Management of Tendinopathy

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Overuse disorders of tendons, or tendinopathies, present a challenge to sports physicians, surgeons, and other health care professionals dealing with athletes. The Achilles, patellar, and supraspinatus tendons are particularly vulnerable to injury and often difficult to manage successfully. Inflammation was believed central to the pathologic process, but histopathologic evidence has confirmed the failed healing response nature of these conditions. Excessive or inappropriate loading of the musculotendinous unit is believed to be central to the disease process, although the exact mechanism by which this occurs remains uncertain. Additionally, the location of the lesion (for example, the midtendon or osteotendinous junction) has become increasingly recognized as influencing both the pathologic process and subsequent management.

The mechanical, vascular, neural, and other theories that seek to explain the pathologic process are explored in this article. Recent developments in the nonoperative management of chronic tendon disorders are reviewed, as is the rationale for surgical intervention. Recent surgical advances, including minimally invasive tendon surgery, are reviewed. Potential future management strategies, such as stem cell therapy, growth factor treatment, and gene transfer, are also discussed.

Keywords: tendon; tendinopathy; management

Overuse tendon injuries are a major problem in sports and occupational medicine. Up to 50% of all sports injuries are due to overuse.[71] Most major tendons, such as the Achilles, patellar, rotator cuff, and forearm extensor tendons, among others, are vulnerable to overuse. This can result in pathologic change in the tendon (tendinopathy).[154] For example, the lifetime prevalence of Achilles tendinopathy in runners has been estimated at 11%.[75]

We advocate the use of the term tendinopathy as a generic descriptor of the clinical conditions (both pain and pathologic changes) in and around tendons arising from overuse.[89,109] The histologic descriptions "tendinosis" (a degenerative pathologic condition with a lack of inflammatory change) and "tendinitis" (implying an inflammatory process) should only be used after histopathologic confirmation.[59]

Histologic studies of surgical specimens in patients with established tendinopathy consistently show either absent or minimal inflammation.[9,17,59,69,131] They generally also show hypercellularity, a loss of the tightly bundled collagen appearance,[150,153] an increase in proteoglycan content,[87] and commonly neovascularization.[64,106,141] This has been termed a "failed healing response" (Figure 1). Although only 2 studies actually report histology findings in early disease,[86,106] evidence from animal models of induced tendinopathy does not support an inflammatory process in all but the most acute of tendon-loading protocols (eg, bouts of 6 hours of extreme muscle contractions in anesthetized animals).[11,19,123,171,199] Inflammation, therefore, may play a role only in the initiation, but not the propagation and progression, of the disease process.

The main body of the tendon has historically been the focus of tendon research. However, the enthesis (tendon insertion or osteotendinous junction) is increasingly recognized as the site of pathologic changes in many common athletic tendon injuries.[22,23] Common injury sites include the Achilles, patellar, rotator cuff, forearm extensor, and the thigh adductor tendons. Histologic changes are similar to those seen in the main body of a tendon and show a lack of an inflammatory infiltrate.[23,114,162]

CAUSES OF TENDINOPATHY

Tendons may be broadly divided into 2 groups: those that experience low strain and those that undergo high strain (eg, the Achilles tendon). High strain occurs when the tendon functions as an energy store, such as during

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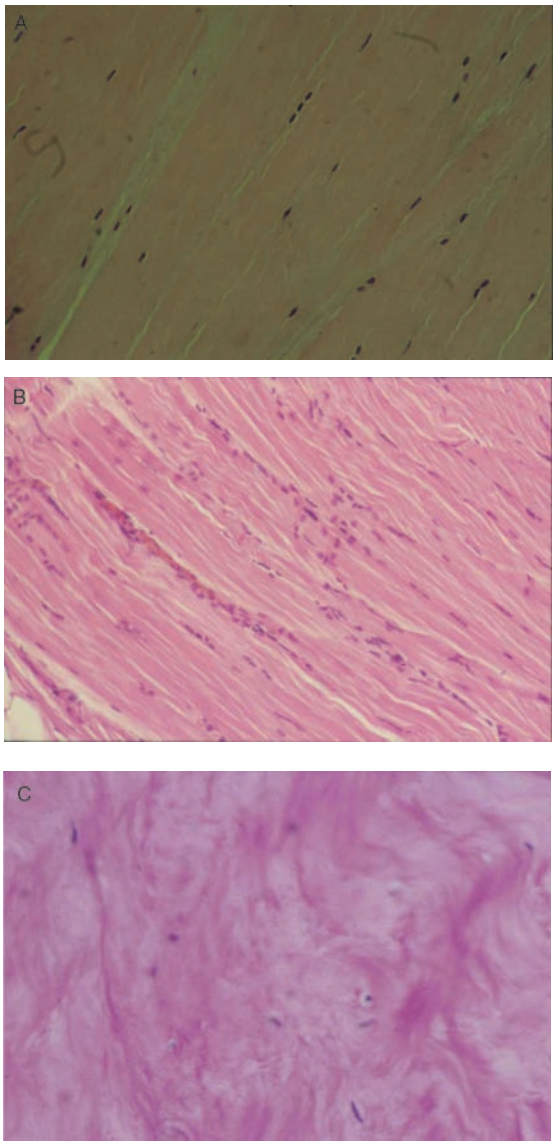

