TENDON TRAUMA: LACERATION AND RUPTURE

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Introduction

The rupture of tendons about the foot and ankle primarily causes disability when there is improper healing. In the hand, this disability usually results from improper healing that leads to a failure of tendon gliding, such as occurs in flexor tendon injuries of the fingers. In the foot and ankle, however, disability results because of a failure of the tendon to heal, and a resultant biomechanical imbalance between the tendon and its antagonist. An example of this is seen in the foot drop that results after an unrepaired tibialis anterior rupture.

The evaluation of the patient with a suspected tendon injury presents one more reason why the podiatrist must be expert in the performance of muscle testing and evaluation. Only by the selective evaluation of individual muscles can one determine whether or not certain tendons have been disrupted. The physician must have a high index of suspicion at the time of injury particularly when dealing with a laceration. Any laceration that penetrates the deep fascia over a tendon must be assumed to have lacerated the tendon until proven otherwise. In the case of a possible closed tendon rupture, the physician's index of suspicion must also extend to the subacute period once swelling and pain have decreased sufficiently to allow for accurate muscle testing and evaluation. Diagnostic techniques such as tenography can be useful in tendons housed in sheaths, such as the tibialis anterior or the peroneal tendons.

Tendon Healing

Much of what we know concerning tendon anatomy and the wound healing of tendons comes from research done on flexor tendon injuries of the fingers. Because these injuries have such a devastating impact in producing disabled workers, there is a tremendous effort to solve some of the most basic wound healing involving flexor tendon healing. Nonetheless, there is a great deal of confusion surrounding the various processes occurring during tendon healing.

For a tendon to heal successfully, the tendon must not only proliferate and join two ruptured ends together, but it must also differentiate from surrounding tissues to allow motion. These two processes which might appear somewhat in conflict, must occur in proper sequence in order to have a successful tendon repair. Historically there have been three basic concepts concerning tendon healing. First is that tendon healing is primarily dependent upon the multiplication of specific tendon cells from the tendon ends themselves in order to bridge the gap in the tendon ends. The second concept is that the healing of the tendon is primarily dependent upon multiplication and differentiation of nonspecific cell types from surrounding mesenchymal tissues. The third concept is that the process is dependent upon both types of cells. At the present time, most literature would support the third concept.

Experiments have demonstrated that isolating a tendon from its surrounding tissues will result in an unsuccessful tendon healing. This is probably a result of two factors. The first is the vascular supply to the tendon and the second has to do with the numbers and types of cells available for proliferation of collagen. In terms of the vascular supply, it is clear that there is a significant longitudinal blood supply in tendons. However, the longitudinal blood supply generally can support only a fourth to a third of the tendon by itself. The remaining blood supply must come from the original insertion of the tendon and surrounding soft tissues such as the paratenon. Therefore, the ruptured tendon is dependent upon the extra-tendinous blood supply for successful repair. In terms of the available cell types, the spindle shaped fibroblast is the dominant cell type in mature tendon. This is a mature fibroblast which has little capability for significant replication and differentiation. Consequently, the "wound module" must provide the platelets and macrophages that determine successful repair as in other types of wound healing.

As the platelets arrive in the wound from the laceration of surrounding blood vessels they secrete a platelet derived growth factor (PDGF) that attracts macrophages to the wound. As the macrophages enter the wound they release other attractant and growth factors to provide for the stimulation and development of mesenchymal cells. In addition, mature fibroblast from surrounding loose connective tissue will mobilize and migrate into the wound module. Eventually a dense irregular scar tissue is produced. This completes the initial synthesis phase of tendon healing.

The second phase of tendon healing involves differentiation of the tendon from surrounding soft tissues. After the synthesis phase the entire wound is a mass of dense irregular connective tissue. If the wound were to stay in

that condition the tendon would be undifferentiated from surrounding soft tissues and unable to glide. All tendon healing appears to result in adhesions between the tendon and surrounding tissues. However, the successful differentiation or remodeling phase of the repaired tendon is characterized by the lengthening of these adhesions. The adhesions are made up of collagenous tissue and, therefore, are not elastic in themselves. It is the reduction in lateral crosslinking or friction between subunits of the collagen that appears to permit longitudinal slipping so that elongation of the adhesion can occur. Microscopic observations reveal that restrictive adhesions are much less vascular than are nonrestrictive adhesions. In addition it appears that scar tissue remodeling is partially dependent upon the architecture of surrounding tissue.

