Advanced Therapy in

MINIMALLY INVASIVE SURGERY

Talamini

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PREFACE

The world of General Surgery has undergone an amazing transformation over the last two decades. Computer and imaging technology is finally being applied to our surgical field to the great advantage of our patients. We have much more equipment in our operating rooms now. The rates of progress and change are accelerating. Thus, staying up to date is more challenging and requires a wider set of training techniques.

This transformation has certainly affected the world of the surgical literature. We have designed this textbook to both reflect those changes and to move in some new directions. Modeled after the very successful Current Surgical Therapy series, edited by Dr. John Cameron, this volume aims to be very practical. The chapters are brief, and are written by clinical surgical practitioners who spend most of their lives caring for patients and working in the operating room. They have endeavored to include common features in most of the chapters, such as port-site maps and key steps to procedures. We have also included key video segments for many of the procedures.

No project this large ever succeeds without a tremendous amount of assistance. I would like to acknowledge Larissa Byj at B.C. Decker for her amazing and efficient publishing work on this book. My long-term administrative assistant and friend, Laura Neuberger, was the real workhorse for the majority of this project. I would also like to thank and acknowledge Rachel Ramiro, my new assistant who has taken the project across the finish line for us. My research fellow, Yoav Minz, provided valuable proofreading assistance. I would also like to thank the surgery residents at the Johns Hopkins University School of Medicine. Particularly, that amazing group of young surgeons has convinced me forever that "the teacher is really the learner."

On a more personal note, I would also like to acknowledge Dr. John Cameron, my surgical mentor since medical school. He is the finest academic surgical role model of this generation, and I owe him a huge debt of gratitude. Finally, as so many others do, I offer my deepest gratitude to my wonderful wife and life-long companion, Carol, and to my three amazing sons, Matthew, Jonathan, and Phillip.

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SECTION I

PRINCIPLES AND FUNDAMENTAL TECHNIQUES

Chapter 1

Energy Sources

Alex Gandsas, MD, Gina L. Adrales, MD

Although significant advances have been made in surgery, from the introduction of anesthetics by Morton in 1846 and antisepsis by Lister in 1867 to the latest technology that enables transcontinental telesurgical procedures, the evolution of surgical instrumentation has been slow.[1–3] This is evident in the history of electrocautery instruments, whose roots lie in ancient times, when the Arabs used hot rods and boiling oil to accomplish hemostasis. Coagulation necrosis of the tissues with subsequent vessel thrombosis was achieved by applying intense heat with fire-treated iron rods. This early "cautery therapy" was applied in the treatment of hemorrhage, strains, aches, joint pains, and sciatica.[4]

During the nineteenth century, the same principles of cautery were adopted in the development of electricity-based surgical instrumentation. In 1875, electrical current was passed through wire loops, providing intense heat and subsequent coagulation on contact. The method of applying local heat with a metal device heated by electricity, but without transmission of electrical current to the target tissue, is known as electrocautery. This therapeutic approach is not useful for fine hemostasis because it produces prohibitive thermal injury to adjacent healthy tissue, with subsequent widespread necrosis.

In the 1890s, D'Arsonval worked with early spark generators and found that high-frequency oscillating currents (> 10,000 Hz) did not produce neuromuscular depolarization in the same way as lower-frequency currents.[5] This allowed the application of electrical current to produce local heat-induced coagulation without widespread muscular contraction and painful nerve stimulation. This was the beginning of electrosurgery, which, unlike electrocautery, involves delivery of electrical current to the target tissue to produce heat and coagulation.

In 1908, Lee deForest developed a high-frequency generator and controlled cutting current for hemostatic incisions using vacuum tubes. In 1910, Clark introduced the first electrosurgical device equipped with a spark generator fixed to a Leyden jar that acted as a capacitor. The electrostatic energy was generated by a motor-driven rotating disk.[6] By 1928, W. T. Bovie, a Harvard physicist, developed a device that was also equipped with a spark generator and able to deliver an output of 1 megahertz (MHz), allowing coagulation and cutting.[7] Although Edwin Beer originally developed this technology for endoscopic removal of bladder tumors, it was not widely adopted until Harvey Cushing endorsed Bovie's high-frequency current electrosurgical device.[8] In 1928, Cushing reported the successful removal of a vascular myeloma invading the scalp, with minimal blood loss, with the use of the Bovie.[9,10] James Greenwood modified a pair of forceps by insulating its blades. One blade was connected to a Bovie spark-gap generator while the other was attached to the ground plate connector, allowing the current to dissipate from the ground plate. The Greenwood system, known as "two-point" coagulation, led to the creation of bipolar electrocautery.[11] With electronic advancements, the old vacuum tubes used in the spark-gap generator were replaced by printed circuit boards. These solid-state units were equipped with transistors that regulated the amount of energy that was applied to the tissue. These modifications have improved on safety and reduced thermal injury risk during surgery.

