Fundamentals Of Electrosurgery

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Abstract: **Electrosurgery uses electricity to remove tissue, coagulate bleeding, or destroy tumors. Modern units, first developed for application in neurosurgery, are now available in office models that are most commonly used by the family physician for cutaneous surgery. Electrosurgery can accomplish cutting, coagulation, desiccation, and fulguration. Electrosurgical equipment for the office is relatively inexpensive and portable. The main advantage of this surgical modality is rapid completion of the procedure with minimal surgical time, because hemostasis occurs at the time of the incision. After some basic instruction and initial practice on animal tissue, which are provided through the guidance of several excellent texts or continuing education courses, the family physician can readily apply electrosurgery in an office-based practice safely, efficiently, and with satisfying results. (J Am Board Fam Pract 1991; 4:419-26.)**

Electrosurgery is use of electrical energy to excise normal or diseased tissue, to control bleeding, or to destroy benign or malignant tumors. Electrosurgery is useful because it provides surgical results rapidly, efficiently, and with affordable equipment.

Historical Aspects

For hundreds of years, heated metal was used to burn or destroy tissue and control bleeding. Heating the metal was originally accomplished with fire; later the metal was heated with electricity, and this procedure was termed *electrocautery*. Electrocautery involves passage of a current through a filament. The filament resists the flow of current and becomes red-hot. The disadvantage of electrocautery is that its use on human tissue results in a third-degree burn with scarring and prolonged healing.

In 1892, Arsene d'Arsonval[1] failed in his attempt to cause neuromuscular stimulation or tetanic response in humans by application of electric currents with frequencies greater than 10,000 Hz. In 1899, Oudin modified d'Arsonval's equipment and was able to generate sparks that caused superficial tissue destruction. In 1907, de-Forest invented a radio tube known as the triode that amplified and modified electrical output. When the electrical output exceeded 70 W and the frequency surpassed 2 MHz, he found he was able to make skin incisions.[2] Harvey Cushing was eager for a practical electrosurgical unit that could be used in neurosurgery for both cutting and coagulation. In 1926, William Bovie, a physicist at Harvard, developed for Cushing a prototype of the modern electrosurgical generator capable of both coagulation and cutting.[3] In 1978, Maness, et al.[4] found 3.8 MHz was an optimal frequency for cutting soft tissue.

Today's popular electrosurgical instrument is often incorrectly referred to as electrocautery. Rather than the electrode serving as the resistance for the passage of current and itself becoming hot, the modern high-frequency electrosurgical apparatus transfers current to the patient via a cold electrode tip. Human tissue in contact with the electrode tip offers resistance to passage of this current, with the result that electrical energy is converted to heat energy in the tissue. Depending on the characteristics of the wave frequency and power output, the result can be excision of tissue, control of bleeding, or destruction of tissue.

Mechanism of Action and Effects on Tissue

When a high-frequency alternating current is applied to tissue, molecular heat is generated and produces a to-and-fro motion of electrons. One theory regarding the effects of high-frequency electrical current on tissue is that within each cell intramolecular fluids are heated to the point of volatilization, and the cell explodes.[5] This explosive vacuolization is thought to result from intracellular steam pressure. When moving the electrode through the tissue, this electrical energy is

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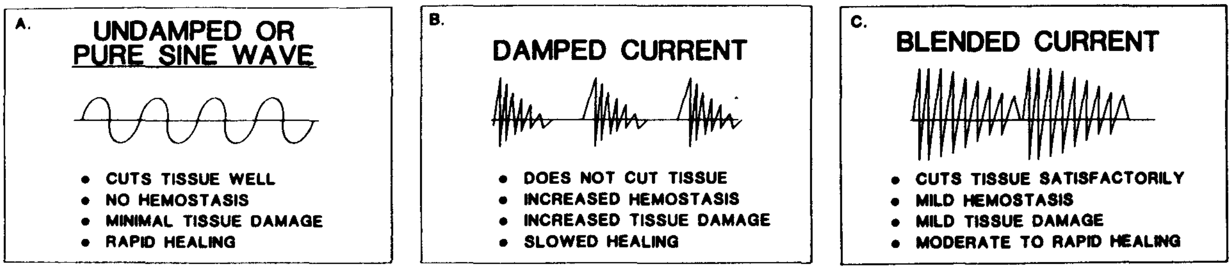

