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The Insight of Tendoachillis Tendon with Special Reference to Surgical Anatomy – A Review

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ABSTRACT

Introduction: the Gastrocnemius-soleus complex (triceps surae), traverses both the ankle and the knee joint and consolidates as achilles tendon, which is the largest, strongest tendon and one of the most common tendons to get ruptured and it is innervated by tibial nerve. Patients having Tendoachilles rupture have chronic ankle pain and are unable to walk pain free. They lose the ability to stand on their toes on the affected side, although standing on both toes may be possible with unilateral cases. Patients will not be able to run as they do not get enough strong push-off by dorsiflexion of the ankle. The management of the ruptured tendon is a challenging job. The management of chronic Tendoachilles ruptures is usually different from that of end-to-end suturing done for acute ruptures, as tendons and ends in chronic tears are retracted, undergo degenerative calcification and are atrophy with short and fibrous distal stumps. Here in this article we have reviewed the tendoachillis rupture and its surgical management.

Keywords: Tendoachillis; Rupture; Surgical repair; Grafting.

Introduction

History of tendoachillis tendon:

The Gastrocnemius-soleus complex (triceps surae), traverses both the ankle and the knee joint and consolidates as Achilles tendon, which is the largest, strongesttendon and one of the most common tendons to get ruptured. It is innervated by Tibial nerve[1]. The word Achilles tendon is derived from Homer, who was a great poet if Iliad, where Achilles was described as a magnificent warrior. He was made invulnerable to any bodily harm by weapons after being plunged in the magical river of Styx by holding his unprotected heel. Consequently, he was wounded here and killed in the great Trojan War[9]. John Hunter[11] himself had this unfortunate incident while he was jumping and he described himself treating with bandaging and non-weight bearing, later with Monroe bandages then designed by Alexander Monroe. Alexander Monroe[12] who was a prominent Anatomist and Surgeon at Edinburg described his experience about sustaining tendoachillis rupture and his management for the same. He described a bandaging technique made of a strong quilted calf piece with aslipper like foot piece, bonded together so as to make the amount of plantar and dorsiflexion of ankle controllable and adjustable. This later was adopted as Monroe bandage technique which became to be widely used by many other physicians.

Various Other contributions in this field were:

- Tendon suture to the bone by Cowan R.J in 1963
- Flap augmentation technique by Brown TD and Gordan MH
- Management of fresh rupture of Achilles tendon by Chambers J and Gilles
- Management of neglected Achilles tendon rupture with V-Y Tendinous flap byAbraham and Pankovich
- Reconstruction with Peroneus brevis by Aurelioperz and Tueffer
- Repair with Achilles tendon with Plantaris tendon reinforcing by Lynn
- Method of operation of subcutaneous rupture of Achilles tendon
- Needle test for complete Achilles tendon rupture by O Brien
- Thompson test by Scott B W *et al*

Gross anatomy of tendoachillis

The TA is formed from two heads of gastrocnemius and soleus. Gastrocnemius arises from the posterior surface of medial and lateral femoral condyles and, soleus from the posterior surface of the tibia and fibula. In 2.9–5.5% of people, there is third head of gastrocnemius, most commonly associated with the medial head[21]. Typically full incorporation of both heads of gastrocnemius and soleus with Achilles tendon occurs at 8 to 10 cm from the insertion on the calcaneus as the tendon fibers descend from the gastrocnemius Achilles tendon narrows but also rotates such that these fibers insert on to the lateral part of the calcaneus and that of the soleus insert on to the medial part of the calcaneus[22]. This spiraling of the fibers results in less buckling when the tendon is lax and is less deformed when put in tension. This reduces both inter-fiber friction and fiber distortion[23].

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Achilles tendon shape varies considerably from proximal to distal. As with any tendon in the body, the Achilles tendon flares out as it reaches its insertion site. This contributes to marked anteroposterior flattening and slight anterior concavity of the tendon, evident at the level of its insertion. Typically, the distal portion of the tendon does not exceed 7mm in thickness and any greater than that is suggestive of pathology[24]. At the insertion site itself the tendon is extremely flattened. It is approximately 2cm wide and 2-3 mm thick[25].

Near its calcaneal insertion, the achilles tendon is sandwiched between two bursae, namely superficial bursa between skin and tendon and Retrocalcaneal bursa that lies between Achilles tendon and superior calcaneal tuberosity that promote tendon movement. Protruding into the retrocalcaneal bursa is wedge-shaped fatty, synovial covering fold that represents the distal tip of Kager's fat pad, a mass of adipose tissue between Flexor Hallucis longus tendon and the Achilles tendon.

