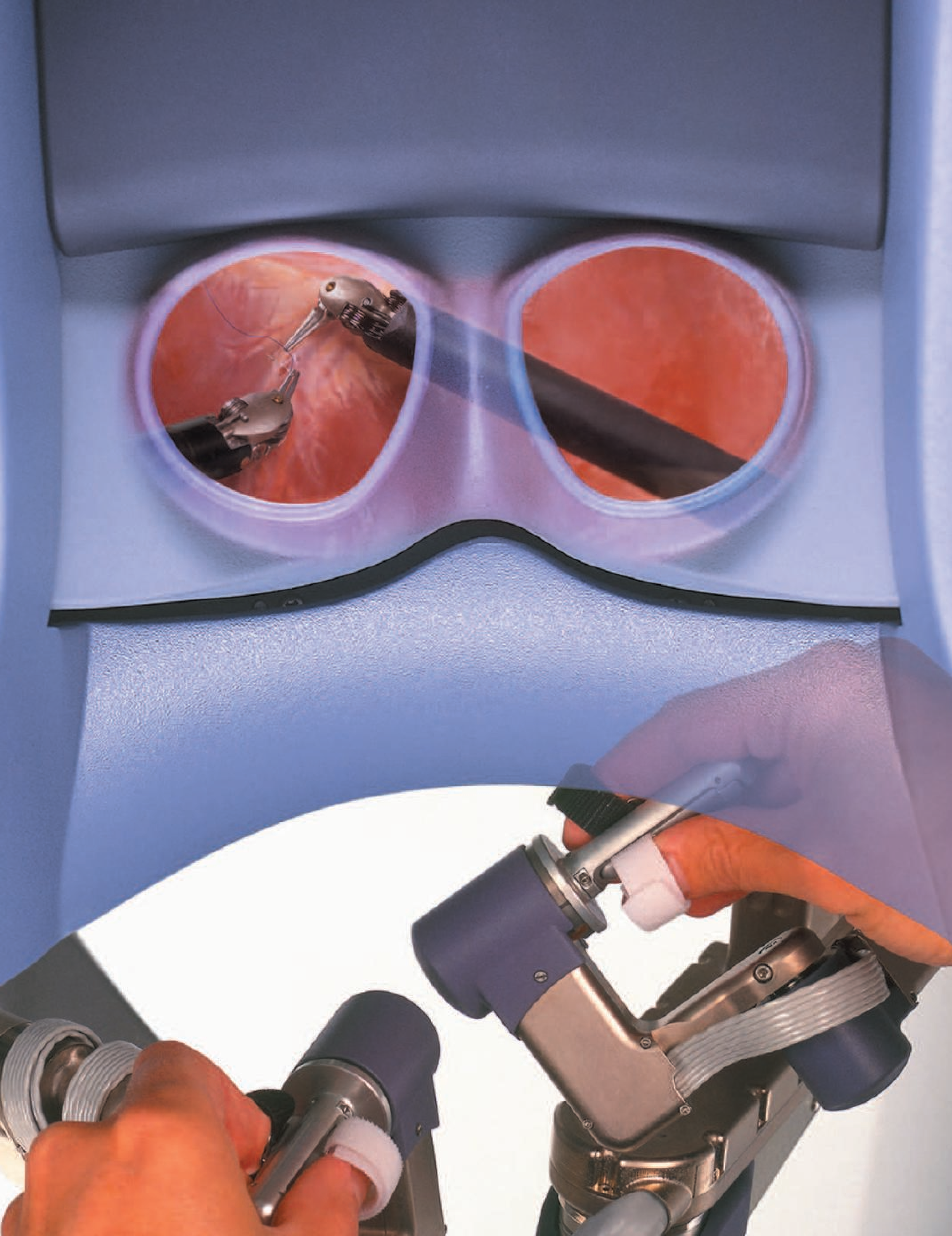

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Technology for the Twenty-First Century