Figure 1. Histopathologic changes seen in tendinopathy demonstrating a lack of an inflammatory response. A, normal tendon with scattered elongated cells. B, slightly pathologic tendinous tissue with islands of high cellularity and initial disorganization. C, highly degenerated tendon with some chondroid cells; there is a distinct lack of inflammatory infiltrate. Reproduced with kind permission of Springer Science and Business Media from Benazzo F, Mosconi M, Maffulli N. Hindfoot tendinopathies in athletes. In: Maffulli N, Renström P, Leadbetter WB, eds. *Tendon Injuries: Basic Science and Clinical Medicine*. London: Springer; 2005:178-186.

locomotion. Indeed, tendons such as the Achilles may have physiologic strain values in the young of 8% to 10%.[100,115,128,132,167] Repeated loading of a musculotendinous unit is regarded to be of fundamental importance to the development of overuse tendon injury, although the exact mechanism by which this happens is still unclear. Certainly choice of sport, and therefore load, has a profound effect on location of tendon injuries.

In the mechanical theory of tendon injury, "overload" of the tendon tissue is believed to be central to the pathologic process. Overload may result in incremental weakening and eventual failure of tendon tissue, as the tendon may be unable to respond adequately to the load over time. Only a relatively small tensile force is required to straighten out the resting crimp. As an increasing load is applied, the load is directly taken up by the collagen fibrils and the tendon enters a zone of linear relationship between load and strain.[45] Toward the higher end of the physiologic range, microscopic failure may occur within the tendon, especially with repeated and/or prolonged stressing (Figure 2). This repetitive microtrauma can eventually lead to matrix and cell changes, altered mechanical properties, and possibly symptoms.[115,132]

Tendon microtrauma can also result from a nonuniform stress occurring within a tendon, producing abnormal loading concentrations and localized fiber degeneration.[85] It is therefore possible that, during a series of repetitive loading cycles, a single abnormal loading cycle could produce strains sufficient to induce isolated (and cumulative) fibril damage but without a history of a specific "injury." The mechanical theory explains how chronic repetitive damage to tendons could accumulate over time. The greater incidence of tendinopathy with increasing age and in the athletically active is consistent with this theory. There is empirical evidence that repeated load associated with athletic activity leads to tendinopathy. In a study of elite soccer players, asymptomatic pathologic changes were common in both the Achilles and patellar tendons,[55] suggesting a link with functional overload. In addition, a greater number of hours per week resulted in a higher prevalence of patellar tendinopathy.[42,43] Also, the number of training sessions per week has also been associated with patellar tendinopathy.[51]

Overload not only affects the matrix components (collagen and proteoglycans) but also elicits an essential response in tenocytes that appears designed to adapt the matrix to the increased load. Matrix load is transmitted into the cell and alters protein and enzyme production. Tensile load itself can actually cause in situ cell nucleus deformation.[12] Mechanical loading of human tendon fibroblasts increases production of both prostaglandin E2[8,190] and leukotriene B4,[97] and these mediators may contribute to the tendon changes identified in tendinopathy.[89]

Furthermore, other forms of load such as compression can affect the tendon. Neer[134] proposed "impingement" of the supraspinatus tendon underneath the anterior margin of the acromion as central to the disease process. The impingement theory was subsequently refined and linked to acromial shape,[136] although the causative effect of abnormal acromial morphologic characteristics has subsequently been disputed.[189,201] An impingement theory has also been suggested in patellar tendinopathy, where the inferior pole of the patella compresses the patellar tendon during knee flexion[76]; however this, too, has been questioned.[166] Compression may be particularly important in lesions of the enthesis.[23] Biomechanical factors may also be important,

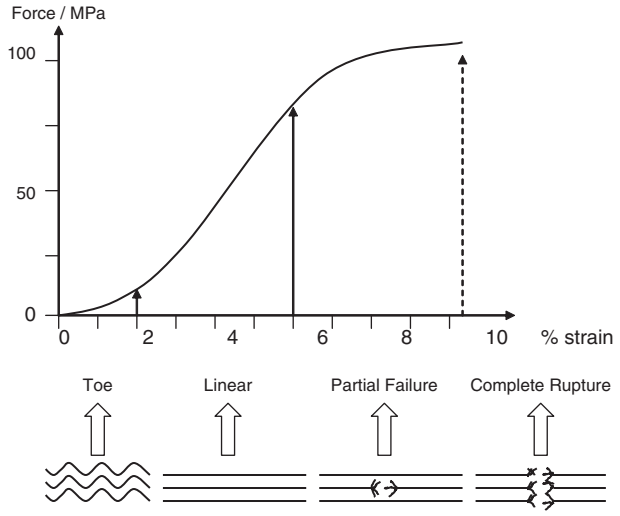

Figure 2. Stress-strain relationship for progressive loading of a tendon showing 3 distinct regions (toe, linear, and partial failure) prior to complete rupture. Approximate stress forces (MPa) and strain values (% strain) are shown. Reproduced with permission from Rees JD, Wilson AM, Wolman RL. Current concepts in the management of tendon disorders. *Rheumatology.* 2006;45:508-521.

and there is evidence that strains near a tendon insertion are in fact nonuniform.[114]

The mechanical theory can be criticized on the basis that in many tissues, such as muscle and also bone in the growing skeleton, physiologic stresses lead to strengthening of the tissue itself. Why this does not happen to tendons is unclear.