Postoperative care principles are heavily dependent on understanding tendon wound healing. The initial synthesis phase generally lasts for 20 to 35 days in healing of long tendon. During this time there is continued increasing collagen synthesis following a tendon anastamosis. Generally, a tendon is immobilized for at least a period of 21 days following repair. If motion begins too early collagen synthesis may increase too rapidly and result in significant adhesions along the tendon. The figure of 21 days has been given as the cut-off line for immobilization of tendons. However, it should be clear that this figure of 21 days is a guideline for mobilization of tendons, but is not the point at which the tendon can be exercised forcefully. Since the collagen synthesis phase often occurs up through day 35, it should be assumed that it takes at least that long for the tendon to be able to resist significant pressures.

Repair: Techniques and Principles

The care with which tendons should be handled is critical to the success of the repair. Dissection must be meticulous to preserve the surrounding soft tissue and particularly the paratenon. Hemostasis must be absolute in order to prevent hematoma formation along the course of the tendon.

A variety of suture materials and techniques have been utilized for anastomosis of tendon ends. In general, a combination of nonabsorbable and absorbable sutures is the most effective. A coated polyester suture such as Ethibond has good handling properties, is nonabsorbable, and has minimal tissue reaction. Other nonabsorbable sutures that can be utilized include the monofilaments polypropylene and nylon. However, the monofilaments may have more of a tendency to cut through the tendon. The absorbable suture material is generally Dexon or Vicryl.

A variety of techniques have also been described with the most famous being the criss-cross suture of Bunnell. This technique can be performed a few different ways. The most common way is for two separate sutures to be criss-crossing on opposite ends of the rupture and then being tied in the ruptured area. This provides for distribution of tension away from the immediate rupture line itself. The suture is then reinforced by simple interrupted sutures around the circumference of the tendon rupture. Another technique is that described by Mason and Allen. Their technique involves utilizing suture away from the incision line to relieve tension directly on the rupture line.

Another technique described by Bunnell is the double right angle suture which is performed exactly as it is described. In large tendons such as the tendo Achillis we frequently utilize the Bunnell type suture and then reinforce it with circumferential simple interrupted sutures. In that case the core suture is nonabsorbable and the peripheral simple interrupted sutures are of absorbable material.

Prior to suturing the tendon ends are debrided of any necrotic tissue and the wound is irrigated. During the course of any surgical repair the wound is kept well moistened in order to prevent dehydration of the tendon or the paratenon.

Tendon Lacerations

Skin lacerations that can result in tendon disruptions are generally those that are over areas of prominent tendons. The tendo Achillis is one such tendon as well as the tibialis anterior and the extensor hallucis longus. The flexor tendons are somewhat protected in the foot until the area around the metatarsophalangeal joint where they become more superficial and, therefore, more vulnerable to laceration.

In general tendons should be repaired and restored to their anatomic position. This is particularly true for major tendons such as the tendo Achillis, tibialis anterior, the tibialis posterior, and the peroneal tendons. However, even seemingly minor tendons such as the dorsal extensors should in general be repaired. The specific indications for repair will depend upon the age of the patient, the condition of the wound, the degree of disruption of the tendon, and the functional significance of the tendon. The disruption of a single extensor tendon to a digit may not seem significant, but may result in a severe contracted digit on an adjacent toe due to the phenomena of transfer or loading.

Prior to repair of the tendon itself, the wound should be thoroughly cleaned and any necrotic ends debrided. If the tendon ends are clearly visible and can be repaired easily then the repair can take place in the emergency room. This is particularly true if the tendon is a relatively minor one such as an extensor to the lesser toes. In the event of major tendon disruption such as the tendo Achillis, or retraction of a tendon end, the repair should be performed in the operating room under general anesthesia in order to make sure that adequate muscle relaxation is present.