As operating room practice continues to incorporate an increased number of technology-based supplies, instrumentation, and equipment, surgical technologists, as an integral part of both the sterile and nonsterile teams, need to have a strong foundation in and working knowledge of today's technology and the information that supports that technology. When the patient's life is on the line, the surgical technologist is called upon to anticipate the use of technology, based on the patient needs, and to troubleshoot that technology as issues arise. This article will introduce some of the basic knowledge that will help techs better understand the principles behind those wires, buttons, knobs, and handpieces currently used in today's surgical arena and will discuss some of the technologies that employ these prin-

Opposite: InSite® Vision technology from Intuitive Surgical and EndoWrist® instruments allows for precise surgical robotic movement with three-dimensional visualization.

Principles of technology

Electrical energy

The atom is the smallest piece of an element that keeps its chemical properties. An atom is made up of a nucleus, containing protons, which carry a positive electrical charge, and neutrons, which carry a neutral charge. Electrons, which carry a negative charge, orbit the nucleus of the atom in valence shells. Electrical energy involves the movement of electrons from one atomic shell to the shell of an adjacent atom. These "moving" electrons are called free electrons. When forces are introduced that cause electrons to leave their base atoms and move to adjacent atoms, the charges of the atoms are changed, with those having fewer electrons than protons becoming positively charged, and those with more electrons than protons becoming negatively charged. During electron movement, like charges repel each other and unlike charges attract. This electron movement is termed electricity.[1]

The greater the number of free electrons involved in this electron movement, the greater the conductivity of the substance or material. Materials that allow the flow of free electrons are called conductors, and include metals, such as copper, silver, aluminum, and brass, and nonmetals such as water, salt water, and carbon. Materials that inhibit the flow of free electrons are called insulators, and include items such as rubber and the plastic casing commonly seen surrounding electrical cords.

Current is a measurement of the rate of flow of the electrons and is measured in amperes (amps). An ampere is a measurement of how much current is flowing past a given point in a circuit in one second. Voltage is the force or push that moves free electrons from one atom to another. It is measured in volts (V) and indicates the strength or energy of the electricity. Voltage is the force that will cause one amp to flow through one ohm of impedance or resistance. Frequency is the number of energy waves that pass through a specific point over a specific amount of time. Frequency is measured in hertz (Hz) or cycles per second. Radiofrequency cycles approximately 100,000 times per second, as opposed to household current, which cycles at 60 cycles per second. Power is the rate at which the electrical movement is accomplished and is measured in watts.

There are two types of current, alternating and direct. In AC, or alternating current, the electrons flow back and forth along a single pathway due to changes in polarity (negative and positive charges). Common, household alternating current changes directions approximately 60 times per seconds. DC or direct current flows in one direction but loses voltage when it travels through conductors over long distances. AC current, supplied through the hospital's electrical power lines, is the most common type of current used in powering today's OR technology, while batteries, used in some devices, are a good example of DC current.

When electrons flow within current, they follow a path called a circuit. A circuit is created when the electrical energy flows from and returns to its point of origin. Along the way, electricity may encounter materials that either facilitate or obstruct this flow. Impedance, also called resistance, is a property of substances that obstructs the flow of free electrons. Impedance is measured in ohms and indicates the ease or difficulty in which a current can flow through that substance. As electron flow encounters impedance, heat builds, resulting in the tissue effect commonly seen when using the electrosurgical device (ESU/Bovie). It is important to remember that electricity flows along the path of least resistance and will find the easiest route to return to the ground or its electron reservoir.[2]

Mechanical energy

Mechanical energy is the energy found in moving objects. Force is any agent that causes a change in movement. Speed is a measurement of how fast an object is moving, regardless of the direction of that movement. Velocity is the direction and speed of an object when moving in a straight line. Acceleration is a change in velocity, including a change in direction, in speeding up, or in slowing down. Force is the energy that causes acceleration. Friction is the resistance of movement of one surface as it passes against another.[2] Mechanical energy is utilized to create the tissue effects caused by use of the Harmonic Scalpel®.

