Principles of electrosurgery

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HISTORY
Heat has been used to control bleeding since the time of the Ancient Egyptians. Heated metal objects and boiling pitch or oil were used on the ancient battlefields to cauterise and control haemorrhage, but the use of electricity to drive devices to heat tissue and control bleeding has been a relatively recent development.

Initially, around 1875, electricity was used to heat a thin platinum wire – electrocautery – which had the ability to both destroy and coagulate tissue. However, electrosurgery did not come into general use until the end of the 1920s. Harvey Cushing, an eminent neurosurgeon, was unable to operate on a number of his patients because of the threat of uncontrolled bleeding. In 1926 he collaborated with a physicist colleague, William Bovie, at the Harvard Cancer Commission to produce a safe and adjustable electrosurgical unit that enabled him to treat his previously inoperable patients. In a lecture in 1927 he said that the unit had enabled him to perform operations to remove certain brain tumours that would not have been possible a year earlier. Just as ‘Hoover’ has become synonymous with the vacuum cleaner, so ‘Bovie’ has become a generic term for the electrosurgery unit.

The technology did not improve in any significant way until the 1960s when small solid state units were produced using printed circuit boards and transistor technology. These progressed to today’s modern units with isolated outputs, complex waveforms and hand-activated controls (Figure 1).

PRINCIPLES OF ELECTROSURGERY
All matter is made of atoms, which consist of electrons (negatively charged), protons (positively charged) and neutrons (no charge). Atoms with equal numbers of protons and electrons are neutrally charged. However, if a force is applied to cause electrons to move from one atom to another the charges are altered – atoms with fewer electrons become positively charged and those with extra electrons become negatively charged. Electron movement is called electricity. Electricity will always follow the path of least resistance and always seek to return to an electron reservoir, such as the ground. This flow of electrons is called the current and its path the circuit. The force pushing the current is the voltage and any obstacle to the flow of the current is termed resistance or impedance. It is this impedance to the flow of the current that generates heat. With electrosurgery, the patient is one of the most important sources of impedance.

Two types of current can be employed in the operating room, direct and alternating current. With direct current flow is in one direction only, whereas alternating current switches flow in different directions. In the UK this polarity reversal operates at 50 times/second or 50 Hertz (50Hz).

These different currents give rise to two distinct forms of use, which are often confused. With direct current, the current never leaves the instrument it is driving and heats a thin wire loop. This is called electrocautery. It has limited use as it cannot adequately cut tissue or coagulate large cut vessels. Safe electrocautery units are exemplified by small hand-held devices used in ophthalmics.

Electrosurgery, on the other hand, uses domestic 50Hz alternating current, which is modified to operate in the 500KHz to 4.0MHz range, often called radio frequency (RF). By

Figure 1. A modern electrosurgery unit.
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adjusting and changing the waveform, it has a large range of therapeutic uses. At these levels of frequency neuromuscular stimulation and electrocution does not occur.

In order to deliver the current to the patient, an electrosurgery system will comprise an electrosurgery generator, an active electrode where tissue changes will take place, and a dispersive electrode to channel the current back to the generator (Figure 2). The passage of this current produces diathermy (from Greek – dia meaning through and thermy meaning heat), which is the heating of tissue by a high frequency current. Diathermy can be labelled as medical or surgical.

Medical diathermy, used in physical therapies, utilises two large electrode plates placed either side of, for example, an injured muscle. The high frequency current passes between the plates heating the intervening tissues. Because the plates are very large, current density at each plate is low and therefore they remain cool and do not harm the patient.

Key point
Medical diathermy is used as a physical therapy to gently heat tissues. Surgical diathermy is used primarily as means of destroying tissue

There are two ways in which surgical diathermy can be achieved – bipolar electrosurgery and monopolar electrosurgery.

