

The Use of EMFs to Modify Inflammation

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Magnetic fields (EMFs) have been used to treat almost every conceivable human illness or malady, including many inflammatory diseases such as arthritis or psoriasis.

EMF therapy has been associated with pain reduction, and accelerated healing. EMF's exert these effects by regulating processes involving inflammation and autoimmune diseases, among other biologic actions.

Inflammation

Inflammation is a cascade of physiologic processes instigated by the body to repair cellular damage in vascularized tissues and to restore the tissue to its normal function.

Characteristic signs and symptoms that accompany inflammation include:

- ❑ redness generated by increased blood flow,
- ❑ heat generated by the metabolism of leukocytes and macrophages recruited to the damaged site,
- ❑ swelling due to edema, and
- ❑ pain caused by the production of pro-inflammatory prostaglandins.

Inflammation is the net result of a cascade of biologic processes that is generated and supported by the interaction of a number of immune cell types, including lymphocytes, macrophages and neutrophils, with other cell types such as the fibroblasts, endothelial cells and vascular smooth muscle cells playing a regulatory role in the cascade.

Acute vs chronic inflammation

While inflammation is a necessary and beneficial process, its intensity during the initial acute phase can be pathologically exaggerated, and it often persists longer than necessary, developing into chronic inflammation.

Chronic inflammation is generally associated with dysfunction of one or more immune system components and it leads to the ongoing tissue damage found in diseases like tendinitis, arthritis or psoriasis. Chronic inflammation has also been implicated in the etiology of cancer and Alzheimer's disease.

Mechanics of inflammation

The various cell types and metabolic pathways that generate inflammation provide numerous targets for therapies aimed at controlling inflammation in the acute phase and in preventing progression to chronic inflammation. Inflammation can be initiated by many causes, and the nature of the precipitating event is important in designing therapeutic interventions.

In bacterial infections, early infiltration of the affected site by polymorphonuclear neutrophils (PMNs) is followed by the arrival of T cells that up regulate PMN-dependent processes, an event that is required to kill bacteria. In this circumstance, eliminating T cells is counterproductive to healing. In trauma-induced injury, T cells are less important for resolving tissue damage, and may be harmful if present for long periods. In this case early elimination of T cells in the acute phase of inflammation could minimize the unwanted effects of inflammation, accelerate healing, and reduce the risk of chronic inflammatory disease. In chronic inflammatory diseases such as rheumatoid arthritis, psoriasis, and chronic tendinitis, maintenance of the disease state is dependent upon the presence of T cells. Here, removing T cells would

be viewed as a favorable method of therapy for these and similar chronic conditions. T cells are a major regulator of the inflammatory cascade.

Research on in vitro lymphocytes has shown that EMF's can induce apoptotic cell death in T lymphocytes.

The primary EMF target on T cell membranes is CD 45, a major membrane glycoprotein. Activating CD 45 happens very early in the T cell signaling pathway. EMF's also influence protein kinase C, an important enzyme in cells. EMF's have been found to affect ion flow through voltage-gated ion channels including those for sodium, potassium and calcium. These events could trigger conformational changes in membrane proteins leading to altered functional status of the ion channels and subsequent intracellular events such as those initiated by CD 45. Ion modulated processes, affected by EMF's, also impact calcium calmodulin, an important second messenger in cells. There it is a tight interaction between the T cell receptor [TCR] and increased intracellular free calcium.

Homeostasis and cells out of balance

Experiments are difficult to control for, explaining often contradictory results, even from the same laboratory. Research has uncovered that these often contradictory results happen because of the unpredictable basic states of the cells are being studied. Normal cells are often not impacted by magnetic fields. Compromised cells, that is, metastable cells, are more likely to be impacted. This means that EMF's have more impact in circumstances where there is imbalance in tissues or cells, ie where there is pathology or chronic inflammation.

Signal transduction and metabolic pathways contain an immense number of downstream feedback regulators that act to restore cellular homeostasis. The more distal the measurement or clinical metabolic endpoint is from the site of pathway stimulation, the more likely the biological system is to be stabilized or buffered by feedback signals. This means that where homeostasis in the body is robust, EMF's, especially weaker EMF's, are unlikely to demonstrate effects. For example, activation of the T cell receptor also activates calcium calmodulin kinase. However, within five minutes after removing the activating signal, the activated kinase returns to control levels because of feedback-induced deactivation.

Reduction of inflammation by EMF's

Significant changes occur in intracellular calcium in lymphocytes from both low intensity, low-frequency EMF's or even DC/permanent magnetic fields. EMF's also have large impacts on cellular electron transfer reactions, and cellular redox potentials. EMF's interact with cellular systems in nonlinear and/or chaotic ways. This means that increasing frequency and or intensity does not always produce a one-to-one change in reaction intensity. This makes the physiologic reactions to EMF's quite unpredictable, even in experimental settings.

The EMF inhibitory effect on lymphocytes, and the inflammatory processes appears to be most apparent, several cell generations after EMF exposure [that is, 48 and 72 hours later], and then the EMF effect seems to disappear. This indicates that the effects of EMF's are additive or synergistic to other natural or externally applied biochemicals or treatments.

EMF's induce downstream effects resulting in growth inhibition and apoptosis. It is this growth inhibition and apoptosis-effect of EMF's on lymphocytes that decreases inflammation.

EMF effects in lymphocytes appear to be different in stressed animals.

EMF effects on lymphocyte metabolism are often weak and counteracted by rapid repair and homeostatic feedback loops. Because of this EMF use for inflammation needs to be optimized so that exposure will lead to long-lasting, therapeutically relevant outcomes.

Pulse-burst-modulated high frequency fields seemed to deliver low frequency signal components to EMF sensitive sites in tissues much more effectively than other frequency signals, and therefore produce improved therapeutic outcomes. While particular types of signals may be most effective, a response is often seen to various kinds of magnetic stimuli. There appear to be similar effects on lymphocytes using pulsed bone healing fields, versus sinusoidal power frequency level.

Pulsed EMF's with flux densities from 5-25 MilliTesla had no effects on normal circulating T cells. This means there is no apparent damage to normal lymphocytes. Inflammatory T cells produce interleukin -2, which acts to stimulate T cell proliferation and regulation of other cells in an inflamed tissue. At high concentrations this interleukin acts as an apoptosis-inducing factor. Activated cells exposed to pulsed EMF's can produce up to threefold increase in interleukin.

Results of studies of higher versus lower strength EMFs are mixed. There appear to be EMF intensity windows. Frequency windows appear to be quite narrow for bone cell cultures. For lymphocytes the frequency windows seem to be broader. Even 5-100 hertz, 0.15 MilliTesla signals modulate calcium flux in lymphocytes. However, 50 Hz EMFs had the greatest effect. Frequency fields, combined with parallel static magnetic fields have also been found to have action.

It is important to know that EMF's affect all lymphocytes, including B cells and T cells and other human lymphoid cell lines.

Summary

EMF therapy specifically targets cells that are metastable as a consequence of disease or other ongoing therapies. Thus, EMFs are probably an important cellular therapy in many diseases, including cancer, psoriasis, wound healing, and bacterial infections because of their effects on inflammation. It is important that normal homeostatically stable cells remain unaffected by EMFs so that the effects of other treatments can be potentiated without proportional increases in side effects. In chronic inflammatory diseases, cells are characteristically maintained in metastable states, as a consequence of cytokine secretions and other stressors associated with the disease. In these cases, EMFs could work as a stand-alone anti-inflammatory therapy. Even weak, low-frequency EMFs induce apoptosis in activated T cells, thereby reducing inflammation.