Principles of Electrosurgery

Electrosurgical devices are now ubiquitous in surgery; it is therefore important for the surgeon to be familiar with the principles of electrosurgery for safe practice. Although difficult to define, electrical energy results from the transfer of electrons or other charged particles through a conducting medium such as copper or tungsten wire.[12] The medium is composed of atoms with a determined number of electrons. If any of these atoms happens to gain an extra electron, then it tries to discard this extra charge in order to achieve electrical equilibrium. Similar to streaming water, this flow of electrons is known as current. It is measured in electrons per second, or ampere, the latter unit in honor of the French physicist Andre-Marie Ampere (1775–1836). One ampere is defined as 6.24×10^{18} electrons per second.[13]

The driving force for electron flow through the medium is powered by the potential difference of the energy source.

This electromotive force is quantified in volts (V) to honor the Italian physicist Count Alessandro Volta (1740–1827).[14] Electrical current is not 100% efficient as a certain amount of energy is lost in the process owing to the friction of the electrons while traveling through the medium. This loss is translated as heat and represents the resistance or impedance of the circuit. The relationship between flow, pressure, and resistance has been postulated by Poiseuille's law describing fluid dynamics, in which the flow rate is determined by the pressure difference divided by the resistance to the flow. This resistance depends linearly on the length of the pipe multiplied by the fourth power of its radius.

Similarly, electrical current is governed by comparable rules described by George Simon Ohm, in which the current is determined by the voltage and by the resistance of the circuitry:

$$\text{Current} = \text{Voltage/Resistance}$$

An ohm is the unit used to define resistance and is equivalent to the resistance of a circuitry with a potential difference of 1 volt that generates a current of 1 ampere. The energy produced or used over a period of time is measured in watts, in honor of the Scottish engineer James Watt (1736–1819). One watt (1 joule/s) is the energy generated by 1 ampere with a potential difference of 1 volt.

Unlike the fixed resistance of a given household electrical circuit, such as the filament of a light bulb, the resistance of living tissue changes as energy is applied. The resistance of living tissue to electrical flow depends on the amount of water in the tissue, with resistance being inversely proportional to the water content. Thus, although maximum flow can be seen in blood, the flow is significantly diminished when traveling through fat or bone. Heat production is directly proportional to the tissue resistance. The goal of an electrosurgical device is to generate the same amount of electrical power and heat production while the resistance of the tissue is modified in the process of coagulation and tissue desiccation. This is accomplished by modifying the voltage of energy delivery to match the expected resistance in an effort to avoid unnecessary thermal injury.

In addition to the contributory factor of tissue resistance, the effect of energy application to tissue is determined by the amount of current that is applied to the target and by the surface characteristics of the electrode delivering the energy. For example, considering a circuit with a constant current, the energy delivered from the pointed tip of an electrosurgical electrode is higher than the energy delivered by a larger flat plate with a greater surface area of tissue contact. This is due to the fact that the energy tends to dissipate over large surfaces of tissue. The concept is known as current density (CD) and is expressed as

$$\text{Current Density} = \text{Current/Area or CD} = \text{Amperes/cm}^2$$

This phenomenon has significant implications in the practice of electrosurgical techniques and should be considered in order to administer effective coagulation and hemostasis as well as to limit thermal injury to healthy tissue. The concept of current density is illustrated in the electrical circuit of the Bovie monopolar electrosurgical device (Figure 1-1). The point of contact (Bovie tip) is small, producing very high resistance and a high energy release (current den-

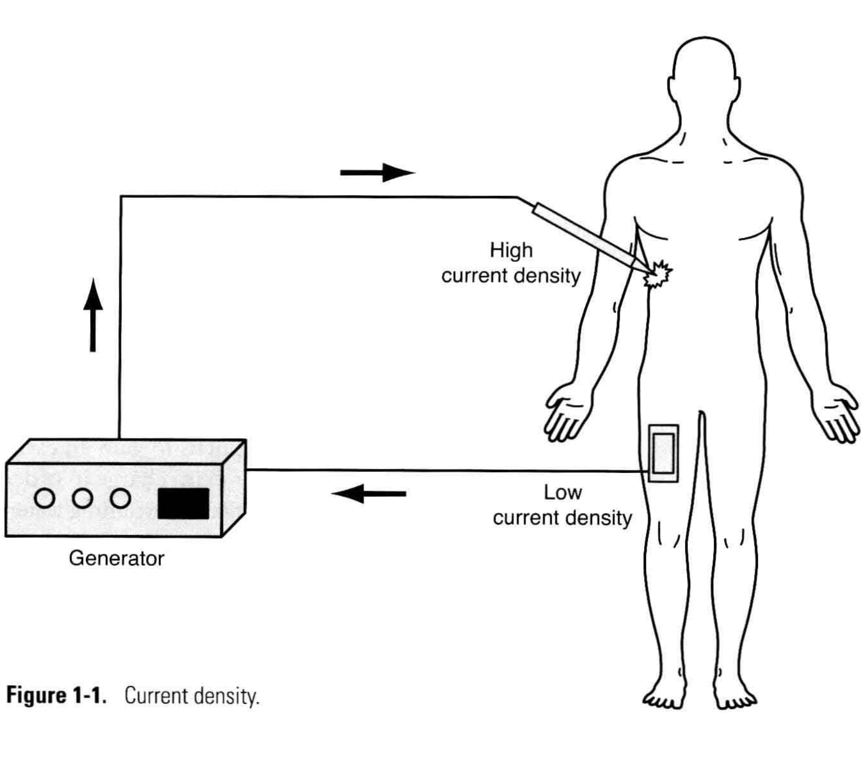

Figure 1-1. Current density.