Figure 1. Electrical wave forms and their tissue effects.

applied to individual cells, sequentially separating the tissue and producing a cutting effect. Although heat produces the cellular effect, the end result simulates mechanical disruption as seen when surgical blades are used in cutting. A second theory postulates that the to-and-fro oscillations produced by the electrical current eventually disrupt and cleave the cell wall.[6] Some electron microscopy evidence seems to support this theory.[7] The cutting effect produced is known as *electrosection.*

If the current used is less concentrated and the heat is produced over a relatively larger area, the cells become dehydrated and their protein contents denatured. Cell outlines are lost, blood vessels are thrombosed, and a *coagulating* effect is produced.

Higher voltage but less current, which causes cell dehydration with shriveling but maintenance of cell outlines and preservation of nuclei, produces a *desiccating* effect. When the electrode tip is moved above the surface of the skin and a strong high-frequency alternating current is applied, a spark gap is produced. The change in tissue that results is carbonization and charring, insulating the tissue from deeper destruction. This is known as *fulguration.*

When both electrodes used are large, the heat is dispersed over a large area and no injury ensues. Tissue warming occurs without localized tissue damage. This technique is known as medical *diathermy* and enjoys current use in physical therapy. In electrosurgery, the emitting electrode used is a small tip that concentrates the current and produces localized tissue destruction.

Electrosurgery applies alternating current to the patient. As a result, the current is moving to and from the patient through the electrode. The electrode concentrates the high-energy alternating current on a focused entry and exit point, resulting in tissue damage. If it is necessary to place the patient directly in the circuit of alternating current, an additional electrode must be in contact with the patient. To avoid tissue damage where the second electrode contacts the skin, the electrode's surface area must be relatively large so that the current can be dispersed over a larger surface area. In this manner, each surface point will receive only a relatively tiny amount of current, and the large electrode will have no effect on the patient. This dispersive electrode is not truly a ground, as it does not connect electrosurgical equipment directly to an external grounding source.

Electrosurgical Modalities

Variations in the voltage, amperage, frequency, and method of application give each of the electrosurgical modalities its unique qualities. The wave form of the current is also important.

Electrosection

Electrical current in the configuration of a continuous, pure sine wave with a smooth and uniform appearance is known as an undamped current (Figure 1a). When such an electrical current is applied at high frequency through an electrosurgical tip, cutting, or electrosection, results. Electrosection is comparable to a cold steel surgical incision except for a small amount of heat-induced tissue damage. When an electrosurgical tip is used in the electrosection mode with a brushing or cursive motion at minimal power settings, there is so little tissue damage that this disadvantage is compensated by the resulting rapid hemostasis (particularly in the blended mode described below) and the decreased manipulation of tissue.

Electrocoagulation

This modality uses current applied in intermittent pulses that are damped, that is, the voltage

Table 1. Electrosurgical Units for Office Use.

Manufacturer	Name	Location
Birtcher Medical Systems	Hyfrecator™	Irvine, CA
Burton Medical Products, Inc.	Electricator™	Van Nuys, CA
Cameron-Miller, Inc.	Various models	Chicago, IL
Ellman International Mfg., Inc.	Surgitron™	Hewlett, NY
Elmed, Inc.	Elmed™	Addison, IL
MDT Diagnostic Co.	Bovie Specialist™	N. Charleston, SC
Valley Lab, Inc.	Surgistat™	Boulder, CO

rapidly returns to zero after each pulse so that a strong initial burst is followed by diminishing waves (Figure 1b). The result is an electrocoagulation effect useful for control of bleeding or for destruction of vascular structures.

Electrocoagulation is used when rapid hemostasis is desired without cutting. An example for which this application might be used is treatment of vascular skin lesions, such as telangiectasia, hemangiomas, dilated venules, or other vascular structures that require coagulation rather than excision. Also, following electrosection, when pinpoint bleeding remains that is not resolved by the initial electrosection, switching to electrocoagulation will produce hemostasis of small blood vessels of up to 1/16th inch in diameter.