In bipolar electrosurgery the circuit is completed by using two poles (one positive, one negative) close together. Usually these poles are the tines of a pair of insulated forceps, which grasp tissue – e.g. small bleeding vessels – and as the current flows between the two poles the tissues will coagulate. Bipolar electrosurgery is very safe using low voltage and only a minimal tissue interface. Its main use in podiatry is in podiatric surgery where it is used for haemostasis of small vessels during procedures (Figure 3).

Monopolar electrosurgery uses a small active electrode (the electrode held by the practitioner) and a large patient dispersive return electrode. Current density is very high at the active electrode producing heat, but very low at the dispersive plate, which remains cool.

Most podiatric applications of surgical diathermy are to be found in monopolar electrosurgery, with tissue effect generated at the tip of the active electrode. The amount of heat produced determines the extent of the tissue effect. A small area will concentrate the current, offering more impedance, requiring more force to push it along, and thus generating more heat. A large area offers less impedance, reducing the amount of heat produced. Thus by altering both the current and the size/shape of the active electrode, various precise tissue effects can be achieved.

Key point
Bipolar electrosurgery is most commonly used for haemostasis during podiatric surgery, whereas the monopolar technique has a variety of surgical applications within podiatry

Electrosurgery units can produce a variety of waveforms (Figure 4). A constant waveform will enable the surgeon to ‘cut’ tissue by vapourising cells. Here the tip of the active electrode should be held just above the tissue, causing cell vapourisation due to the very high temperatures produced. This will give a pure cut. At the other end of the scale is an intermittent waveform of ‘coagulation’ where the duty cycle is modified such that the current flows for only about six per cent of any time scale as compared to that for ‘cutting’. This interrupted waveform produces less heat, and a coagulum is formed in the tissues, rather than vapourisation; this is useful for haemostasis of vessels up to 2-3 mm diameter. Between these waveforms are ‘blended currents’ with varied duty cycles. These allow for almost bloodless surgery by blending
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Electrosection (cut) and electrocoagulation waveforms, but require a great deal of expertise and experience in their use to give the best results.

Key point
By altering the output of the unit, various tissue effects can be achieved, such as cutting and coagulation.

The unit can also be used for electrodessication and fulguration. With electrodessication the active electrode is placed on or in the tissue, and employing the ‘cut’ mode will produce tissue destruction (Figure 5a). Fulguration, which uses the ‘coagulation’ waveform, is created by holding the active electrode above the tissue, producing sparking at the tissue surface (Figure 5b). Much shallower tissue destruction occurs with fulguration and depth of effect can be carefully controlled. For many podiatric uses of both desiccation and fulguration the process is performed by a monoterminal technique. Here the large patient dispersive plate is not required and the current runs to earth through the path of least resistance. This is normally through the operator’s free hand (i.e. the one not holding the active electrode), which should be placed on the patient’s leg or foot. However, many practitioners will still employ a dispersive plate for safety – this practice is to be encouraged.

Other factors that influence tissue effect include the active electrode shape and the length of time that the electrode is active. If activation time is too long then wider and deeper tissue damage will ensue, commonly referred to as thermal spread. Various shaped active electrodes are used for specific applications and include needles, blades, balls and loops (Figure 6). For example, very fine wire electrodes will produce a high current density at the tip and are best used for fine cutting (vaporising) tissue. A ball electrode will provide a lower current density and, used in ‘coagulation’ mode, produces haemostasis over a large area. It also follows that the patient dispersive electrode should be very large with a very low current concentration, thereby eliminating heat build up and preventing burns to the patient at its point of contact.

Key point
Selection of the appropriate electrode can improve the outcome of electrosurgery.

Overall the combination of settings, active electrode type and time of application should all be carefully chosen to ensure that the lowest possible power setting can be used with an appropriate electrode to produce the desired effect. This will cause minimal peripheral tissue destruction and successful outcome.

COMMON PODIATRIC PROCEDURES
All procedures will require adequate local analgesia. A system review should be done to ensure that there are no contraindications to the LA in much the same way that a system review is done for nail surgery. If you feel that the patient could undergo nail surgery under LA then the patient should be suitable for electrosurgery.

