fibrosis, to name a few, whose lives have been extended for several decades by modern health care.

Clinicians need to be as effective as possible in the least amount of time as possible. More is not necessarily better. Pursue specialization but not at the expense of always considering the client as a whole. Current knowledge of neurophysiology, motor and cognitive learning, is I believe as important to musculoskeletal specialists as knowledge of muscles, joints and kinesiology is to the neurology specialist, to give a few examples. Other health care professions have adopted a more administrative role but I believe that our profession, physical therapy is, at its heart, a hands-on, caring profession and should never lose sight of that core. Numerous other disciplines and professions are reaching out for a 'piece of the rehabilitation pie' and if physical therapy is to be *first among many,* not just *one of the many* (Walker 2002), our practice must be holistic and with a scientific basis.

For the clinician of today and tomorrow, first access, autonomous practice, and physical therapy diagnoses carry an awesome responsibility and a greater potential of legal issues. A critically thinking and constantly evaluating clinician will better overcome these hurdles.

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HAND MADE HISTORY

Electromagnetic therapy: fact or fiction

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Electrotherapy and electromagnetism

Electrotherapy and electromagnetism have recently been reintroduced into medicine, principally in the field of locomotor systems. Extravagant claims have been made and the various techniques in use have been disputed vehemently. Is this another example of the 'Emperor's clothes' phenomenon or is there somewhere a germ of truth?

Historical

Four hundred and fifty years ago Theophrastus Bombastus Paracelsus von Honenheim reported on the use of magnetic iron rodlets which, when adequately placed, 'Heal fractures and ruptures, pull hepatitis out and draw back dropsy, also healing fistulae, cancer, and blood flows of women'. Naturally, such claims did not endear Paracelsus to the medical establishment of the day, and his observations were not investigated again until Franz Anton Mesmer,a qualified physician, began to study magnetism in the 18th century. He achieved cures with his iron rod magnets, but unfortunately, later moved on to the transmission of 'magnetic forces' by the laying on of hands.

In the course of the 18th century, basic studies on electricity were carried out by Franklin, Lavoisier, Galvani and Volta. Some of these studies are still done by every medical student today. At the end of the 18th century, Michael Faraday discovered electromagnetic induction, and based on his work, inventors in England developed in 1869 a device into which the patient was placed. The device produced magnetic waves which flowed lengthwise through the patient. Outside of Eastern Europe, such devices were regarded as the implements of quacks and charlatans.

Electromagnetism began its long trek back to orthodox medicine with a classic experiment of Fukada and Yasuda[1] which demonstrated the piezo-electric property of bone. Piezo electricity is a property of anisotropic crystalline structures and consists of elastic and electric oscillations in reversible causality. Elastic and electrical polarisation has a linear dependence; both can be produced not only though mechanical forces, but also through the forces of an electric field. This gave the first rational explanation of Wolff's law that in bone, function determines form.

This led to considerable investigative activity and it was shown that constant direct current in the microampere range when applied to bone will cause new bone formation mostly around the cathode or negative electrode.[2] It was then shown that both pulsed direct current, and alternating current produced bone formation at both electrode sites. These effects can be produced either invasively, i.e. by implanting an electrode, or non-invasively by inducing electrical potentials by means of electric fields, or pulsed magnetic fields in close proximity to tissues. The hazards associated with high voltage electric fields made it less attractive than pulsed magnetic fields for clinical

Cameron HU (1983). Electromagnetic therapy: fact or fiction. New Zealand Journal of Physiotherapy 11(2):31-32.

use. Magnetic fields, when pulsed in close proximity to tissues will induce a current, the direction of which will alternate as the magnetic flux rises and collapses.

Current state of the art regarding bone healing

Several systems are currently available for clinical use. These are used when a fracture fails to unite or to obtain fusion in difficult cases.

Non- invasive

The two commonly used non-invasive systems are the EBI system developed by Bassett[3] and the DeHaas system.[4] The EBI system is calibrated for each patient and uses very low intensity magnetic fields with a very rapid pulse. This device has been widely marketed and does appear to have an 80 to 85% success rate in achieving union. The DeHaas system, developed in Calgary, uses a high field strength of 200 gauss pulsed at 1 Hz. The success rate for this device is similar to that of Bassett's. These systems can be used in the patient's home and are generally used for 20 hours/ day for six to 12 weeks, which means that during this time the patient is relatively immobile. A cast or splint is used to protect the bone and support the magnet.

Invasive

A totally implantable system was developed by Alan Dwyer of Australia in early 1971 to promote posterior spine fusion. His work was expanded by Sir Dennis Paterson to provide electrical stimulation for the treatment of non-unions, delayed unions congenital pseudo-arthrosis and bone defects. This method also has an 80 to 85% success rate and is useful in that no patient compliance is required. This system can be used in places where it would be impossible to apply a magnet externally. It is possible to use this in conjunction with plates and screws. The disadvantage is that an operation, with its attendant risks, is necessary, and at the end of treatment, usually six months, the implant has to be removed. Naturally, in such a system, problems do appear given the relatively short shelf-life of six months and the rather fragile cables. Improvements in this system are overdue and hopefully will soon be available.

A system exists in which percutaneous electrodes are used with an external power source, but this would seem to have the disadvantages of both of the other systems demanding both operative insertion and patient compliance.