A *blended* current combines characteristics of the continuous sine wave used in electrosection with those of the damped sine wave in electrocoagulation (Figure 1c). This combination produces a modulated effect that results in both electrocoagulation and electrosection when applied to tissue. Thus, incisions with minimal blood loss can be obtained.

Electrodesiccation

Electrodesiccation is produced also by the damped oscillation described under electrocoagulation. In this case, voltage and current are varied to generate heat that desiccates tissue. When using minimal power, most of the damage is confined to the upper layers of skin, and there is minimal risk of scarring. When using this modality with higher power settings, deeper tissues can be coagulated, and subsequent scarring can occur. Electrodesiccation is useful for treating superficial skin lesions, such as actinic or seborrheic keratoses. Warts can also be treated by this method. Combining scalpel or shave excisions with electrodesiccation of the base of pigmented nevi or malignant skin lesions, such as in removal of basal cell carcinoma, is also popular in cutaneous surgery.

Electrofulguration

The same electrical energy in the damped sine wave configuration used in desiccation can be applied with the electrode positioned slightly above the surface of the skin. A spark traverses the air gap between the electrode and the patient's skin, producing a charring effect in which tissue is carbonized, which insulates deeper skin structures from heat. Cutaneous lesions treated by this method usually heal rapidly because there is little damage to deeper structures of the dermis. In clinical practice, electrofulguration and electrodesiccation usually occur at the same time, because the electrode, as it is passed over the surface of the lesion, is never always in contact with the skin or always above the skin, so that a combination of electrodesiccation and fulguration is usually the result.

Electrosurgical Equipment and Technique

Table 1 lists several manufacturers of electrosurgical equipment. Small office-based instruments that can be obtained in the $1000 to $2000 range include a basic unit and a set of electrodes. Not every piece of equipment listed in Table 1 allows the user to select all the modalities previously described.

Electrodes come in a variety of sizes and shapes and vary in their clinical application. Fine-wire or needle-shaped or wire-loop electrodes will be most commonly used by the family physician for cutaneous surgery. Diamond-shaped or triangular-shaped electrodes are also available.

The larger the electrode, the greater the power that is required to affect the tissue. Fine-wire electrodes work nicely for incisions and require minimal power. One can incise an ellipse around a cutaneous lesion and lift up a corner with forceps. The same needle electrode can then be used to separate the undersurface of the lesion from the dermis by retracting one corner with forceps and placing the needle electrode underneath the raised edge and steadily advancing to the opposite corner. Using a blended mode for cutting, hemostasis can be achieved simultaneously. Primary closure of the wound can be achieved with sutures or sterile adhesive strips, or healing can be left to occur by secondary intention.

Another technique involves using a wire loop, diamond, or triangular electrode placed directly over a skin lesion. The lesion can then be grasped by forceps placed inside the loop, retracted above the level of loop, and the electrode pulled through the base of the lesion. It is best to hold the electrode nearly perpendicular to and slightly above the surface of the skin, activating the electrode and then placing the electrode tip in contact with the skin. This position minimizes the portion of the electrode in contact with the skin, so that if a proper power setting is obtained, the electrode can be pulled through the lesion like a knife through butter. If the lesion is small and the excision superficial, healing by secondary intention produces cosmetically acceptable results.

A foot-operated or handpiece-operated switch or both may be available to control the equipment. A needle hub attachment for the handpiece is available so that disposable needles can be used as the electrode. This feature is particularly useful when treating telangiectasia or coagulating small blood vessels. A variety of additional attachments can serve as the electrode, including knife handles that accept surgical blades or bipolar forceps, which can directly coagulate small blood vessels. There are several excellent textbooks that provide more information on technique and clinical applications.[8-10]

The handpiece can be sterilized between patients by gas sterilization techniques if it is not disposable. The handpiece should not be immersed in disinfectant unless it is waterproof. Disposable covers are available that can be placed on the handle in sterile fashion and then discarded after each use. Some prefer to wrap the handpiece in a sterile 4 × 4 gauze and maintain sterile technique in that fashion.

