aspect of your practice as a result of this activity? If yes, what?

Scoring Key: 1=Poor    2=Fair    3=Average    4=Good     5=Excellent

Organization of content  1  2  3  4  5
Effectiveness of this learning method  1  2  3  4  5
Relevance of content to practice  1  2  3  4  5
Relevance of test questions to content  1  2  3  4  5
Overall quality  1  2  3  4  5

Suggestions for additional topics to be presented in this format:

How much time did it take to complete this activity? ______

Comments:

________________________________________

__________________________________________________