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Veterinary applications of pulsed electromagnetic field therapy

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ABSTRACT

Pulsed electromagnetic field (PEMF) therapy can non-invasively treat a variety of pathologies by delivering electric and magnetic fields to tissues via inductive coils. The electromagnetic fields generated by these devices have been found to affect a variety of biological processes and basic science understanding of the underlying mechanisms of action of PEMF treatment has accelerated in the last 10 years. Accumulating clinical evidence supports the use of PEMF therapy in both animals and humans for specific clinical indications including bone healing, wound healing, osteoarthritis and inflammation, and treatment of post-operative pain and edema. While there is some confusion about PEMF as a clinical treatment modality, it is increasingly being prescribed by veterinarians. In an effort to unravel the confusion surrounding PEMF devices, this article reviews important PEMF history, device taxonomy, mechanisms of action, basic science and clinical evidence, and relevant trends in veterinary medicine. The data reviewed underscore the usefulness of PEMF treatment as a safe, non-invasive treatment modality that has the potential to become an important stand-alone or adjunctive treatment modality in veterinary care.

1. Introduction

Pulsed electromagnetic field (PEMF) therapy is a non-invasive, non-thermal treatment that involves pulsing electromagnetic fields in tissue to promote healing (Strauch et al., 2009). PEMF devices have been approved by the U.S. Food and Drug Administration (FDA) to treat non-union fractures and cleared to treat post-operative pain and edema, osteoarthritis, and plantar fasciitis. Implementation of PEMF therapy in veterinary medicine is increasing. Pathologies that are often treated with PEMF devices include bone fractures, inflammation and arthritis, pain, edema, and chronic wounds. Though there is a growing body of basic and clinical evidence in support of PEMF treatment as a therapeutic modality, veterinary practitioners and animal owners report significant confusion about PEMF devices largely due to the number of different types of devices and the varying amounts of evidence that support each type of device. This lack of clarity regarding the PEMF modality is furthered by poor dissemination of data on mechanisms of action and a wide variety of unsubstantiated claims that are used for marketing purposes. In an effort to unravel the confusion surrounding PEMF devices, this article reviews important PEMF history, device taxonomy, mechanisms of action, basic science and clinical evidence, and relevant trends in veterinary medicine. The goal of this overview is to provide readers with a clearer understanding of the PEMF treatment modality, with an emphasis on recent PEMF technologies that are rooted in basic science and clinical research and are well-positioned to augment veterinary care.

2. History

Electromagnetic field devices have been used therapeutically for more than a century and for a variety of applications (Fig. 1) (Strauch et al., 2009). Historically, most devices have had a wide range of operating modes and were largely promoted without scientific evidence or validation. The era of modern PEMF technologies began in the 1930s when a vacuum tube-based diathermy machine, a radio-frequency electromagnetic device used to deliver heat deep into tissue, was adapted to produce little to no heat. This was accomplished by reducing the duty cycle of the diathermy device, or the percentage of the electromagnetic signal's on-off cycle in which the signal is active, to about 4%. These new non-thermal devices were purported to have therapeutic effects in wound healing and treatment of pain, though via unknown mechanisms at the time.

Commercial distribution of these “non-thermal diathermy” devices started in 1950 (Al-Mandeel and Watson, 2008). In parallel work during the 1970s, clinician researchers began to employ direct electrical currents to treat non-union fractures, using electrodes surgically implanted

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Fig. 1. 1920's era fischer diathermy machine.
This device is an example of an early pulsed electromagnetic field technology that was used for therapeutic heating of tissue. This device was developed and sold by Fischer & Co in the early 1920's.

Fig. 2. Modern bone growth stimulator.
This device is an example of a modern bone growth stimulator device use for treating non-union fractures. When in use, the device is positioned such that the two coil panels are on opposite sides of the fractured bone. Because of the weak fields generated by these devices, they are often used for several hours per day for weeks or months.

in bone (Paterson et al., 1977). By the late 1970s, implanted electrodes were being replaced with non-invasive inductive antennas (Bassett et al., 1977). During that period PEMF was successfully used to treat delayed and non-union fractures in Beagles and, shortly thereafter, humans. After extensive clinical research, by the early 1980s low-powered PEMF devices called bone growth stimulators (BGS) were approved by the U.S. FDA for human use (Fig. 2) (Bassett et al., 1982). Subsequently, in the 1990's, a next generation class of PEMF devices was developed for treating soft-tissue instead of bone. These devices were solid-state and smaller, improving upon the cumbersome large vacuum tube models.

The growing body of research and clinical evidence supporting PEMF therapy in the 1980's and 1990's also fostered greater understanding of mechanisms of action (Pilla, 2006). Scientists began to develop PEMF devices with waveforms designed, a priori, to modulate specific biological processes. For example, one device termed “targeted PEMF” was successfully developed to reduce inflammation and has become a FDA-cleared therapy for treating postoperative pain and edema (Fig. 3) (Pilla, 2013). Non-targeted PEMF systems, also readily available, were not specifically configured to a known biological target, and thus demonstrated a wide range of technical specifications and

Fig. 3. Targeted pulsed electromagnetic field device.
This targeted PEMF device consists of a single loop antenna and battery-powered pulse generator. The targeted PEMF waveform was designed to reduce inflammation in soft tissue. Characteristics of the waveform, such as the long burst width and the high frequency 27.12 MHz carrier wave, result in very efficient delivery of electric field to tissue, and, therein, beneficial clinical effects with small doses of treatment.

clinical effectiveness. Although devices without FDA clearance are utilized in human and veterinary care, this review will concentrate on FDA-cleared devices, as they are supported by basic science and clinical research studies that help illustrate relevant areas of clinical application and therapeutic utility in veterinary medicine.

2.1. Taxonomy

PEMF is a type of electrotherapy that employs an active electromagnetic waveform that is typically delivered via an antenna to treat an area of tissue on a subject. Many different types of PEMF devices have been developed both for research and clinical applications. These technologies are differentiated by (1) the shape and strength of the electromagnetic waveforms they emit, (2) the size and geometry of antennas used, and (3) the duration and frequency of treatment application. These variables combined determine the strength of the magnetic and electric fields generated by each device and, ultimately, whether the devices provide safe and efficacious therapy.

To showcase the intricacy of these variables, Fig. 4A shows the shape of the waveform used in the original BGS device to promote healing of non-union fractures. Fig. 4B illustrates the very different waveform used in the targeted PEMF device referenced above, which has been successfully used to treat pain and inflammation (Pilla et al., 2011). Furthermore, the strength of the magnetic fields generated by PEMF devices can vary dramatically from less than one Gauss to several thousand Gauss. Obviously, not all PEMF signals are alike. Consequently, this substantial variability in device parameters underscores the necessity of rigorous animal and human research for the sake of validating individual PEMF therapies for specific clinical applications.

PEMF waveforms, in the configurations cleared for human use by the FDA, were designed to penetrate completely through tissue of all types, allowing for effective non-invasive delivery of the therapy. These PEMF devices differ significantly from other forms of electrotherapy