Electrodes can be disposable or reusable. Those that are reusable will require periodic cleaning to remove charred tissue from their surface. The electrode can be cleaned by wiping with gauze, occasionally scraping with a surgical blade, or using an abrasive pad that the manufacturer supplies. Disinfectant soak or gas sterilization is used to sterilize reusable electrodes. Although activating the electrical charge through the electrode (minimum 40 W for 4–6 seconds) prior to touching the patient can sterilize the metal electrode tip, the nonmetallic insulators around or near the tip of the electrode will not be sterilized by this method; thus, gas or disinfectant sterilization of the entire electrode is necessary.[11]

Power level is an important aspect of electrosurgery but is difficult to specify for each piece of equipment. Power outputs on machines vary considerably among models and manufacturers, and the power adjustment dials are usually calibrated in relative numbers only. When unfamiliar with an instrument, it is best to start with a low setting and practice the different modalities on flank steak. The laboratory exercises described in Sebben's[10] excellent text, *Cutaneous Electrosurgery*, are a good way to learn and practice skills safely with this equipment.

Physicians unfamiliar with this equipment can take any of a number of continuing education courses to learn to use it. After a few hours of practice, one can begin clinical applications, preferably after supervision by someone skilled in this technique. When beginning to use the equipment on patients, it is best to choose small cutaneous lesions in cosmetically unimportant areas and gain experience before attempting to treat larger lesions or those in cosmetically sensitive areas.

Clinical Applications

Family physicians will find that the most frequent application of electrosurgery is treatment of cutaneous lesions. In cutaneous surgery, it is important to know the type of skin lesion being treated to determine the electrosurgical modality to be used. Table 2 lists examples of cutaneous lesions and the electrosurgical mode suggested for treatment. If a lesion is to be destroyed by electrodesiccation or fulguration, a small punch biopsy specimen can be removed first if there is uncertainty about the nature of the superficial lesion. A lesion that is excised using electrosection or shave techniques can be submitted for pathologic evaluation. Most hyperpigmented lesions should be submitted for pathologic evaluation. Lidocaine or another anesthetic agent is locally infiltrated or

Table 2. Cutaneous Lesions and Electrosurgical Modality Recommended for Treatment.

Lesion	Electrosurgical Modality
Nevus Basal cell carcinoma Keratoacanthoma Pedunculated fibroma Acrochordon (skin tag) Papilloma Dermatofibroma	Electrosection or blended setting
Telangiectasia Hemangioma	Electrocoagulation
Seborrheic keratosis Condyloma Actinic keratosis Common wart Basal cell carcinoma (after shave biopsy)	Electrodesiccation or fulguration

administered by nerve or field block before electrosurgery. Adding epinephrine to the anesthetic agent is recommended, except at the digits or tip of the nose, as the additional hemostatic effect is beneficial.

There are a wide number of applications of electrosurgery technology in addition to cutaneous surgery. Those family physicians whose skills include gynecologic surgery may use this equipment to perform a type of conization of the cervix known as large loop excision of the transformation zone (LLETZ). Following total or partial avulsion of a toenail, the nail matrix can be destroyed with electrodesiccation using specially adapted electrodes that are insulated on the side facing the skin fold when the electrode is placed between the skin fold and the nail matrix at the base of the nail. Electrosurgical equipment can be used in hair removal and has applications in a wide range of other surgical procedures.

Wound Care

Small surgical wounds made in superficial layers of skin heal nicely with minimal scarring after electrosurgery when the modality and power level are properly applied. Usually the wound is left to heal by secondary intention and can be treated with topical antibiotics daily with or without dressings. Larger wounds can be closed by suturing, but the time gained by electrosurgery is diminished if one sutures the wound.

Wound healing is more impaired with electrosurgery than excision with a scalpel blade, but in some situations this distinction is probably insignificant.[12,13] Electrosurgery seals the blood vessels, which are the main avenue for inflammatory cells and other modulators of wound healing. Also, electrosurgery produces some necrotic tissue, which may be recognized as a foreign body. Necrosis is greater with a damped current (electrodesiccation or coagulation) than with the undamped electrosection or cutting current. Interestingly, the tensile strength of electrosurgically made wounds is *increased* within the first 4 days compared with similar wounds made by scalpel.[14] After this time, these effects are reversed until they become equivalent in about 6 weeks. Care in selection of electrosurgical modalities, experience in technique, and use of lowest required power settings can all minimize lateral heat damage in the wound and result in a rapidly healing wound with good cosmetic effect and minimal scarring.

