The Effects of Radiofrequency Energy Devices on Achilles Tendinosis: A Case Report and Literature Review

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Thermal surgical devices have broadened their scope from general surgery to orthopedic and podiatric surgery. Radiofrequency technology has been utilized in ligamentous, fascial, and tendinous applications without supportive basic science research and long term clinical studies. The purpose of the current study is to present a case of Achilles tendinosis exacerbated by radiofrequency energy. The included discussion and literature review heightens the readers’ understanding of the mechanisms by which radiofrequency energy works and the associated histological and biomechanical sequela.

Key words: Microdebridement, Thermal, Ablation, Microtenotomy, Electrosurgery

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With the advent of thermal energy as a means to stimulate soft tissue contraction and neovascularization, there has been considerable interest in its use to treat a variety of musculoskeletal problems. Initially applied with laser technology, thermal devices have evolved to utilize radiofrequency energy. The use of radiofrequency thermal devices in capsular instability of the shoulder has been greeted with transient success. Proponents have mentioned ease of use, a minimally invasive nature, and decreased post-operative immobilization making the radiofrequency technique a far-sighted attractive alternative to conventional open procedures.

Numerous in vivo and in vitro studies have investigated the biology and biomechanics of thermally modified tissues without consensus towards efficacy.

Regardless, the scope of thermal energy devices has expanded to ligamentous, fascial, and tendinous pathologies, though their use has not yet been substantiated with long term studies. The purpose of this report is to present a case of Achilles tendinosis exacerbated by radiofrequency energy treatments.

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Case Report

A 69 year-old female who was complaining of insertional Achilles tendon pain underwent radiofrequency ablation of the Achilles tendon with a bipolar single electrode radiofrequency-based probe (Topaz® Microdebrider; ArthroCare, Austin, TX) at an outside facility. The patient related that her pain had markedly increased since the procedure. Three months prior to the surgery, she experienced pain with moderate ambulation; after the surgery, her pain significantly exacerbated to the level of excruciating pain with each step. Surgical reports from the outside facility reported the radiofrequency treatment was applied to the distal 10cm of the Achilles tendon.

Physical exam denoted over 40 pinpoint areas of hyperpigmentation over the Achilles tendon associated with known application of the bipolar single electrode radiofrequency-based probe. (Fig. 1) An exquisitely tender bulbous mass visible clinically and on magnetic resonance imaging (MRI) was present at Achilles tendon insertion. (Fig. 2)

Pain was exacerbated with slight ankle dorsiflexion. Biomechanically, the patient presented with an equinus deformity during knee flexion and extension. MRI indicated severe tendinosis of the distal 6.6 cm leading to the calcaneal attachment with abnormal anterior convexity. MRI demonstrated partial tears throughout the Achilles tendon and calcaneal marrow edema with concomitant erosive changes. (Fig. 3) A discussion to including debridement and repair with cadaveric Achilles graft supplementation was planned and all consents for the procedure were signed by the patient.
Surgical Findings

A 10cm posterior longitudinal incision was made medial to the Achilles tendon and over the inferior calcaneus, the incision curved in lateral direction parallel to relaxed skin tension lines. The skin and subcutaneous tissue were incised and a fusiform mass appeared to occupy several centimeters of the distal and insertional Achilles tendon. (Fig. 4)

The paratenon was scant and atrophic with multiple adhesions to the underlying Achilles tendon and the circumferential fibrotic exuberance at the insertion. The Achilles tendon appeared to have a yellow tinge and fibers of no distinct orientation. The myxoid degenerated tendon encompassing over 70% of its stock was resected and sent for pathological examination. (Fig. 5) Reports later confirmed the presence of multiple foci of collagen degeneration, heavy mucoid matrix, areas of entire necrosis with apoptosis within the specimens. Multiple insertional calcific masses were resected from within the tendon. (Fig. 6) The circumferential fat was removed from the retrocalcaneal bursa displaying chronic inflammation on MRI.

Throughout resection, the medial and lateral subcutaneous attachments running along side of the Achilles tendon and the calcaneal insertional area were preserved. After the intratendinous calcific deposits and the superior edge of the calcaneal enthesiophytes were resected, a cadaveric Achilles tendon was prepared for incorporation.
Figure 5 Degenerated tendon sent for histopathologic evaluation reported to have areas of total necrosis.

Figure 6 Calcific masses seeded within inflammatory sites in insertional Achilles tendon.

Figure 7 Preservation of medial and lateral soft tissue attachments to Achilles tendon and application of corkscrew anchor within central calcaneus.