Other applications

Devices, similar to that developed by Smith in 1869 are currently being marketed and supposedly effect dramatic cures in a range of illnesses. These claims are so fantastic as to invite disbelief. One such unit* was tested at the Orthopaedic and Arthritic Hospital in Toronto, to determine if it could reduce postoperative swelling in total knee replacement. Surprisingly, the pulsed magnetic fields were found to reduce swelling significantly. However, no other parameter was tested.[6]

Workers with the DeHaas system have demonstrated improved tendon and ligament healing in experimental animals, and there is some suggestion that pulsed magnetic fields may have a role to play in the treatment of osteoporosis.

*Magnetopulse®-Elec Canada

The Bassett and DeHaas systems have been tried in osteomyelitis. In infected non-unions, as the bone heals it has been found that the infection subsides. In a few cases, the author has tried these units in cases of chronic osteomyelitis. While the systems were in place, the sinuses tended to heal, but most recurred with cessation of treatment. In the laboratory, electromagnetic stimulation appears to have no effect whatsoever on bacterial growth.

Mode of action

The fundamental cellular mechanism of action is unclear. Various observations have been made; i.e. it has been shown that electromagnetic stimulation alters the hydroxyproline/ hydroxylysine of healing tendons. An increase in collagen formation and proteogly synthesis has been demonstrated in experimental osteoporosis. In established non-unions, the tissues in the gap between the bones appear to calcify progressively and then to be invaded by blood vessels coming from the bone margins; there is progressive replacement of calcified cartilage by woven and lamellar bone.

Clinical use

At present, clinical use of these techniques is restricted to delayed union and non-union of fractures. The speed of healing in a normal fracture is not influenced by electromagnetic stimulation. The techniques do not work in synovial pseudo arthrosis or in the presence of uncontrollable movement. Interposed soft tissue and a radiographic gap of more than 1em may prevent union. The presence of any of these factors necessitates surgical intervention with bone grafting and, if necessary, with internal fixation.

Infected non-union should be handled in the normal way with thorough debridement, either closed suction irrigation or wide saucerisation, bone wafting and then stimulation. Infection is probably a contraindication to the use of a fully implantable stimulator.

Avascular necrosis of bone is a relative contraindication and bone transplantation using microvascular techniques is preferable under these circumstances.

While not clinically proven, suspicion exists that pulsed magnetic fields help in the healing of chronic ulcers and perhaps even help in the return of sensation and pseudomotor function in chronically insensate skin such as that following degloving injuries.

Conclusions

Much basic work is required to be done in this field of electromagnetic stimulation, but a very powerful tool has been added to the treatment of extremely difficult problems.

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Commentary

Almost 30 years has passed since Cameron wrote this article on the use of electromagnetism to aid bone healing. The second paragraph describes the historical development of such an approach with the final sentence delivering a startling message of the times in 1869; "*outside of eastern Europe, such devices were regarded as the implements of quacks and charlatans*". What view does the physiotherapy profession hold in New Zealand in 2012?

In the early 1950s, work was published on the piezoelectric forces within bone (Yasuda 1953), and consequently this led to scientists exploring the manipulation of electromagnetic fields (EMF) to enhance the healing process. Since then numerous studies have been published reporting on the effects. However, a recent Cochrane review concerning the use of EMF to stimulate bone healing (Griffin et al 2011) found only 4 RCTs published between the years 1984-2003 that met their inclusion criteria. Not unexpectedly they concluded that although the meta-analysis favoured EMF stimulation, it was not statistically significant and the lack of evidence precluded any recommendation for use in clinical practice. The United States Food and Drug Administration have approved the use of pulsed EMF for the treatment of musculoskeletal disorders such as non-union of fractures (Bassett et al 1978; Heckman et al 1981), congenital pseudoarthroses (Bassett et al 1991), RA (Ganguly et al 1998), OA (Nelson et al 2012) and tendinopathy (Binder et al 1984). In order to receive such approval manufacturers of these devices must show through scientific evidence that the device is effective and safe.

Research suggests that the mechanism of action of pulsed EMF is the induction of ionic currents within the tissues which in turn stimulate changes in cellular calcium and cyclic adenosine monophosphate levels (Thumm et al 1999), along with increased synthesis of collagen, proteoglycans, DNA and RNA (Pezzeti et al 1999; Goodman et al 1989). Pulsed EMF has also been shown to increase levels of reactive oxygen species and nitric oxide production (Kim et al 2002); all essential for the healing and remodeling of damaged tissue. So, when the direct effects are measureable, as in cellular and animal studies, it is very difficult to dispute that EMFs have an effect on the healing process. When it comes to clinical trials where the outcome measures are mostly indirect measures of effects, the evidence turns out to be not as robust and strong. This is due to a number of confounding factors such as application technique, treatment regime, dose/response relationships etc; resulting in some trials reporting positive effects and others reporting no effect.

In today's healthcare climate one of the most widely accepted definitions of EBM is "*the explicit, judicious, and conscientious use of current best evidence from health care research in decisions about the care of individuals and populations*" (Sackett et al 2000). This definition puts meta-analysis and RCTs above opinion of the expert, who uses knowledge from a variety of sources, including knowledge of pathophysiological mechanisms, and knowledge derived from clinical experience, to inform decisions. The evolution of EBM has seen a softening of strict adherence to "evidence from research is the best evidence", to include clinicians' experiential evidence, and the patient's goals and values. Therefore, the above definition of EBM has more recently been modified to; "*the integration of individual clinical expertise and patient preferences with the best available external clinical evidence from systematic research and consideration of available resources*" (Tonelli 2006).

Considering the more recent definition of EBM, and the improvement in the dissemination of research knowledge and knowledge in general, what is your view on pulsed EMF for the treatment of musculoskeletal disorders? Is it different from the popular view of 1869?

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