Adverse Effects of Electrosurgery

As with any electrical device, harm can come to the patient from either defects in the machinery or operator error. The actual frequency of serious adverse incidents is unknown, but they appear to be rare when reasonable safety precautions are observed (Table 3).[15] Unintentional burns are possible through faulty application of the dispersive electrode or because of faulty electrical cables. Unintentional burns occur more commonly in the operating room, where the patient under

Table 3. Safety Precautions for Use of Electrosurgery Equipment.

1. Properly ground the equipment at the power source (3-pronged plug and receptacle).
2. Make sure the unit is functioning properly before using it with your patient.
3. The emitting electrode should be sterilized and free of charred material.
4. The electrode wire should be without signs of wear or damage.
5. Place the dispersive electrode on clean, dry skin as close to the operative site as possible and not in contact with other conductive surfaces.
6. Do not place the patient in contact with other grounded pieces of equipment, including power examination tables. If the treatment table has a power outlet, do not use this outlet for the electrosurgical unit.
7. Avoid treating patients who are on cardiac monitoring equipment, are using heating pads, or have pacemakers.
8. Avoid alcohol, oxygen, or other flammable material in the proximity of the electrosurgery equipment.
9. A fire extinguisher should be available where electrosurgery is performed.

general anesthesia is unable to respond to a burn and the equipment used is more powerful than that used in the office setting. Burns are seen rarely, if at all, in the office setting, where lower wattage electrical equipment is used.

Electrosurgical devices are leading causes of fires in the operating room.[16] Sparks from the electrosurgery unit can ignite inflammable anesthetic gases or alcohol-containing skin disinfectants. As a precaution, alcohol should not be used for skin disinfection. Ignition of bowel gas, which can occur if the electrosurgery unit is used around the rectum, can be prevented by placing cotton in the rectum while working on perianal condylomata, for example. Such events, however, would be rare when this equipment is used for cutaneous surgery. Electrosurgical equipment should not be used around high-concentration oxygen.

Electrosurgical units can interfere with patients' pacemakers.[17,18] Modern well-shielded pacemakers are largely immune to such electrical interference. Demand pacemakers, which have both a sensing and pulse-generating function, would be the most sensitive to electromagnetic radiation from an electrosurgery unit. In practice, it may be preferable to avoid electrosurgery in patients who have pacemakers. It would be wise to at least place the dispersive electrode as far from the heart but as close to the active electrode as feasible. Similarly, the electromagnetic radiation from electrosurgical units could interfere with cardiac monitors or other patient-monitoring devices, but again these concerns arise in the operating room or emergency department, not when the family physician performs elective procedures on healthy patients in the office.

The risk of accidental tissue damage by patient contact with a grounded piece of equipment elsewhere in the physician's office, such as a metal portion of an examination table, is minimal for the low-output generators usually used in office settings. If the physician has direct skin contact with a patient during electrical current delivery, a shock may be noted if the area of contact between the physician and patient is small. A dispersive electrode and examination gloves will eliminate this problem.

The worst event that can occur with an electrosurgical unit is ventricular fibrillation resulting in electrocution. Ventricular fibrillation has been reported with use of electrosurgical apparatus, but only in patients who were unusually susceptible because of pacemaker wires or catheters placed in contact with the heart and with connections outside the body.[19] Because the human body, unless wet, has considerable resistance to current, a high voltage is required to produce a dangerous current flow. Modern electrosurgical machines are well grounded and isolated from the main power source by transformers that lower voltage and minimize the possibility of an accidental electrocution.

As with any equipment used for invasive procedures, infection can be transmitted by improperly sterilized equipment. Such risk is a major concern in this era of transmissible deadly viruses. Electrosurgery can produce fine smoke or vaporized tissue and blood. Although vaporized tissue has not shown to be an infectious hazard, appropriate precaution seems prudent. Tissue smoke was found to have a mutagenic potential in animal studies, and some form of smoke evacuation or frequent air exchange is desirable.[20]

Comparison of Electrosurgery with Other Surgical Methods

Advantages

The major advantage, when compared with other methods of surgical incision or excision, is that electrosurgery takes little time. Electrosurgery is among the fastest surgical techniques because the equipment is simple to set up, the procedure takes little time, and control of bleeding at the time of the incision is rapid. Electrosurgery produces immediate effects, and the physician can control the extent of treatment. Operation of the device is usually straightforward, and the technique is easy to master.