The indications for repair of tendon are generally quite obvious and the techniques are quite simple. Where most of us stray into difficulty is when we fail to be observant enough with what seems like a minor laceration. It is

imperative that muscle testing be performed after all lacerations. Many physicians have been fooled by seemingly inconsequential lacerations which hid a lacerated tendon beneath its tissues.

Specific Tendon Ruptures

Tibialis Anterior

The tibialis anterior is more commonly injured by laceration than by rupture. However, rupture of the tendon does occur and the most common location is at the insertion into the first metatarsocuneiform area. The loss of the tibialis anterior results in a significant decrease in dorsiflexory power and a partial foot drop. In most patients with a disruption of the tibialis anterior, surgical repair is indicated.

Repair of the tibialis anterior is generally not too difficult unless there is excessive disintegration of the tendon ends or a retraction of the proximal end of the tendon. The surgeon should be careful to place the incision to one side of the tibialis anterior sheath, generally medial. This helps to some degree in preventing excessive adhesions between the superficial fascia and the sheath. The repair itself can usually be performed with simple interrupted sutures and utilizing a combination of absorbable and nonabsorbable suture. A bunnell type suture may be necessary in a larger or heavier individual.

The patient is then casted in neutral position for a minimum of three weeks. At that time, the patient can begin some passive range of motion exercises without putting excessive tension on the repair. The patient is put back into a bivalved cast for a minimum of three additional weeks.

When secondary repair is performed on the tibialis anterior, tendon grafting may be necessary from the peroneus tertius or a partial segment of the peroneus brevis or a slip of the extensor digitorum longus.

Tibialis Posterior

The entity of tibialis posterior rupture has been well defined by Banks and McGlamry. The patient's biomechanical foot type becomes critical in determining the etiology of the rupture as well as the proposed treatment plan. Frequently, patients with posterior tibial tendon rupture present with subacute symptoms such as generalized foot pain or noticing a decrease in the height of their arch.

The most telling physical sign in tibialis posterior tendon rupture is the asymmetrical arch height variation between the two feet. In addition, some patients will demonstrate a chronic palpable tenosynovitis along the course of the tendon sheath. The specific etiology for rupture of the tibialis posterior tendon may be either traumatic or degenerative in nature. The vast majority are degenerative in nature either partially or completely. The support for this concept comes from the empirical observation that most of these patients have a pes valgus foot type bilaterally to begin with. In addition, the analysis of patient histories indicates that the majority are degenerative in nature.

The type of repair that can be performed for tibialis posterior rupture is heavily dependent upon how long the injury has been present. The greater the adaptation of the foot to a collapsed position, the greater the degree of bony work that must be performed. Conservative care for these patients has been unsuccessful in my experience. However, in certain elderly patients conservative care with shoe and appliance modifications may be adequate. Specially designed molded shoes in particular can offer some relief to these patients.

In general, the majority of these patients deserve surgical repair. In a younger patient who has not had the rupture for a significant period of time, a soft tissue repair may be adequate. This may consist of a primary repair of the tibialis posterior, with or without graft, and other medial arch reconstructive procedures to augment the repair. These may consist of partial anastomosis of the flexor digitorum longus into the tibialis posterior to increase its strength and a shortening of the spring ligament. In general, a soft tissue repair of the tibialis posterior and medial arch will produce a less painful foot but there may not be significant difference in arch height.

In several situations osseous procedures are indicated. The most common procedures to be performed are the isolated talo navicular fusion or a triple arthrodesis. The fusion procedures are particularly indicated in patients who have had severe osseous and soft tissue adaptation, in older individuals who may not respond as well to soft tissue repair, and in heavier individuals. The talo navicular fusion can be performed when there has been only mild to moderate degree of forefoot supinatus or varus deformity resulting from the rearfoot valgus position. The triple arthrodesis is a preferable procedure in those situations where there is significant forefoot deformity because it allows for correction of both the subtalor and midtarsal joints.

In tibialis posterior ruptures the majority of repairs are secondary in nature. This means that a combination of tendon grafts, tendon transfers, and fusion procedures is more common in these repairs. Primary repair of the tendon is generally restricted to fresh ruptures where there has not been a significant degeneration of the tendon ends.

