From Mini-Invasive to Non-Invasive Treatment Using Monopolar Radiofrequency: The Next Orthopaedic Frontier

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KEYWORDS

• Radiofrequency • Tendinopathy • Sprains
• Non-invasive • Inflammation • Anti-nociceptive

RADIOFREQUENCY

Radiofrequency (RF) was first introduced to the field of neurology in the nineteenth century.[1] RF energy is currently the most commonly used energy source to generate therapeutic levels of heat. Supraphysiologic temperature has been used medically to produce structural and biologic responses in tissue. In orthopaedics, the main target of supraphysiologic temperatures is collagen-based connective tissue. Although most commonly used as an ablative fine focus (electrocautery) tool, it is possible to use radiofrequency in a nonablative form for controlled heating of target tissues for structural and biologic therapeutic effects.

STRUCTURAL EFFECTS

Collagen Connective Tissue

Heating collagen with RF energy is time-dependent. At temperatures of 60°C, the long sequences of the hydrogen bonds that stabilize the triple helix of collagen molecules[2] break, which collapses the molecule and causes soft connective tissue to shrink. The linear collagen fibers of the tissue are coagulated, as appreciated on light microscopy and with polarized light. The process has been used to shrink and tighten joint capsule tissue and ligaments in a predictable fashion (**Fig. 1**).

Nociceptors

The actual symptoms of tendinopathy may arise from biochemical agents that irritate nociceptors.[3] Takahashi and colleagues[4] studied the antinociceptive effects of RF: bipolar RF induced acute degeneration and ablation of sensory nerve fibers. There is also a delayed regrowth of nociceptive afferent fibers into irradiated tissues. This afferent denervation produces an antinociceptive effect in treated tissues and forms the basis for the clinical use of RF in pain management.

BIOLOGIC EFFECTS OF RADIOFREQUENCY

At temperatures above 60°C, there is a predictable influx of macrophages and other inflammatory cells. These cells produce heat shock proteins. Supraphysiologic temperatures induce an overexpression of heat shock proteins.[5] These proteins protect cells in vivo and in vitro against a variety of insults.[6–9] Wound healing responses (WHRs) of surgical and thermal injuries follow a predictable cascade of inflammatory events. Using RF to irradiate tissues to heat them to supraphysiologic temperatures induces a predictable inflammatory response similar in time and nature to the WHR.

EFFECT ON TENDONS AND LIGAMENTS

The histopathologic lesion of tendinopathy is a failed WHR. In 1979, Nirschl described the

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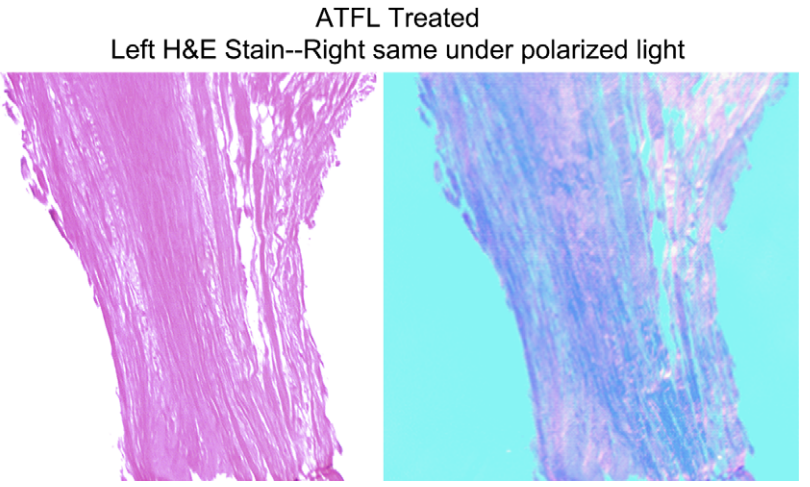

Fig. 1. Section of mcRF treated human ATFL.

histopathologic findings of 88 elbows treated operatively for tennis elbow and reported immature fibroblastic and vascular infiltration[10] known as myxoid degeneration, "the result of failed tendon healing."[11] Cellular hallmarks of inflammation were notably absent. Common problems of tendons and ligaments (eg, tennis elbow, golfer's elbow, and patellar and Achilles tendinopathy) are noninflammatory conditions. Given the lack of inflammation, anti-inflammatory therapeutic options, including nonsteroidal anti-inflammatory drugs and corticosteroids, are contraindicated.[12] Preclinical and clinical studies have demonstrated the benefit of inducing an appropriate WHR for the management of tendinopathy.[13–18]

Ligament injuries are common and debilitating musculoskeletal injuries. Conservative management protocols have remained essentially unchanged for decades. Despite ice, compression, elevation, and splinting of acute ligament injuries, still some 40% of acute ankle sprains, for example, remain functionally unstable and susceptible to reinjury. Treatment of injured ligaments with radiofrequency physically shortens the elongated structural fibers, which improves stability of the joints they span.

EFFECT ON MUSCLE

The effect of RF on muscle is mediated by the impact on myogenic precursor cells and is emerging as an effective treatment for some blunt trauma muscle injuries.[19] RF stimulates the production of myogenic precursor cells for muscle tissue repair and replacement, simultaneously inducing the inflammatory cascade necessary to remove hemorrhage remnants and produce an antinociceptive response.

Noninvasive Monopolar Capacitive-coupled Radiofrequency

Noninvasive monopolar capacitive-coupled RF (mcRF) is made possible by the production of a reverse thermal gradient and capacitive coupling the energy into a volume of tissue (**Fig. 2**).

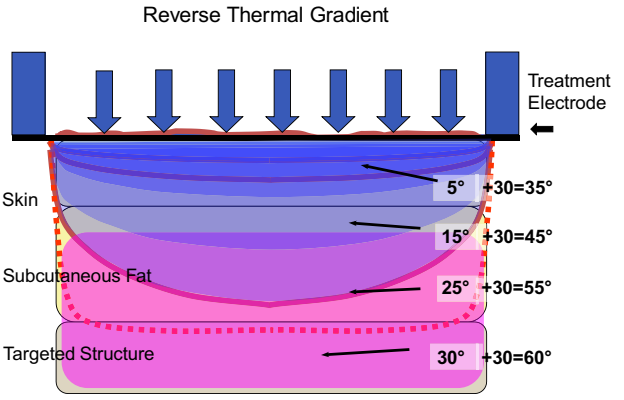

Fig. 2. Conceptual illustration of Reverse Thermal Gradient protecting superficial structures from mcRF heat.