Electrosurgery equipment is compact and relatively inexpensive. Modern devices are reliable and require little maintenance. Small units are portable or are sufficiently affordable to be placed in more than one treatment room.

Although a wide variety of benign cutaneous lesions can be treated by electrosurgery, this procedure is particularly useful for superficial lesions. Because the current can be concentrated in a small area, tiny lesions can be treated effectively. Electrosurgery can be used to treat some of the more common cutaneous malignancies. Because many cutaneous malignancies are vascular, electrosurgery is useful for performing a biopsy on malignant neoplasms.

Disadvantages

Although the technique of electrosurgery is easy to learn, a novice may mistreat or overtreat with a false sense of security. With proper technique, scarring should not exceed that caused by any other method of surgery. In inexperienced hands, excessive application of electrical energy can increase the risk of hypertrophic scars. Electrical energy can be conducted deeper into tissue than is visible at the time of treatment, although this rarely occurs. It is possible for electrical energy to be "channeled" down vessels and nerves. High levels of current should be used with caution around important vessels and nerves, particularly in the distal areas of the arms and legs.

Delayed hemorrhage is possible as a result of the coagulated tissue that during the healing phase can slough and produce some degree of postoperative bleeding. Delayed hemorrhage is rare, and careful postoperative wound care will minimize such a risk.

An electrosurgically produced wound will be obvious for some time, particularly if the area is large. A sutured wound can heal more quickly. The healing of the site must be balanced against the complexity and rapidity of the procedure.

Electrosurgical destruction of a small lesion will, of course, obliterate tissue for histologic examination. If excessive current is not used, the band of coagulation artifact at the excisional margins is usually narrow and shows minimal alteration when examined histologically. Damage is also dependent upon the type of current used, becoming far less extensive with the least damped forms of electrosurgical current (electrosection or blended current).

Electrosurgery versus Scalpel Excision

As stated earlier, thermal damage can delay wound healing, which would make cold steel incision superior, because there is no heat-induced tissue damage that is often associated with electrosurgery. For large, rapid excisions, particularly when the cutaneous areas are vascular, however, electrosurgical excision may be the method of choice. The rapid hemostasis decreases overall manipulation of tissues and associated damage. When used with brisk motions at minimal power settings, electrical cutting current produces so little tissue damage that the incision approximates that of cold steel incision. Intricate incisions commonly used in plastic surgery would need to be made quite slowly, and therefore electrosurgical incision is not recommended.

Electrosurgery versus Lasers

Lasers have become a useful tool for many clinical applications. Lasers have revived interest in the concept of bloodless surgery, which was first discussed in relation to electrosurgery. Laser treatment is the technique of choice for clinical conditions in which tissue reaction is based on energy absorption of specific wave lengths. The carbon dioxide laser is the most popular surgical laser for superficial destruction of lesions and cutaneous incisions and is used widely in treatment of extensive condylomata. When electrosurgery and laser surgery are performed with equal skill, the histologic damage is comparable between the two methods.

Equipment used in electrosurgery is much less expensive, is more readily available, and requires less training to use than laser equipment. Electrosurgery has fewer hazards than laser surgery because the laser beam can be directed outside the operating field, creating risks of inadvertent tissue damage and fire hazards. Many operators find the electrosurgical handle much easier to manipulate than the complex arm of the surgical laser. A comparison study involving cutaneous surgery of the nose found that with similar treatment results electrosurgical excision was faster and more convenient than carbon dioxide laser excision.[21]

Electrosurgery versus Cryosurgery

Both electrosurgery and cryosurgery techniques are popular in cutaneous surgery. Cryosurgery is the preferred method for treating superficial cutaneous lesions for which a diagnosis is obvious, such as warts or minor actinic keratoses. Most of these lesions can be treated without anesthesia by cryosurgery, and there is minimal risk of scarring, both advantages compared with electrosurgery. There is, however, the risk of hypopigmentation with cryosurgery. With deeper or large pedunculated warts, such as extensive condyloma acuminata, either a combination of electrosurgery and cryosurgery or excision by electrosurgical cutting may be superior to cryosurgery alone.