Tendoachilles tendon receives its blood supply from the vessels running in the paratenon, largely derived from the posterior tibial artery[27]. The vessels enter the tendon through the structure that is comparable to the mesotenon.[19] The mid- region (Zone II) of the tendon is relatively poorly vascular, and this may contribute to the vulnerability of the tendon to rupture, 2-6 cm above the calcaneus. The proximal part of the tendon receives its blood supply from the muscle bellies that continues to the tendon via the endotenon. The distal region also receives vessels from the periosteal plexus on the posterior aspect of the calcaneus. This supply starts at the margin of insertion and extends up the endotenon for approximately 2 cm proximally. A healthyfibro cartilaginous enthesis is avascular so that the vessels do not normally pass directly from bone to the tendon at the osseocartilaginous junction. There is no single comprehensive study of the innervation of the Achilles tendon from its myotendinous junction to its enthesis. Nevertheless, the sensory supply to tendon and its sheath is of nociceptive and proprioceptive significance. The integrity of nerve supply to the tendon may also play an important role in allowing its repair. The Achilles tendon supplied by sensory nerves from the contributing muscles and via twigs from neighboring cutaneous nerves, notably from sural nerve[28]. The paratenon contains Pacinian corpuscles which are important in proprioception and is more richly innervated than the tendon itself. Both muscle spindles and Golgi tendon organs have been demonstrated in association with the Achilles tendon of a cat. The former lie in the muscle-tendon itself, close to the myotendinous junction, but later are located moredistally in the tendon.

Zone l of the Achilles tendon is the area from the calcaneal insertion to a point 2 cm above it. Ruptures and avulsions in Zone I area are very common in patients with chronic insertional tendinitis, retrocalcaneal bursitis, and history of steroid injection at this site. Ruptures of the tendon in Zone ll i.e., 2-6cm from the insertion site, are common in the cases of non-insertional tendinitis. The area more than 6 cm from the insertion of the Achilles tendon is considered as Zone lll.

Structure of tendon mid substance

Achilles tendon is dominated by Type I Collagen, which accounts for its tensile strength in the order of 50-100 N/mm[29]. Fukashiro *et al.* measured a peak force of 2233 newtons in the human Achilles tendon in vivo[30]. However, it is an underestimate because of the difficulty in clamping tendons which by their

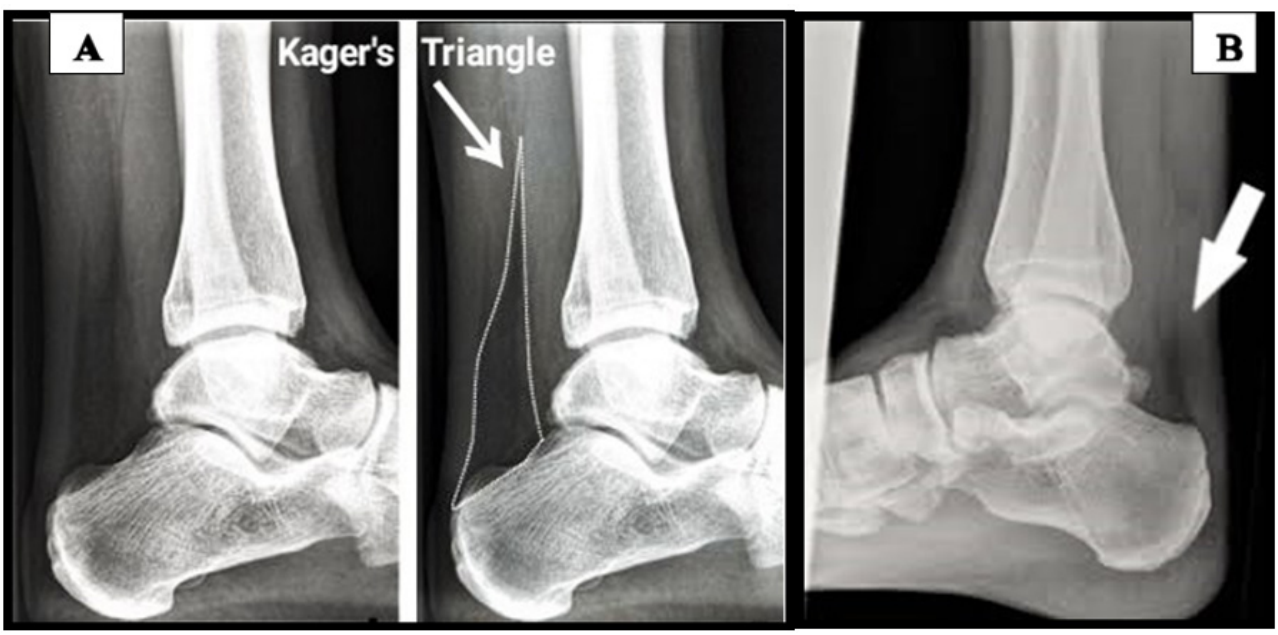

Figure 1. Radiographs showing A. Kager's Triangle (Normal) and B. Obliterated in TA Tears

nature consist of a large number of partly independent fibers. Collagen accounts for the 70% dry weight of the Achilles tendon[31]. In general fibers in the tendon running a wavy course, i.e., crumpled, with an axial periodicity of approximately 100 micrometers. Such pre-buckling is thought to contribute to flexibility, along with the partial independence of fascicles and fibrils thatderives from the low compressive stiffness of extracellular matrix[32]. The cells in the mid-substance of Achilles tendon are fibroblasts that are arranged in longitudinal rows and have a highly complex shape; and the collagen fibers are present in bundles. This is due to a number of broad, flat cell processes thatextend laterally from the cell bodies.