The vascular theory of tendinopathy suggests that tendons generally have a poor blood supply,[50] and that certain tendons, such as the supraspinatus,[102] the Achilles,[1] and the tibialis posterior,[56] are particularly vulnerable to vascular compromise in specific areas. If these tendons with a poor blood supply are subjected to heavy training or functional overload, then tendon injury could occur. Using the Achilles tendon as an example, a hypovascular region in the midtendon area, roughly between 2 cm and 6 cm proximal to the calcaneal insertion, has been described.[37] However, more recent physiologic examination of Achilles blood flow suggests that, in reality, blood supply is uniform along the whole tendon.[16,18] Vascular insufficiency may be more important in lesions of the enthesis. Generally, the tendon "flares out" at the enthesis to improve load distribution. Fibrocartilagenous entheses (most common in tendons susceptible to tendinopathy)[22,23] are relatively avascular, and this can contribute to a poor healing response.

On balance, however, the vascular insufficiency theory remains controversial. Åström and Rausing[17] suggested that there was uniform blood flow in the Achilles tendon with the exception of its distal insertion, and other work shows no evidence of hypovascularity in the Achilles tendon.[92] An alternative explanation is that perhaps exercise-induced localized hyperthermia may be detrimental to tendon cell survival, rather than vascular compromise.[25,193]

There is increasing interest in the role that the nervous system may play in the tendinopathy process. Neurally mediated mast cell degranulation could release mediators such as substance P and calcitonin gene-related peptide.[65] Certainly substance P, a proinflammatory mediator,[65] is increased in rotator cuff tendinopathy. The neurotransmitter glutamate has been identified in greater amounts in the ultradialysate in Achilles tendinopathy compared with normal tendons.[3] However, the neural theory does not explain why morphologically pathologic tendons are not always painful.[68] Indeed, this remains one of the most intriguing questions in tendinopathy research.

Although the effect of overload on tendons can be catabolic, not loading a tendon is also detrimental, and "underuse" of tendons may be implicated in the cause of tendinopathy.[114] Using a rat-tail tendon model, Arnoczky et al[12,13] studied the in vitro mechanobiologic response of tenocytes in situ to various tensile-loading regimens. These studies have raised the hypothesis that the etiopathogenic stimulus for the degenerative cascade is the catabolic response of tendon cells to mechanobiologic understimulation.[93] Further research is needed to determine whether and how these mechanobiologic mechanisms are really involved in the etiopathogenesis of clinical tendinopathy.

FACTORS THAT INFLUENCE THE DEVELOPMENT OF TENDINOPATHY

Some individuals are more susceptible to developing tendinopathy than others who have similar levels of physical activity. It is possible that an interaction between various intrinsic and extrinsic factors affecting tendon health increases the likelihood of that individual developing tendinopathy.[116]

With the intrinsic-extrinsic factors model of injury, intrinsic factors leave a person predisposed to injury. One of the strongest intrinsic factors may be an individual's genetic characteristics. The ABO blood group and tendon molecular structure were suggested as possible factors predisposing an individual to tendinopathy. In 1989, Jozsa et al[79] reported an increased frequency of blood group O tendon rupture at multiple sites in a Hungarian population. Subsequent studies were unable to confirm this association.[96,110] More recently, researchers have investigated target genes close to the ABO gene on the long arm of chromosome 9. Both the alpha 1 type V collagen (COL5A1) gene, which encodes for a structural collagen in tendons, and the guanine-thymine dinucleotide repeat polymorphism within the tenascin-C gene, have been associated with chronic Achilles tendinopathy.[116,129,130] This genetic link could also explain the increased risk of contralateral rupture of the Achilles tendon in subjects with a previous rupture.[14]

Gender is a key genetic expression, and women seem to have less tendinopathy than men.[42,43] Women are also prone to Achilles tendon rupture (endstage tendinopathy)

after the onset of menopause,[112] suggesting that estrogen may protect tendons. Recently, this association was examined in women using hormone replacement therapy and controls; the Achilles tendon health of women on hormone replacement therapy was better than the controls.[41]

Age is another factor that appears to predispose to tendon lesions, and certainly the prevalence of tendinopathy seems to increase with age. However, it is important to discriminate between increasing age leading to (causing) intratendinous changes and increasing age predisposing a person to tendinopathy. There is good evidence that tendons do not degenerate with age as such,[108] but a reduction in proteoglycans and an increase in cross-links as a tendon ages make tendons stiffer and less capable of tolerating load. Thus, older people exposed to only moderate tendon loads should not necessarily have an increase in tendinopathy. Body composition has recently been linked to tendinopathy; a greater waist circumference has been shown to increase the prevalence of patellar tendinopathy.[119] In addition, other studies suggest that both upper limb and other lower limb tendinopathies increase when adipose tissue levels increase.[60]

Range of movement, specifically decreased ankle dorsiflexion, has also been implicated in the development of Achilles[84] and patellar tendinopathy.[118] Decreased ankle dorsiflexion increases the amount and rate of loading on both these tendons, adding further to evidence that overload is a critical factor in tendinopathy. Lack of flexibility has been associated with tendinopathy in the lower limb.[44,194] Again, flexibility may affect a tendon by changing its load, although the mechanism for the association has not been identified.[195] There is conflicting evidence for an association between strength and tendinopathy. Some studies report an association,[98,99] while others do not.[61] The different measures of strength and their relationship to function may be the reason for the differences in findings.