For the podiatric surgeon, the most useful aspect of electrosurgery is probably the bipolar modality for haemostasis, as the majority of podiatric surgery involves bone sectioning, which is not possible using monopolar electrosurgical techniques. Inevitably, small vessels will be encountered during procedures and bipolar diathermy allows safe coagulation of vessels up to 2-3mm in diameter, stopping intra-operative bleeding. This also seals vessels to help prevent post-operative haematoma formation or excessive bleeding. However, where soft tissue sectioning is required then monopolar electrosurgery can be employed. This allows for precise clean cutting of skin and gentle atraumatic dissection of tissues.
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Warts and corns
Out of theatre, other procedures can be undertaken in the clinical setting using similar aseptic technique to that used in nail surgery with smaller more affordable electrosurgery units. For example, loop excision of warts and verrucae can be performed quite easily, usually with an excellent outcome. The wart can be excised with a ‘scooping’ action and the wound edges should be ‘feathered’ to produce a shallow ulcer with gently sloping sides to help promote scar-free resolution. Following excision, excessive bleeding is prevented by coagulation, sealing any small papillae.

Heloma dura and verrucae plantaris can also be treated using desiccation and fulguration. Corns on the apices or dorsum of toes can be desiccated using a ball electrode gently worked over and around the lesion. The area should be constantly wetted with an isotonic solution of NaCl, e.g. Normasol, during the procedure to maintain good current flow, but also to prevent excessive heat build-up where the corn may be over a prominent bony site. The tissue will gradually blanche and the epidermis, containing the corn, will separate from the dermis. Once this has occurred, the desiccated tissue can be removed with a scalpel blade (Figures 7 & 8). Usually no haemostasis is required with this technique and scarring will be minimal. Desiccation by insertion of the electrode into the lesion is also possible but should be restricted to larger lesions. The tissue should be systematically destroyed, whilst ensuring that it is confined to the lesion itself with minimal peri-lesional thermal spread. The resulting eschar can be removed (by curettage or careful scalpel technique) and the base of the lesion fulgurated to help destroy any remnants of the lesion and to provide haemostasis. For very shallow lesions, or where delicate advancement of tissue destruction is required, fulguration can be used along with curettage. Tissue can be removed in very thin layers and provides good control of bleeding to help maintain excellent visualisation of the progress of the procedure. This is useful for the treatment of shallow mosaic warts, where deep tissue destruction is unnecessary and also where delicate structures may be under the lesion.

Nail surgery
Matrix ablation for either partial or total nail avulsion has, for a number of years, been primarily achieved by the application of liquefied phenol to the nail matrix in a controlled way such that re-growth of the nail is usually eliminated. Recently there has been discussion as to the withdrawal of phenol for this process, and other matrix ablation techniques have been explored, including the use of other chemicals (e.g. sodium hydroxide), cryosurgery and electrosurgery. Certainly matrix ablation can be effected by careful use of an insulated electrosurgery blade electrode and, in expert hands, will give excellent results. The nail should be resected in the normal fashion and the flat matricectomy electrode, which is coated on one side to avoid damage to the overlying proximal nail fold, is placed beneath the nail fold just above the nail bed. Treatment should be in a bloodless field using a coagulation current as fulguration for 2-10 seconds treating the entire exposed nail bed and matrix twice. This should give a white appearance following electrosurgery.

Other lesions encountered in the podiatric clinical setting that are amenable to electrosurgery include acrochordons (skin tags), pyogenic granulomas, molluscum contagiosum and plane warts.