A corkscrew anchor was placed in the posterior central aspect of the calcaneus deep to the foreseeable cadaveric Achilles tendon insertion. (Fig. 7) With #2 nonabsorbable polyblend suture, cadaveric Achilles tendon was sutured between the medial and lateral remnant tendon with the graft held in tension and the ankle in slight plantarflexion.
Figure 8 Krackow stitch anchoring cadaveric Achilles tendon graft to remnant medial and lateral Achilles tendon borders sown in slight plantarflexion. Further reinforcement with bone anchors and to circumferential soft tissue increases stability of construct. Release of tourniquet depicts ability of adequately vascularized cadaveric graft.

Using the #2 Force Fiber® (Tornier, Edina, MN) from the 5mm corkscrew Insite™ anchor (Tornier, Edina, MN), a Krackow stitch was applied to the inferior 3cm of the medial and lateral aspects of the Achilles tendon graft.

Two medial strands were anchored into a secondary medial Piton® anchor (Tornier, Edina, MN) and two lateral strands were anchored into a tertiary lateral Piton® anchor. (Fig. 8) The Piton® anchors were approximately 2cm apart and 1cm inferior and equidistant from the central corkscrew anchor to increase bone-tendon interface. Care was taken to ensure ankle resting position remained in slight plantarflexion. (Fig. 9)

Figure 9 Lateral view denoting amount of tension present in resting Achilles tendon.

After tendon and circumferential soft tissue attachments were reinforced, the surgical site was flushed and closed in the usual technique. A posterior splint was applied. Postoperative care consisted being non-weightbearing for 8 weeks with a gradual transition from range of motion exercises to weightbearing. Patient continues to demonstrate improved pain and ease with ambulation.

Discussion

The initial surgical use of thermal delivery systems involved cutting and coagulating tissue. The concept of tissue welding was introduced with the ability of heat to divide and seal with interdigitations. Thermal welding has long-standing implementation in transmyocardial revascularization, gastric bypass, hemorrhoidectomy, and cholelithiasis among other visceral procedures.\(^\text{1-13}\) In the paucity of orthopedic and podiatric literature, thermal devices have been applied in chondromalacia, patellar tendinosis, rotator cuff tears, lateral ankle instability, plantar fasciosis, and Achilles tendinopathy.\(^\text{1,2,9,14-24}\) The mechanism of radiofrequency electrosurgery is similar to a surgical cautery, which can coagulate at high voltages or cut and ablate at low voltages.\(^\text{46}\)
Macroscopically, the active electrode vaporizes water in the underlying soft tissue dissipating the density and creating a “shrinking” effect. As heat disorients the linear connective tissue pattern and produces swelling across the transverse axis, the modification in tissue structure is visualized as additional “shrinking”.

More recently, radiofrequency devices have been used in thermal delivery systems to provide the beneficial effects of heat while mitigating detrimental thermal penetration. Radiofrequency energy is a form of electromagnetic energy that operates by producing localized heat in an ionized field. The bipolar single electrode radiofrequency-based probe (Topaz® MicroDebrider; ArthroCare, Austin, TX) is advertised to work through “non-thermal” means though heat is an inherent part of the shrinkage mechanism. In radiofrequency, heat is generated extrinsically through electrolyte oscillation in an ionized field rather than intrinsically from the probe itself. Any ultrastructural alteration of collagen architecture utilizes heat as the predominant mechanism. In addition, the radiofrequency-based probe allegedly accomplishes volumetric reduction and surface contouring through debridement although this claim has not been substantiated.

The term “debridement” may be a misrepresentation of the biologic remodeling process, seeing as there is no removal of devitalized tissue. However, radiofrequency energy can smooth and contour circumferential tissue irregularities. A review of several studies evaluating the effect of radiofrequency on articular cartilage demonstrated smoothing of cartilaginous fibrillations with no evidence of debridement suggesting that radiofrequency energy “anneals” rather than “debrides”.

Arthroscopic examination during radiofrequency treatments demonstrate melting of the fine fronds protruding from the articular surface although deeper clefts remained. With longer treatments (15 seconds) the color of cartilage changed to light gray, then to light yellow, and eventually to brown. Color change is no doubt an indication of chondrocyte viability. Thermally induced volumetric reduction and surface contouring through radiofrequency energy are well-documented phenomenons though the molecular mechanism still require elucidation.

The architectural denaturing of collagen molecule is theorized to cause shrinkage and subsequent fibroplasia, neovascularization, and fibrovascular formation. However, in vivo histologic studies have found the contrary. Similar to the pathology report presented with the present case report, post-thermal tissue analysis demonstrates inflammatory cell infiltration, vascular stagnation, and necrosis of fibroblasts, smooth muscle, synovial cells, and endothelial cells. Repeat histological examinations report persistent inflammation and reactivity several months into the postoperative period. MRIs show periarticular swelling with effusion, extensive abnormal signal penetrating the subchondral marrow, and development of subcortical cysts post-radiofrequency treatment similar to the findings of the current case report.