Other risk factors for tendinopathy have been identified, particularly for rupture of the Achilles tendon. These include the use of quinolone antibiotics[127] and corticosteroids.[53,183] Environmental factors reported to be associated with tendinopathy may also act through increasing the load on the tendon. For example, training on concrete floors increases the prevalence of patellar tendinopathy compared with training on a more forgiving surface.[117]

MANAGEMENT

The management of tendinopathy revolves around modulating tendon pain, as pain is the presenting and limiting factor for activity. Pain appears only moderately correlated with pathologic changes; only some tendinopathic tendons are painful[55] and some morphologically normal tendons are painful.[117]

The origin (or cause) of pain in the body of a tendon or at the enthesis is presently unknown. Some authors have suggested that the presence of neovascularization is fundamental to the pain process.[5,138,139,141] However, this theory does not explain why morphologically tendinopathic tendons, with neovascularization, are often painless. In a young athletic population, tendon symptoms are not necessarily related to neovascularization.[64]

Many tendon injuries are chronic and prone to recurrence of pain.[59] Compounding this problem has been a lack of agreement on management. [154] Prevention is better than cure; appropriate coaching, training, and attention to equipment should reduce the incidence of tendon injuries. However, when injury occurs, the starting point for management must be an analysis of why the injury arose, with identification of the relevant precipitating factors. Without this, there will always be the risk of reinjury.

Conservative Management

The mainstay of tendinopathy management remains conservative (nonoperative) treatment. Numerous management options have been tried, including, rest, exercise, training modification, splinting, taping, cryotherapy, electrotherapy, pharmaceutical agents such as nonsteroidal anti-inflammatory drugs (NSAIDs), and various peritendinous injections. Many of these interventions have not been studied in a controlled and prospective manner.[9]

Traditionally, rest was regarded as an effective treatment for tendinopathy. However, there has been a move toward early rehabilitation for tendinopathy in both operatively and nonoperatively managed tendon disorders.[81,175] In the acute stages of tendon pain, modification of risk factors such as training errors or biomechanical and flexibility issues are often advised, together with measures to reduce symptoms such as cryotherapy (often with physical compression). Cryotherapy seeks to reduce blood flow and swelling at the site of injury.[155,172] Indeed, the combination of compression and cryotherapy exerts effects at the microcirculatory level of the main body of the tendon, with decreased capillary blood flow, preserved deep tendon oxygen saturation, and facilitated venous capillary outflow. This may provide a mechanism for therapeutic benefit, although the analgesic effect of cryotherapy alone may explain its popularity.

Exercise is the most common intervention, and exercise with an eccentric bias is clearly superior to a general exercise program alone.[113] Heavy-loading eccentric exercises (EE) improve tendon pain in controlled trials in the short term[113,168] and might lead to normalized tendon structure.[140] Eccentric exercises involve active lengthening of the muscle-tendon unit (Figure 3). These exercises were pioneered nearly 30 years ago, although the initial studies did not include a control group and were not widely adopted.[175] Subsequently, EE were shown to be highly effective in midbody Achilles tendinopathy.[113] These EE programs require highly motivated patients who are willing to perform multiple repetitions, twice daily, 7 days a week for 12 weeks. Also, the exercises may often, at least initially, be painful. Questions remain, however, regarding EE. When used in nonathletic patients with Achilles tendinopathy, despite a high compliance rate, eccentric training produced good or excellent results in less than 60% of patients,[164] a rate of success markedly lower than reported in other

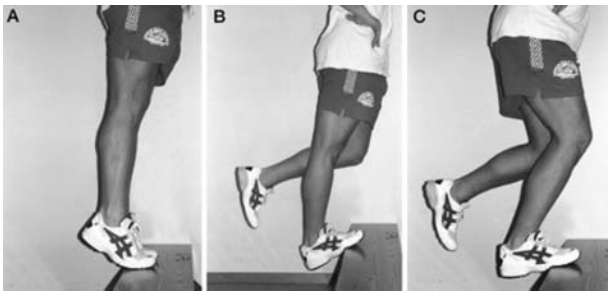

Figure 3. Eccentric loading of the right gastrocnemius muscle and Achilles tendon. From an upright body position and standing with all body weight on the forefoot and the ankle joint in plantar flexion lifted by the noninjured leg (A), the calf muscle is loaded eccentrically by having the patient lower the heel with the knee straight (B) and the knee bent (C). Three sets of 15 repetitions are performed twice per day, 7 days per week for 12 weeks. Image reproduced with permission from Alfredson H, Pietilä T, Jonsson P, Lorentzon R. Heavy-load eccentric calf muscle training for the treatment of chronic Achilles tendinosis. *Am J Sports Med.* 1998;26:360-366.

studies.[113,168] There is no clear idea why the treatment works and what the correct intensity, speed, load, and frequency are.

Despite this, EE has become the treatment of choice, particularly for midsubstance lesions of the Achilles tendon where there is the greatest degree of evidence for its effectiveness, and has probably been the greatest single advance in the management of this condition in the past 20 years.[7,113,140,168] Although EE are less effective for insertional Achilles lesions, a recent pilot study has shown increased effectiveness in insertional Achilles tendinopathy when EE are completed without moving beyond plantigrade.[77] Eccentric exercises are effective in patellar tendinopathy,[33] and their effectiveness is enhanced using a decline board.[152,196]

Some evidence exists for the benefit of EE in lateral humeral epicondyle pain,[125,179] although the evidence is weak and further assessment is required.[177] The technique of EE has been extended in a small uncontrolled pilot study of patients with "chronic painful impingement syndrome" in the shoulder. The initial results are promising,[78] but clearly there is a need for further studies in this area.