Tendo Achillis

Achilles tendon injuries usually occur in healthy males between the ages of 30 and 40 years. Frequently, effected individuals are sedentary workers who may have a history of previous pain or peritendonitis in the heel region. The usual mechanism of injury is indirect violence caused by pushing off with the weight-bearing foot while extending the knee such as occurs at the start of a spring or in running or jumping. Other mechanisms can include sudden unexpected dorsiflexion of the ankle such as occurs when a person slips on a stair or ladder, or violent dorsiflexion of a

plantarflexed foot that occurs when jumping or falling from a height and landing with the foot plantarflexed. The tendon can also be ruptured by direct trauma over the tendon.

The most common site of rupture is an area 2 to 5 cm proximal to the insertion of the tendo Achillis. The diagnosis is established on the basis of the history and the clinical picture. Typically, patients present with pain and swelling in the posterior aspect of the ankle and distal aspect of the leg. Most individuals report having been involved in some form of strenuous activity at the time of injury. Some patients report a loud snap in the heel region while others describe a sensation of being struck on the heel or posterior leg. While there is generally severe pain immediately, frequently the pain subsides quickly and causes the individual to delay seeking care for a few days to a few weeks.

Physical examination reveals a palpable gap or defect of the Achilles tendon with an overlying visible indentation. Frequently there is significant swelling and ecchymosis at the area of rupture. Even with a complete rupture, some tendon fibers can frequently be palpated running from one ruptured end to the other. These strands are not able to support tension and are simply necrotic. There are additional physical and radiographic findings which have been described to make the diagnosis. In young active patients surgical repair of the tendo Achillis remains the accepted mode of therapy. This is largely because it can accomplish end to end anatomical repair. However, there are some instances where conservative management can be indicated and can achieve satisfactory results. In those cases the treatment consists of a well-molded short leg cast in relaxed plantarflexion for a period of four to eight weeks. There is increasing weightbearing to tolerance and the followup is with a heel lift inserted into the shoe for four to six weeks.

Surgical techniques for repair range from the simplest end to end repair to complex plastic procedures. The simple techniques can be performed with absorbable, nonabsorbable, or pull out wire suture. They may also include suture around the circumference of the tendon. The main difficulty with simple end to end repair is the fragmented mop end pieces of the tendon which often will not hold the suture well.

A variety of reinforcement techniques are available including utilization of the plantaris tendon, fascia lata, and plastic repair utilizing local flaps from the gastrocnemius. Other techniques include vascular graft material for repair and percutaneous repair. The most common technique for us involves Bunnell type repair with reinforcement of simple interrupted sutures around the circumference of the tendon, after debridement of necrotic ends. Local flaps of gastrocnemius tendon or reinforcement with the plantaris tendon are then performed if needed. The dissection for the tendo Achillis repair must be meticulous in order to preserve the paratenon and deep fascia. Patients are then casted for six to eight weeks.

Comparing various studies that have been performed on conservative and surgical repair is quite difficult since the methodologies and the studies differ significantly from one to the other. However, it does appear that there is a somewhat higher risk of rerupture with conservative casting for tendo Achillis ruptures than with primary surgical repair.

A separate classification of tendo Achillis repairs involves the repair of neglected ruptures or reruptures. These differ significantly from primary repair because of tendon hypertrophy at the ruptured ends, poor tissue environment, and retraction of tendon ends. The techniques for repair of neglected ruptures or reruptures must address those concerns. They are broken down into the following categories:

1. End to end repair with reinforcement with connective tissue or synthetic grafts.
2. Proximal tendon lengthening to allow end to end repair.
3. Tendon transfers to restore power to the triceps.
4. Interpositional grafting.
5. Other miscellaneous techniques that can be used to assist with bringing the tendon ends together.

Summary

Primary repair of ruptured tendons is the general treatment of choice. This is particularly true in younger patients and in functionally important muscles. Secondary repair is usually more difficult because of retraction of tendon ends and loss of vitality of the tendon. The initial evaluation of the traumatized patient must include evaluation of all muscle groups in order to rule out tendon ruptures.

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