Kinetic energy is the energy an object has while in motion or during activity. Kinetic energy overcomes friction and resistance to produce movement. Potential energy is the energy an object has at rest or stores for use when resistance is lowered or removed.[2]

Light energy

Light energy consists of a series of photons emitted by an object both in the form of waves and particles. Photons are light particles that are emitted by an electron. They are created when an electron is moved to a higher orbit or valence shell and permitted to return to its preferred lower orbit or valence shell. The photons generated have the same wavelength and waveform as the original electron.

The characteristics of light energy that differentiate it from other energy forms are reflection, refraction, and color. Reflection is the ability to bounce light rays off a particular object. Light rays tend to bounce off at the same angle in which they were originally sent. Refraction is the ability to bend or redirect light rays as the light passes through an object. Color is determined by the height and distance of a light waveform, and includes infrared waves and ultraviolet waves, both of which are invisible to the human eye, and waves of the human visual spectrum, including red, orange, yellow, green, blue, indigo, and violet.[2]

Technology applications

Electrosurgery

Electrosurgery has become an integral part of most surgical interventions. Even with all of the safety features built into electrosurgical generators, handpieces, and related equipment, the ESU remains one of the most dangerous pieces of equipment in today's operating room. Understanding the principles of electricity and current flow will assist in the prevention of inadvertent patient injury.

Electrosurgery (ESU) involves the use of electric current to seal blood vessels, achieving hemostasis, and to cut or dissect tissue. Two types of current can be delivered by the ESU generator: a dampened interrupted current, which results in tissue desiccation and coagulation, and an undampened or continuous current, which results in tissue cutting. A blend mode combines these two currents in quick alteration, providing both effects simultaneously.[3]

The pathway of current flow in electrosurgery begins at the ESU generator. When activated,

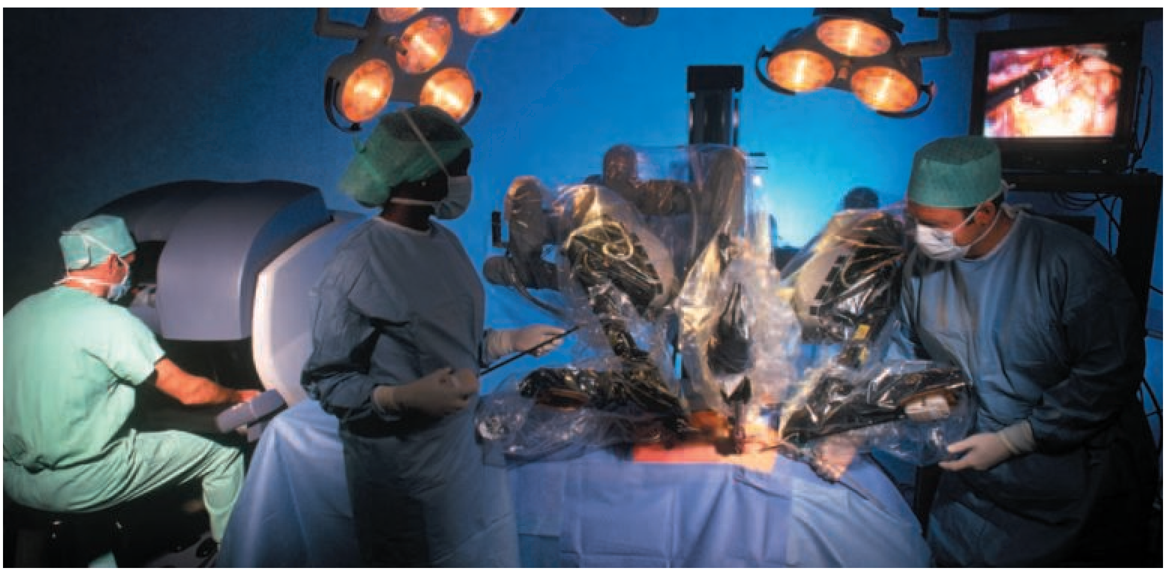

FIGURE 1

The DaVinci® surgical system allows for precise surgical movements from a remote controlled console.