Stretching is often advocated in the management of tendon disorders. Stretching does lead to increased elongation capabilities of the muscle tendon unit.[48] Two types of stretching are commonly employed—static and ballistic.[195] There is no evidence to confirm the beneficial effect of either type of stretching in the management of tendinopathy.

Manual therapy techniques are commonly employed, the most common of these being soft tissue mobilization and deep-tissue friction massage (DTFM). A Cochrane review of DTFM in 2002[29] found only 2 studies of acceptable quality: one involved tendinopathy of the extensor carpi radialis brevis (lateral epicondylopathy); and the other, the iliotibial-band friction syndrome. Neither study showed a consistent benefit of DTFM over the control group, and both studies were underpowered. A more recent study of DTFM in the management of patellar tendinopathy showed that DTFM was less effective than EE in patellar tendinopathy, although that study was underpowered as well.[176]

Both therapeutic ultrasound and low-intensity laser (light amplification by stimulated emission of radiation) are used to treat tendon pain. Both treatments may result in local heating of tissue. There is, however, no in vivo evidence of benefit in controlled trials.[20,156,173,184,191]

Extracorporeal shock-wave therapy (ESWT) has shown benefits, particularly in insertional and calcific tendinopathy. Examples are insertional Achilles tendinopathy,[58] tendinopathy of the main body of the Achilles tendon,[161] plantar fasciopathy,[137,158] calcifying tendinopathy of the shoulder,[63,104,163,188] and lateral elbow pain.[31,160] However, not all studies of ESWT report positive results, and a recent review of the literature relating to chronic plantar fasciopathy concluded that EWST should only be considered after other more common and accepted treatments have failed.[159] When compared with EE,[161] ESWT showed comparable favorable outcomes for managing tendinopathy of the Achilles tendon at about 60%. An algorithm with a summary of a pragmatic approach to the management of tendinopathy is shown in Figure 4.

Pharmacologic Interventions

Despite the popularity of NSAIDs in the management of tendinopathy, there is surprisingly little quality evidence supporting this management option. A comprehensive review of 32 studies revealed only 9 prospective and placebo-controlled trials.[9] Five of these demonstrated an analgesic effect of NSAIDs, and this may explain their continued popularity. Tendon healing, however, was not studied in any of these trials. This is an important point, as the anti-inflammatory action of NSAIDs could potentially interfere with healing and reduce tendon tensile strength, causing deleterious effects to tendon healing.[116] Animal studies have produced conflicting results; some studies suggested increased tendon tensile strength,[36,54,187] while a primate study suggested a reduction in breaking point.[91] Recent experimental work on the rat patellar tendon showed that common anti-inflammatory drugs, with the exception of ibuprofen, had a detrimental effect on healing. The authors suggest that selective and nonselective cyclo-oxygenase (COX) inhibitors should be used judiciously in the acute period after injury or surgical repair of tendon injuries.[52]

The use of corticosteroid injections (CSI) is highly contentious. There is a lack of good quality research data to support the widespread use of these drugs. In humans, there are numerous case reports of tendon rupture after CSI.[53,90] Animal studies have suggested that local CSI may lead to a reduction in tendon strength,[82] but this finding is not universal.[126]

Corticosteroid injections for tennis elbow (lateral epicondylopathy) appear to be effective in the short term (2-6 weeks), but there is no long-term benefit when compared with a control group.[15,70,174] This short-term improvement may explain the popularity of CSI as a treatment. In some