Damage from cryosurgery can extend far beyond the area that appears to be frozen, so there is some guesswork when treating large cutaneous lesions with this method. In contrast, electrosurgery is specific, and the extent of damage is usually immediately visible. In addition, cryosurgery produces more postoperative swelling and can produce hemorrhagic or extensive lesions with scarring in the few patients who have cryoglobulinemia, such as those with collagen vascular diseases, chronic hepatitis, or lymphoma.

Conclusion

Electrosurgery is a procedure readily mastered and applicable for office-based care, particularly in cutaneous surgery. Electrosurgical procedures are rapid, efficient, and affordable, and they produce good postoperative results. As with any technique, adverse effects are possible but are usually minimal when the physician uses reasonable precautions and is experienced. Knowledge of electrosurgical techniques and their clinical applications add to the family physician's range of choices for treating a variety of common cutaneous lesions.

References

1. d'Arsonval A. Action physiologique des courants alternatifs a grande frequence. Arch Physiol Norm Pathol 1893; 5:401-8 (5th series).
2. Sebben JE. Electrosurgery principles: cutting current and cutaneous surgery—Part I. J Dermatol Surg Oncol 1988; 14:29-31.
3. Goldwyn RM. Bovie: the man and the machine. Ann Plast Surg 1979; 2:135-53.
4. Maness WL, Roeber FW, Clark RE, Cataldo E, Riis D, Haddad AW. Histological evaluation of electrosurgery with varying frequency and wave form. J Prosthet Dent 1978; 40:304-8.
5. Blankenship ML. Physical modalities. Electrosurgery, electrocautery and electrolysis. Int J Dermatol 1979; 18:443-52.
6. Burdick KH. Electrosurgical apparatus and their application in dermatology. Springfield, IL: Charles C Thomas, 1966.
7. Eisenmann D, Malone WF, Kusek J. Electronmicroscopic evaluation of electrosurgery. Oral Surg Oral Med Oral Pathol 1970; 29:660-5.
8. Popkin GL. Electrosurgery. In: Epstein E, Epstein E Jr. Skin surgery. Philadelphia: W.B. Saunders, 1987:164-83.
9. Bennett RG. Fundamentals of cutaneous surgery. St. Louis: C.V. Mosby, 1988:553-90.
10. Sebben JE. Cutaneous electrosurgery. Chicago: Year Book, 1989.
11. Shaw DH, Kalkwarf KL, Krejci RF, Edusib AR. Self-sterilization of the electrosurgery electrode. Oral Surg Oral Med Oral Pathol 1988; 66:290-2.
12. Pope JW, Gargiulo AW, Staffileno H, Levy S. Effects of electrosurgery on wound healing in dogs. Periodontics 1968; 6:30-7.
13. Glover JL, Bendick PJ, Link WJ. The use of thermal knives in surgery: electrosurgery, lasers, plasma scalpel. Curr Prob Surg 1978; 15:1-78.
14. Tipton WW, Garrick JG, Riggins RS. Healing of electrosurgical and scalpel wounds in rabbits. J Bone Joint Surg 1975; 57:377-9.
15. Sebben JE. The hazards of electrosurgery. J Am Acad Dermatol 1987; 16:869-72.
16. Neufeld GR. Principles and hazards of electrosurgery including laparoscopy. Surg Gynecol Obstet 1978; 147:705-10.
17. O'Donoghue JK. Inhibition of a demand pacemaker by electrosurgery. Chest 1973; 64:664-6.
18. Schutz W. [Transurethral electro-resection in patients with cardiac pacemakers.] Urologe 1979; 18:247-9.
19. Hungerbuhler RF, Scope JP, Reves JG. Ventricular fibrillation associated with the use of electrocautery: a case report. JAMA 1974; 230:432-5.
20. Tomita Y, Mihashi S, Nagata K, Ueda S, Fujiki M, Hirano M, et al. Mutagenicity of smoke condensates induced by CO_2-laser irradiation and electrocauterization. Mutat Res 1981; 89:145-9.
21. Greenbaum SS, Krull EA, Watnick K. Comparison of CO2 laser and electrosurgery in the treatment of rhinophyma. J Am Acad Dermatol 1988; 18:363-8.