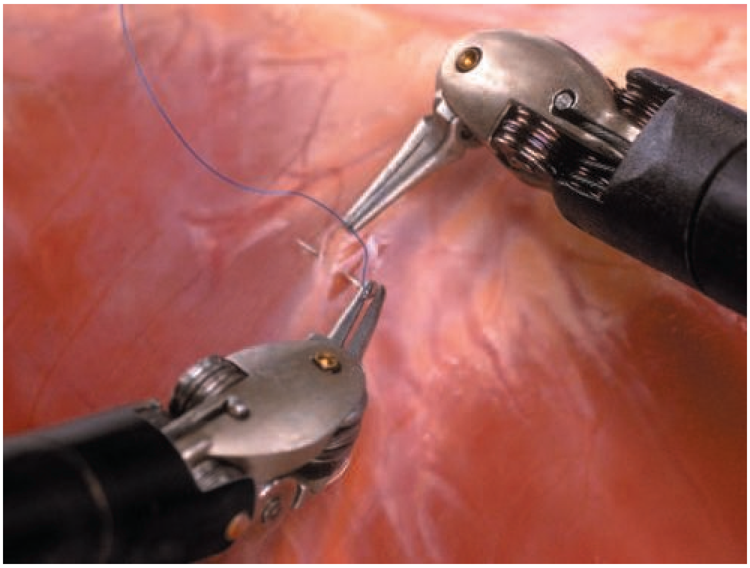

FIGURE 2 EndoWrist® instruments are controlled from a remote surgical console.

the current flows through a conducting cable to an active or positive electrode, which contacts the patient tissues at the point of desired effect. The current passes through the tissue and returns back to the generator via the patient's inactive or return electrode. In monopolar ESU, the flow of electricity occurs in one direction, in that, the active and inactive electrodes are separated by a significant distance, resulting in the need for the electrical energy to pass through adjacent body tissues before contacting the return electrode. As electrical current will follow the path of least resistance in returning to a ground, this current pathway may inadvertently include tissues that can be damaged by this flow of electricity. If the current is concentrated enough, an alternate-site burn may occur. In bipolar ESU, the active and return electrodes are contained within the same delivery device. The current flows from one jaw of the instrument to the opposite jaw of the instrument, thus providing a readily available return to ground pathway and minimizing unintentional tissue contact.[4]

Electrosurgical generators today are equipped with a monitoring system to assist in the prevention of alternate pathway burns. The remote electrode monitoring (REM) return-patient electrode utilizes a divided, disposable return-electrode pad that is able to sense the amount of electrical impedance/resistance at the contact point between the pad and the patient's body. This sensor will interrupt power delivery if the quality of the contact is compromised. This assures an adequate flow of electricity from the patient to the generator without creating a burn at the pad site. An active electrode monitoring system also permits measurement of the amount of current delivered to the active electrode in comparison to the amount of current returned to the generator. If the difference between the two amounts exceeds pre-set parameters, the generator will shut down and alarm.

Capacitance pads, used in place of traditional adhesive patient-return electrodes, consist of a large piece of conductive fabric encased in urethane insulating material. The pad, covered with linen, is placed under the patient's torso area. This pad provides a significant area of contact surface for dispersion of electrical energy over a large area, dispersing the electrical energy and preventing electrical burns.[5]

LigaSure™

The LigaSure™ device utilizes electrosurgical energy combined with a specially designed bipolar forcep with inserts. This device delivers electrical current to tissue placed between the jaws of the forcep. The combination of force and energy cause the collagen matrix in vessel walls and connective tissue to reform into a permanently fused tissue zone. This fusion permits the formation of a permanent autologous seal with minimal sticking, tissue charring, and reduced thermal spread into adjacent tissues. A variety of delivery forceps lengths, angles, and thicknesses, including the Std, Max, Axs, Xtd, and Precise™ handpieces may be used in open surgical interventions. The 5 mm Lap and 10 mm Atlas™ forceps are used for minimally invasive interventions.[6]