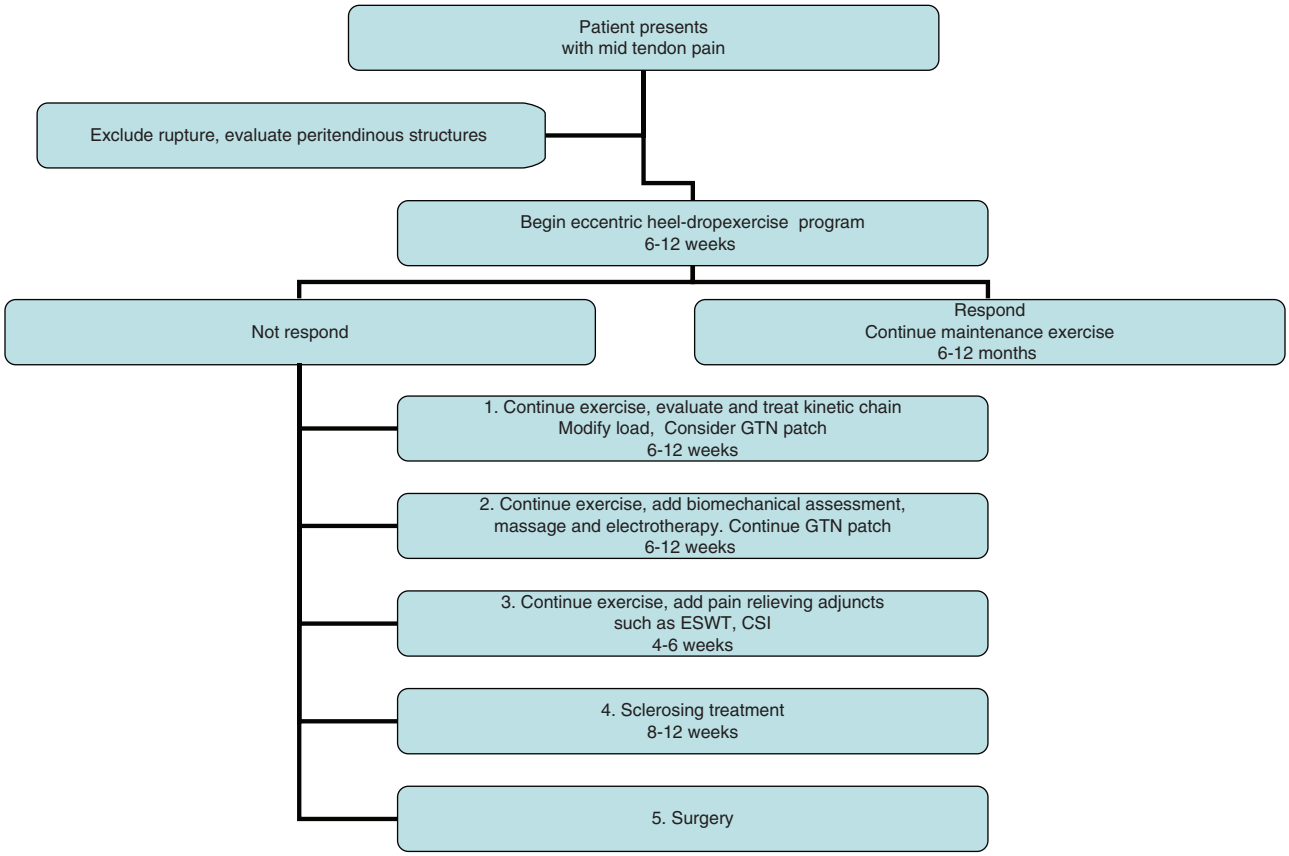

Figure 4. Suggested algorithm for managing patients with Achilles tendinopathy. GTN, glyceryl trinitrate; EWST, extracorporeal shock-wave therapy; CSI, corticosteroid injections. Reproduced with permission of the BMJ Publishing Group from Alfredson H, Cook J. A treatment algorithm for managing Achilles tendinopathy: new treatment options. *Br J Sports Med.* 2007;41:211-216.

studies, CSI were associated with a higher recurrence rate than a "wait and see" conservative approach over the longer term.[26,169]

Another common site for CSI is around the supraspinatus tendon. In a Cochrane review, 2 studies showed a small benefit of CSI for patients with rotator cuff disease at 4 weeks,[32] but the numbers treated were small.

Recently, the use of an injection of autologous red cells around a symptomatic tendon has gained popularity. Three small studies, on elbow pain[47,178] and patellar tendinopathy,[74] report benefit from this technique. Unfortunately, the quality of all 3 studies is relatively poor; for example, they did not include a control group of patients in whom no injection had been performed. This is particularly important in conditions such as medial epicondylopathy, known to improve spontaneously without any intervention.[26,169] Better quality studies in this area are required.

Aprotinin, a broad-spectrum protease inhibitor most commonly used in open-heart surgery, has been studied in 3 randomized trials in Achilles and patellar tendinopathy.[30,34,35] Aprotinin may inhibit enzymes that break down or degrade the ground substance tendons, hence possibly leading to a therapeutic result. Two studies suggested significant benefit from aprotinin.[34,35] However, a further underpowered study reported that aprotinin was no better than placebo.[30] Aprotinin has been temporarily withdrawn by its manufacturer after adverse data relating to cardiac surgery.

Three studies utilizing ultrasound-guided sclerosant injections, aimed at obliterating the neovascularization accompanying tendinopathy, have reported decreased pain and neovascularization.[4,101,139] Further pilot studies in insertional Achilles tendinopathy,[138] tennis elbow,[200] and shoulder impingement[2] also suggest beneficial results. However, only 2 studies included controls,[4,72] and all were underpowered. Also, they used generic, non–condition-specific assessment tools.

One recent small noncontrolled study has investigated the effect of ultrasound-guided electrocoagulation in noninsertional Achilles tendinopathy in 11 patients. This treatment was effective for symptom relief, but there was no effect on ultrasound-assessed neovascularization.[28]

The use of topical glyceryl trinitrate has been investigated in tendinopathy of the Achilles, supraspinatus, and forearm extensor tendons. These well-designed studies, which were double-blind placebo-controlled, showed improvement in the treatment arms compared with controls at 6 months.[145-147] It is suggested that nitric oxide enhances the extracellular matrix and improves the mechanical properties of injured tendons.[133] These results

remain to be repeated by other groups but are a potentially exciting development. Nitric oxide, a vasodilator, has the opposite effect of sclerosant injections.

In summary, there are a wide variety of conservative management options, both pharmacologic and nonpharmacologic, for the management of the tendinopathic tendon. However, the evidence base surrounding many of the treatments is still relatively poor. There is still a need for further well-designed controlled trials.