Thermal injuries, in particular, are associated with a high degree of cell death and matrix alteration. Consequently, the inflammatory response generated in response to thermal injury is markedly protracted compared to traumatic insults. Thus a prolonged post-operative period is expected from the heat generated in radiofrequency treatments. Compounding the effect of heat, tendons, ligaments, and other tissues of a denser, less aqueous composition harbor heat for longer periods of time. Cool saline irrigation is applied to mitigate the thermal effects. However, the ablated tissue acts as a heat sink resulting in cellular death and necrosis. In the thermal algorithm utilized by radiofrequency, a temperature of at least 65°C is required to cause shrinkage despite the fact that any temperature over 45°C is lethal to most cells. Optimal shrinkage is noted to occur in the range of 60°C to 80°C. Consequently, a significant portion of visibly shrunkened tissue is necrotic. Focal heat generated by radiofrequency produces necrosis, fibrosis, and adhesions and clinically results in decreased structural integrity as seen in the current study.

Deformation of tissue under constant loads or “creep” is a primary mechanism of laxity after thermal reconstructive surgery. Mechanical testing post-thermal treatment verifies weakening of the intrinsic structural properties of the tissue itself.
Ligamentous structures were nearly normal initially and became attenuated in the following weeks.\textsuperscript{23,28,30,46,47} Prior to the thermal insult, initially damaged tissues including scars, are noted to creep more than intact noninjured ligaments.\textsuperscript{48} Radiofrequency treatments themselves are noted to compound the biomechanically inferior results.\textsuperscript{46} Studies have suggested a minimum of twelve weeks for the thermally modified tissue to commence recovery of biomechanical properties.\textsuperscript{28,49} However, collagen healing and maturation takes three to four months.\textsuperscript{6} With early rehabilitation regimens, collagen tissue is associated with thinness, elongation, weakness, and attenuation.\textsuperscript{3,21,28} Capsular repairs have resulted in multidirectional or stretch-type instability.\textsuperscript{7,50} Consequently radiofrequency “tightening” actually weakens the anisotropic capsular and ligamentous structures, sustaining loads from multiple directions.\textsuperscript{17,28,40,51} Heat-applied tendons demonstrate a significant one-third decrease in load-to-failure compared to controls.\textsuperscript{51} These poor biomechanical results associated with thermal procedures often require revisional surgery which is noted to be more difficult secondary to poor tissue quality and heavy scarring.\textsuperscript{6} The clinical loss of stiffness and inherent stability appear to be concomitant with radiofrequency-generated surgery.\textsuperscript{28,30}

Histological evidence and biomechanical studies antagonize anecdotal speculation of neovascularization and increased structural strength. Consequently, thermal procedures are associated with a higher percentage of failures than conventional capsular and ligamentous stabilization procedures.\textsuperscript{2,6,8,52} Furthermore, studies maintaining a nine month to five year follow-up period reveal a substantial 37\textendash;47\% failure rate involving recurrent joint instability, chondrolysis, capsular thinning, heavy scarring, and tissue necrosis.\textsuperscript{2,6,9,17,19,20,22,45,52,56} These among other published complications have subdued the initial wave of enthusiasm for surgical thermal devices.\textsuperscript{57} The findings of the present report support previously published complications in other relevant sites and structures. Nonetheless, these findings should be interpreted in light of several limitations.

Due to the single patient case report, it may not be possible to fully extrapolate these findings to all patients who endure tendon surgery utilizing radiofrequency technology. Also, the degree of pre-existing pathology in the current study cannot be determined. However, according to patient history and the severe abnormality visualized during surgery, on MRI, and in histopathologic analysis, this patient’s Achilles tendon pathology was markedly and acutely exacerbated by the radiofrequency application.

**Conclusion**

The exact mechanism of collagen destruction resulting in thermal shrinkage is less than poorly understood. Furthermore, no studies have specified the exact technique, amount of energy, threshold for coagulation versus ablation, or type of tissue for effectual coagulation.\textsuperscript{2} Indications and results have been anecdotal with capsular instability, chondronecrosis, tendinopathy, ligamentous laxity, and avascular necrosis as major documented complications.\textsuperscript{6,10,21,28,37,41,42} The clinicians’ focus of literature reviews should be directed towards the additional information presented with each study and how it plays into the risk-benefit ratio of radiofrequency generated thermal surgery. These procedures are increasing in usage and becoming an adjunctive or mainstay surgical technique without proper supportive research. A true understanding of the clinical implications of using radiofrequency necessitates more basic science and clinical studies. With its future in ligamentous, fascial, and tendinous pathology in question, further evaluation is necessary to establish safety and efficacy of radiofrequency in orthopedic and podiatric surgery.

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