Argon-enhanced coagulation (AEC)

The argon-enhanced coagulation system is not a laser. This electrosurgical unit utilizes a handpiece to simultaneously deliver a stream of argon gas with the electrical current. The current ionizes the gas, leaving a more conductive pathway to deliver the current to the target tissues. The gas conducts the current to the tissues, permitting tissue effect without direct active electrode contact. This "no-touch" technique is invaluable when cauterizing, cutting, or sealing large areas of non-specific, oozing, friable tissue, such as a liver or kidney parenchyma. In addition, AEC produces less smoke and odor, and reduces tissue adhesion to the electrode (in cut). Since the electrical energy is delivered using a monopolar handpiece, a patient-return electrode is required during its application.

CUSA

The Cavitational Ultrasonic Suction Aspirator (CUSA) consists of an ultrasonic vibrating tip used to "break up" and vacuum away tissue. The sensitivity of the ultrasonic activity can be adjusted to accommodate different densities of tissue, permitting the skeletonization of vital structures such as blood vessels and the removal of density-specific tissues. This technology provides rapid, selective tissue fragmentation with quality visualization of the operative site.[7]

Harmonic Scalpel®

The Harmonic Scalpel® delivers ultrasonic sound waves that simultaneously cut tissues and seal blood vessels. Electrical energy is delivered to a piezoelectric transducer which creates mechanical friction energy capable of coagulating tissue through the process of denaturation of the tissue protein, forming a sticky coagulum that seals blood vessels, or cutting tissue through the process of cavitational fragmentation. This friction is created by movement of the scalpel blade up to 55,500 times a minute. This rapid movement causes tissue effect without tissue charring and desiccation. The application of this technology is achieved using a handpiece with disposable blades, hooks, and/or balls.[8]

Morcellator

The morcellator is a mechanical device that fragments tissue into long strips that can be extracted through the barrel of the instrument. This extraction can be accomplished via a small incision during minimally invasive surgery, facilitating the debulking and removal of benign tissue in a reduced time period.[9]

Robotics

The introduction of robotics into the surgical arena permits the development of surgical applications previously restricted by human limitations. The concept of surgical robotics applies three different technologies to enhance the skills of the surgical team. These concepts include the robotic arm, voice-activated control systems, and remote surgical manipulators.

The robotic arm is a device that manipulates surgical instrumentation under the guidance of the surgeon (Figure 1). It is used to manipulate endoscopic telescopes or, when integrated with a remote surgical manipulator and fitted with surgical instrumentation, to perform dissection, suturing, and manipulation of internal tissues and structures. The robotic arms attach to the bed rail of the operating table, permitting them to remain in geometric alignment with the surgical patient when the table is repositioned intraoperatively. The robotic arm can be voice-controlled by the surgeon using a voice-recognition command system, or hand-controlled by the surgeon seated at a remote surgical manipulator console (Figure 2). The potential exists for the surgeon to control the robotic arm from truly remote sites utilizing the concepts of telesurgery.[10]

The relationship between physics and medicine

Physics principles	Medical applications
Sound waves (frequency and wavelength), speed of sound, acoustic impedance, reflection of sound waves from interfaces, the Doppler effect	Diagnostic ultrasound imaging and Doppler flow; echocardiography
Principles of light, optics	Light microscopy, lasers, fiber optics
Atomic physics, light behavior (wave properties, frequency, and wavelength, color of tissues), photon energy, the electromagnetic spectrum, power, energy, photon energies (emitted or absorbed)	Surgical lasers and photodynamic therapy
X-ray energies and wavelengths, production of gamma rays, electromagnetism, energy and momentum conservation	Radiography, CT imaging, PET, and MRI scanners
Nuclear physics	Radioisotope labeling, nuclear medicine, radiation therapy
Reflection and refraction, index of refraction	Fiberoptic scopes
Snell's Law of Heat, principles of energy and power, properties of liquids and gases, sound waves, vibrations, pressure	Sterilizers, ultrasonic washers
Electromagnetism	Pacemakers, defibrillators
Mechanics, power, energy, electromagnetism	Robots
Reflection and refraction, properties of gases, electromagnetism, light properties, pressure	Minimally invasive surgery
Sound waves (frequency and wavelength), speed of sound, acoustic impedance, reflection of sound waves from interfaces	Cavitron Ultra-Sonic Aspirator (CUSA)
Electromagnetism, power, energy	Electrosurgical unit