Operative Management of Tendinopathy

Despite the advances made in conservative management, overuse tendon disorders often remain difficult to manage successfully in the longer term, with up to 29% of Achilles tendinopathy patients requiring surgery.[143] The timing of surgical intervention can only be made on a case-by-case basis and is recommended only after exhausting conservative methods of management.[148]

There is accordingly great interest in the surgical management of tendinopathy. Unfortunately, the evidence base for the surgical management of tendinopathy is disappointing. This section reviews the rationale for surgery, the common techniques used, and the evidence base for surgical management. Much of the following discussion concentrates on the surgical management of tendinopathy of the Achilles and patellar tendon, as tendinopathy of these tendons is the most studied and most commonly encountered clinically. We stress that there are no level I evidence studies on the use of 1 technique over another in the surgical management of a given tendinopathy.

The goal of surgery is to promote wound repair by modulating the tendon cell–matrix environment.[95] The biologic objective of surgery is to modify vascularity and possibly stimulate the remaining viable cells to initiate cell-matrix response and healing.[16,21,38,39] Classically, the technical objective of surgery is to excise fibrotic adhesions, remove degenerated nodules, and make multiple longitudinal incisions in the tendon to detect and excise intratendinous lesions. More recently, however, less invasive procedures have been promoted that focus instead on the disruption of the neoneurovascularity associated with long-standing symptomatic tendinopathy.[6,105]

In the Achilles tendon, in the absence of frank tears, the traditional operation involves a longitudinal skin incision over the tendon paratenon incision and stripping, multiple longitudinal tenotomies, and excision of the area of degeneration if present.[142] Surgical management of Achilles tendinopathy can be broadly grouped in several categories: (1) open tenotomy with removal of abnormal tissue without stripping the paratenon; (2) open tenotomy with removal of abnormal tissue and stripping of the paratenon; (3) open tenotomy with longitudinal tenotomy and removal of abnormal tissue, with or without paratenon stripping; (4) percutaneous longitudinal tenotomy[94,135,165,182]; and (5) disruption of neovascularity and pathologic innervation.[159]

The reasons why multiple longitudinal tenotomies may be successful are unclear. The procedure triggers well-ordered neoangiogenesis in the tendon, with increased blood flow.[57] This may result in improved nutrition and a more favorable environment for healing. It also increases the overall dimensions of the tendon and may reduce stress with load.[95] Reconstruction procedures may be required if large lesions are excised.[103] Transfer of the tendon of peroneus brevis or the flexor hallucis longus tendon, when the tendinopathic process has required debulking of at least 50% of the main body of the Achilles tendon, has been reported.[46,149]

A variety of surgical methods for management of patellar tendinopathy have been described. These include drilling of the inferior pole of the patella, realignment,[24] excision of macroscopic degenerated areas,[83] repair of macroscopic defects,[124] longitudinal tenotomy,[151] percutaneous needling,[95] percutaneous longitudinal tenotomy,[181] and arthroscopic debridement.[40]

Outcome After Surgery

The outcome after surgery for tendinopathy is unpredictable. A review of 23 studies on the outcome of surgical treatment of patellar tendinopathy showed that the favorable outcome of surgery varied between 46% and 100%.[40] In the 3 studies that had more than 40 patients, the authors reported combined excellent and good results of 91%, 82%, and 80% in series of 78, 80, and 138 participants, respectively. In Achilles tendinopathy, several authors report excellent or good results in up to 85% of cases, most reporting surgical success rates over 70%.[180] However, this is not always observed in clinical practice.[107]

The scientific methodology behind published articles on the outcome of tendinopathy after surgery is poor, and the poorer the methodology, the higher the success rate.[40] Therefore, the long-term outcome of operative management of tendinopathy is still not fully clarified. From the handful of studies performed, it appears that in the Achilles tendon, the rate of complications is relatively high (in the region of 10%) and that the rate of success, measured as full return to preinjury level of sporting activities, is in the region of 85% in specialized centers.[144] Also, after surgery, nonathletic patients experience more prolonged recovery, more complications, and a greater risk of further surgery than athletic patients with recalcitrant Achilles tendinopathy.[111]

There is a lack of evidence regarding the operative management of insertional lesions. Operative management should therefore be offered to patients who have failed 3 to 6 months of conservative management.[88]

Arthroscopy is now among the tools orthopaedic surgeons use for the routine management of rotator cuff disorders.[27] "Tendoscopy" is used to approach, in a minimally invasive fashion, a variety of tendinopathic tendons, including tibialis anterior[122] and the Achilles tendon, where the surgical endoscopic technique includes peritenon release, debridement, and longitudinal tenotomies.[120,121] The technique has been extended to the patellar,[157] peroneal,[185] and tibialis posterior tendons,[186] and tennis elbow,[66] also with encouraging results. Some authors have used arthroscopic techniques for biceps tenodesis.[62] The advantages of endoscopic surgery include smaller scars, reduced wound pain, and a shorter inpatient stay.