PURCHASE AND USE OF AN ELECTROSURGICAL UNIT
Units are available for use in clinics and there is a wide choice. Prices range from between £750-£2500 for the basic unit, which will normally be supplied with full instructions (often now on video), a selection of active electrodes, a hand piece, all leads and sometimes a footswitch although this may be an extra. Loop excision of verrucae for best results requires a radio frequency (RF) unit, which will offer a full range of waveforms and controllability. For electrodesiccation and fulguration then a low power moniterminal unit may suffice. However, it is important to ensure the scope of the machine prior to purchase to ensure it is able to carry out each of the desired functions. For additional safety a unit with a patient dispersive electrode is desirable. Many machines have ground referenced generators, which can cause current division. This is where the current finds the quickest way to return to the ground, which may be where the patient’s hand or knee touches the side of the treatment chair/couch and causes a burn, or at least a spark, and subsequent patient discomfort. Most modern RF units are isolated electrosurgical units that isolate the current return to the generator only and thus eliminate the possibility of current division. These units will always include patient dispersive electrodes.

SAFEY
When using the patient dispersive electrode (Figure 9) it is imperative that it should be properly placed on the patient. It should be as close as possible to the surgical site and over a large muscle mass. It is essential that it is in good contact with the patient’s skin and generally, flexible plates are preferable. It should not be placed over scar tissue, bony prominences, metal prostheses or internal fixation (plates/screws) as these will increase impedance therefore increasing heat at the dispersive plate/patient interface. Some very high frequency RF units have a patient dispersive plate that does not need to be in contact with the patient as it works as an antenna and therefore position on the patient is not important. Units employing these tend to be very expensive.

Key point
Prior to purchase, it is important for the practitioner to ensure the electrosurgery unit is able to carry out the desired functions
Adequate vapour extraction is required when using the device.

Key point

For patients with a pacemaker, the operator should check with the manufacturer as some devices are susceptible to electrical interference. In any case the active electrode and patient dispersive plate should be as close to each other as possible to ensure the current passes well away from the pacemaker.

Post-operative care for electrosurgery procedures should allow the skin to be kept clean and moist with tulle dressings (e.g. Bactigras®) and should be redressed on a regular basis. Scarring will vary from person to person, but will also be influenced by the expertise of the practitioner. Partial thickness wounds, e.g. desiccation or fulguration/curettage of verrucae, will heal by secondary intention and are thus more liable to scarring than full thickness wounds, which are closed with sutures and heal by primary intention.

As a note of caution, if the lesion is large, is in a sensitive area, diagnosis is uncertain, there is a possibility of malignancy or there is an increased chance of complication, then referral to a dermatologist should be a matter of course.

As with all skills and techniques, practitioners should attend appropriate programmes of training and clinical update such as uses and techniques of electrosurgery, local anaesthesia and wound healing.

Key point

Where the diagnosis is in doubt prior to electrosurgery, referral on to an appropriate professional is essential.

SUMMARY

Electrosurgery offers an added dimension to podiatric practice both in theatre and in the clinical workplace. There is a fairly large initial financial outlay for the equipment. This will need to be recouped by extended practice, which the podiatrist will need to augment with extra training and a desire to widen their horizons. All procedures will require the use of local analgesia and thus adequate time must be allowed for treatment, not only for profundity of analgesia, but also for careful and considered tissue handling during the electrosurgery.

Outcomes of treatment will depend on a wide understanding of the processes involved in the techniques employed, but also on the practitioner’s capabilities. However, none of this should stop the progressive podiatrist from exploring the techniques in more detail to enable them to arrive at a fully informed decision as to whether or not to extend their scope of practice by utilising electrosurgical techniques.

REFERENCES

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5. Zuber T J. American Family Physician 62(12); 2002; p2547-2550.

USEFUL WEBSITE

www.lasertraining.org

Free Material – Practical Electrosurgery Manual
Post-reading activity

Reflection

After reading this CPD article, take a few minutes to reflect on electrosurgery and how it is used. Areas for reflection could include:

- What conditions do I see currently in clinic that may benefit from this intervention?

- Would this be a suitable extension to my current scope of practice?

- Would I need to consider any supplementary training or CPD, such as local anaesthetic techniques, wound healing knowledge etc?
• What courses or training programmes are available for me to pursue this?

• Could I receive mentorship from a colleague currently using this technique?