sity). There is no significant heat release beyond the point of contact because it then spreads over a greater area, with resultant lower resistance and current density. The grounding pad return electrode is large, with greater tissue contact surface area, lower resistance, and high conductivity. In terms of the application of the electrosurgical device, a smaller delivery electrode tip results in greater current density and heat production at the tissue level. The fine-hook cautery tip used in laparoscopic surgery has a higher current density than that of the larger spatulated tip most often used in open surgery. To reduce the risk of thermal injury, the voltage settings of the electrosurgical device should be reduced when used in laparoscopy. The device should be applied appropriately as well. For example, if during laparoscopic cholecystectomy the side of the hook cautery device contacts the liver bed during application of the tip of the device to the gallbladder peritoneal attachments, then the coagulation effect at the gallbladder dissection will be less effective because the total surface area of tissue contact is increased and the current density is decreased. Owing to the ineffective destruction of the attachments, this, in turn, increases the amount of time the device is applied to the gallbladder. As heat production is proportional to the power of the current and the time in which the current is applied, the potential for thermal injury increases with time.

Electrical Current

Electrical flow can be unidirectional or bidirectional. In direct or galvanic current (DC), all charged particles flow only in one direction. This phenomenon can be seen in regular batteries, in which the electrons always flow from the negative electrode to the positive one. Direct current is usually used in medicine for acupuncture or endothermia.[15]

There is a bidirectional flow of electrons in alternating current (AC) because of the constant and rapid reversal in the polarity of the circuitry. Household electricity is supplied in this manner, and all electrosurgical applications are based on this type of current. As a result, there is a maximum voltage in one direction followed by a sudden drop to zero voltage and then an increase to the same voltage in the opposite direction. The frequency at which the AC is reversed is quantified in Hertz (Hz), named after the German physicist Rudolf Hertz (1857–1894). One Hz is a frequency of 1 cycle per second. Standard electrical current in American households alternates at a frequency of 60 Hz. Because nerves and muscles depolarize to frequencies below 10,000 Hz, modern electrosurgical devices usually convert standard current to deliver a flow of AC with a frequency that ranges between 300,000 and 4 million Hz. This rapid change in flow direction is known to be safe because it has no impact on cell resting potential. Energy delivered at frequencies higher than 100 kHz can pass through the patient with minimal neuromuscular stimulation. Lower frequencies can result in variation of cellular membrane permeability, with consequent ventricular fibrillation. This is known as the faradic effect.[16] Pulsed current is characterized by a high discharge of energy in a short period of time. This type of current has been successfully used in the treatment of cerebrovascular and vertebrogenic pathology, pain suppression, and muscle dysfunction.[17]

Fundamentals of Electrical Circuits

A complete circuit must exist in order for electrons to flow. The circuitry should consist of a generator for current production, an active electrode responsible for current delivery, and a return electrode for energy exit from the patient. Because the energy that flows through the return electrode is not needed for surgical purposes, this energy is dissipated by increasing the size of the return electrode (grounding pad) and reducing the current density. Although the current density at the return electrode is low when used correctly, there is still potential for electrothermal injury at this site. The grounding pad should be placed smoothly, with complete contact between the pad and the patient to ensure the reduction in current density. Additionally, if the return electrode is positioned incorrectly, metallic objects (eg, towel clips, stirrups, and metal prostheses) or the surgery staff in contact with the patient can act as a return electrode, producing undesired tissue thermal damage.

Based on the distance between the active and return electrodes, there are two types of electrosurgical modes: (1) unipolar or monopolar and (2) bipolar. In monopolar mode, the active and return electrodes are separated and the current travels long distances from the active electrode through the patient's body to the grounding pad. Because the current tends to follow the path of least resistance and can be relatively unpredictable, it is important to place the return electrode close to the operative site to allow a more direct pathway. For example, when performing an open appendectomy, the ideal location for the grounding pad is the right buttock. Additionally, a relatively dry operative field is optimal because the current will pass through any conducting medium.

In bipolar mode, the active and return electrodes are adjacent to each other, with a very small distance between them, which creates a more controlled pathway with less thermal spread. However, as the tissue between the electrodes is desiccated by heat coagulation, the resistance increases as water is lost and the current may affect a wider area of tissue beyond the electrode tips.

Tissue Effects of Electrosurgery

The tissue effects of electrosurgery depend on the cutting and coagulating waveforms, power settings, electrode size and geometry, activation time, and tissue impedance. The cutting effect or division of tissues is best achieved when a continuous high-frequency AC current is delivered with no