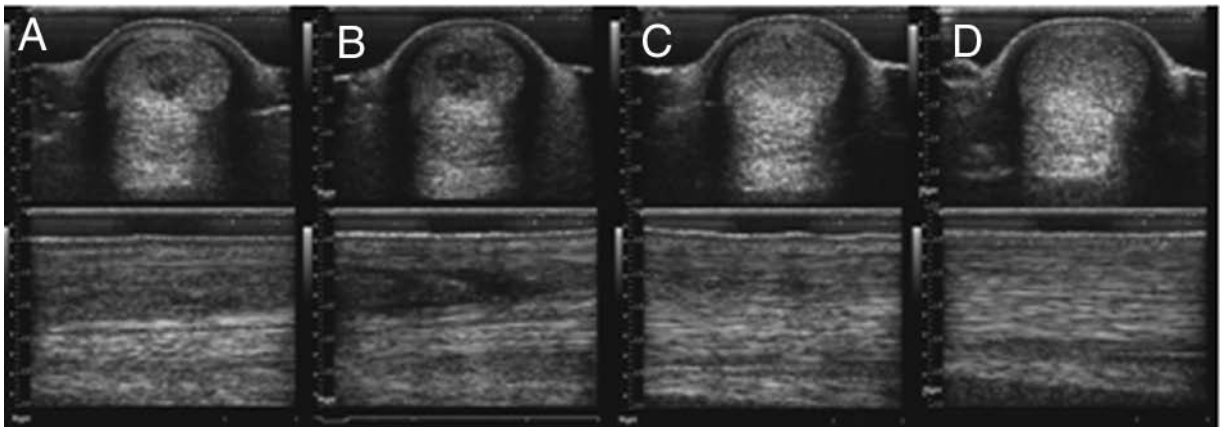

Figure 5. Sequential transverse (top row) and longitudinal (bottom row) ultrasonographs taken from a horse treated by the stem cell technique: A, at bone marrow (BM) aspiration; B, 1 month after aspiration, just before implantation; C, 1 month after implantation; and D, 3 months after implantation. Note the rapid infilling of the lesion within 1 month of implantation, whereas there was little change in the lesion in the preceding month. Reproduced with permission of the BMJ Publishing Group from Smith RKW, Webbon PM. Harnessing the stem cell for the treatment of tendon injuries: heralding a new dawn? *Br J Sports Med.* 2005;39:582-584.

To our knowledge, only 1 study has compared arthroscopic techniques with classic open techniques.[40] In that study, which focused on the patellar tendon, the arthroscopic approach was as successful as the traditional open procedure, and both procedures provided almost all patients with symptomatic benefit. However, only about half the patients who underwent either open or arthroscopic patellar tenotomy were able to compete at their former sporting level.

Most recently, in patellar tendinopathy, arthroscopic shaving of the area with neovessels and nerves on the dorsal side of the patellar tendon has been used to reduce the tendon pain and allow for the majority of patients to go back to full tendon-loading activity within 2 months after surgery.[192] This approach is not addressing the tendon lesion, but it disrupts the neovascularity associated with the tendinopathic lesion and, with it, the neonerves accompanying these neovessels.[10]

FUTURE DEVELOPMENTS

Complete regeneration of the tendon is never achieved after injury. The characteristic eventual injury response is fibroplasia, and the tissue replacing the defect remains hypercellular with thinner collagen fibrils. In tendinopathic and ruptured tendons, there is a reduction in the proportion of type I collagen and a significant increase in the amount of type III collagen.[108] This reduces the mechanical strength of the tendon, as type III collagen has a reduced number of cross-links compared to type I collagen.[80]

Consequently, there is much interest in trying to influence the healing process so that more physiologic and functional tendon tissue will be produced. One possible way of accomplishing this is by manipulating various growth factors. Growth factors and other cytokines play a key role in the embryonic differentiation and in the healing of tissues.[67] Growth factors stimulate cell proliferation and chemotaxis, and aid angiogenesis, influencing cell differentiation. They regulate cellular synthetic and secretory activity of components of extracellular matrix. Finally, growth factors influence the process of healing. The growth factors of the transforming growth factor–beta superfamily induce an increase in messenger RNA expression of type I collagen and fibronectin in cell culture experiments.[73] Therefore, growth factors could potentially be used to influence the processes of regeneration of tendons therapeutically. However, it is unlikely that a single growth factor will give a positive result. The interaction of many factors present in the right concentration at the right time for the correct length of time will be necessary.[49]

A second area showing promise currently is that of stem cell therapy, especially the use of postnatal mesenchymal stem cells. This technique has been used in both small and large animal models; for example, mesenchymal stem cells do promote healing in a rabbit Achilles tendon.[197] Although the technique resulted in healing of the defect, subsequent histologic assessment revealed that the new cells were more similar to fibroblasts that tenocytes.

Using autologous bone marrow–derived stromal cells, Smith and Webbon[170] have developed a treatment for the management of injuries to the digital flexor tendons in horses, a tendinopathy of a similar nature to Achilles tendinopathy in humans. The technique involves initial harvest of the stem cells, in vivo expansion, and then implantation under sonographic control. Early studies suggest a rapid infilling of the tendon defect (Figure 5). This is an exciting area of current research.

Other possible therapeutic targets include manipulation of transcription factors that regulate the determination and differentiation of tendon cells such as scleraxis and

Sox9. Also, because excessive apoptosis has been reported in tendinopathic tendons, this raises the possibility that manipulation of this process may be used for therapeutic purposes.[198]

SUMMARY

The management of tendinopathy within sports medicine remains a major challenge. Advances in both conservative and operative management are being made and are underpinned by a greater understanding of the pathologic changes of the overuse tendon injury within sport. The lesion is noninflammatory and is likely to be of a failed healing response nature, with differences dependent on the site of the lesion (tendon body or osteotendinous junction).

There remains, however, an enormous need for further controlled studies not only to assess common existing treatments but also to evaluate (and improve) more novel treatment approaches.

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