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Laser

Laser is an acronym for light amplification by the stimulated emission of radiation. Laser light is created when a medium, either gas, solid, liquid or semi-conductor, is stimulated or "excited" to release electrons from their preferred valence shell. Upon return to their valence shell, the electrons give off photons or light energy. This process is repeated to a point where an intense beam of light is created.

Laser light differs from other types of light in that it has unique characteristics, including coherence, collimation, and monochromatism. The coherence of laser light indicates that all of the light waves are in phase as they travel in the same direction, meaning that they peak and trough in the same sequence. Collimation means that the light waves travel parallel to one another rather than in haphazardly crisscrossing pathways.

Monochromatism means that the laser light is comprised on only one pure light wavelength. This purity permits collimation and coherence of the light energy, creating an intense light capable of tissue dissection and vaporization.

The tissue reaction to laser is referred to as radiant exposure. Radiant exposure, or the tissue effect, depends on the absorption of the laser light by the target tissue, the power settings and time of exposure to the laser light, and the size of the target tissue. When exposed to laser light, tissues may react in one of two ways. The first, thermal dissolution, occurs when the laser light causes intracellular water to heat, creating steam. Since steam in a closed structure generates pressure, the cell wall lyses or "explodes", releasing the steam and carbon in the form of eschar and plume. The second tissue reaction is called photodynamic destruction. Photodynamic destruction occurs when the light energy interacts with chemically-sensitized cells resulting in a disruption of the cell's basic metabolic processes, resulting in cell destruction.

Lasers are commonly named by the medium used to generate the laser light. Some of the more common mediums used in the operating room setting today include: carbon dioxide (CO_2) gas;

yttrium-aluminum-garnet (YAG) crystal, which can be doped with Neodymium (Nd:YAG), holmium (Holmium:YAG), or erbium (erbium: YAG), or Nd:YAG light that is then passed through a potassium titanyl phosphate crystal (KTP); Argon gas; or tunable dye, where the color achieved is obtained by changing the composition of the dye and employing prisms or filters along the light pathway.[11]

The future

The evolution of technology in the operating room setting is already evident. Monitors, light sources, lasers, and computers are but a few of the technologies used on a daily basis in caring for the surgical patient. Surgical technique has evolved to include less and less invasive techniques, whenever applicable. The evolution of technology, instrumentation and techniques to support minimally invasive surgical applications continues to develop rapidly, barely keeping pace with the demands of the profession. This technology moves the surgical team further from the invasive, hands-on patient care of yesteryear.

As the demand for the support, management, and maintenance of technology increases, the role of the surgical technologist will continue to expand. Technologists have the professional obligation to increase their knowledge base in the areas of biomedical technology in order to understand and troubleshoot electrical circuitry. This, in combination with their specific knowledge of surgical interventions and target anatomy and physiology, will allow them to better anticipate the needs of the surgical team when addressing surgical anomalies and unanticipated complications, and to be prepared for expanded roles within the surgical field, including direct and indirect patient care, to enhance their skills sets as human resources in specialty areas become more scarce.

As the profession of surgical technology continues to emerge, practitioners need to move beyond the standards of the 20th century and embrace their roles as active members of the surgical team with knowledge, skill, and behaviors that promote, support, and incorporate the surgical technologies of the 21st century.

About the author

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