The enthesis and enthesis Organ

Tendo Achilles attaches to a rectangular area in the posterior surface of the calcaneus, with a greater surface area of the tendon is attached medially than laterally[33]. The tendon flares out considerably at the enthesis, and this will dissipate the region of stress concentration. In various positions of the foot and leg, the direction of the achilles tendon approaching its insertion site is kept relatively constant. When the foot is dorsiflexed, the superior tuberosity of the calcaneum acts as a gliding pulley, but during plantar flexion, the deep crural fascia must be primarily responsible for controlling the insertional angle. In supination and pronation movements of the calcaneum, comparable gliding control mechanisms for maintaining the constancy of a bone-tendon position are less obvious. Although continuity of crural fascia with the periosteum on medial and lateral aspects of the calcaneus is likely to be a factor, the fibro cartilaginous nature of enthesis is probably also important. The enthesis fibrocartilage balances the differing elastic moduli of tendon-bone and reduces stressconcentration at the insertion site.

In a dorsiflexed foot, the adjacent anterior surface of the tendon presses against the superior tuberosity of the calcaneus, and this reduces stress concentration at the enthesis itself. What never seems to be acknowledged is the surgical management of retrocalcaneal exostosis, there is an increase in stress at the enthesis that inevitably follows any removal of bone from the superior tuberosity. An increase in stress concentration is depends on the prominence of the calcaneal tuberosity. This type of considerations is particularly important when contemplating surgery on elite athletes in whom the Achilles tendon may periodically be heavily loaded. Due to intermittent contact between the superior tuberosity and tendon is associated with structural specializations at both surfaces because of the compression of the tissues. Thus, the calcaneus is covered by a thick fibrocartilaginous periosteum, and the deep surface of the tendon is lined by a "sesamoid fibrocartilage"[34]. The latter term was coined because this fibrocartilage lies within the substance of the tendon itself. The retrocalcaneal bursa promotes the free movement of the opposing surfaces due to downward tongue like extension of Kager's fat pad into it in plantar flexed foot. The enthesis itself, the periosteal and sesamoid fibrocartilage, bursa, and fat pad collectively constitute an "enthesis organ". This enthesis organ is a composition of tissues that all contribute to the common function of reducing stress and the chances of failure at the bone and tendon junction.

Degenerative changes are in line with those seen in osteoarthritic articular cartilage is common in elderly people. The Detachment of tissue fragments into the bursa is also frequently seen. The inflammatory changes characteristic of retrocalcaneal bursitis may be a secondary consequence of what is primarily an issueof fibrocartilage degeneration.

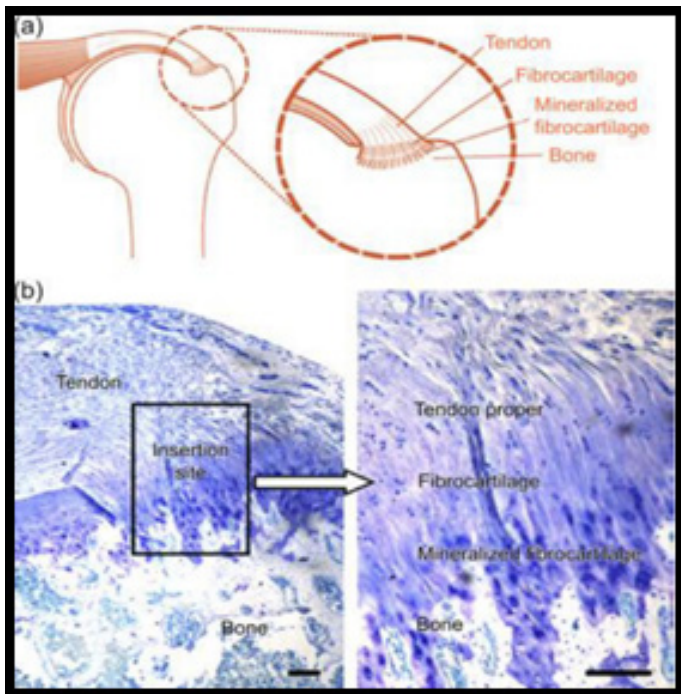

Figure 2. Parts of the Enthesis.

Surgical anatomy of tendo-achilles tendon:

The tendo-achilles is the thickest and the strongest tendon in the human body and serves to attach the Triceps surae to the calcaneus. It is also said that this tendon has helped shape the human evolution. The emergence of man is critically limited to the ability of him to run with unique combination of moderate speed and excellent endurance[16].

• Achilles Tendon has several unique functional demands which add to its vulnerability:

• The upright posture and the pull of the tendon are at right angles to the foot generating heavy torque.

• The muscles which contribute to the formation of TA are physiologically and functionally different. The Soleus plantar flexes the foot on flexion of knee and has a higher proportion of Type I slow twitch fibers, which facilitate posture maintenance. Whereas Gastrocnemius contains a higher proportion of fast

twitching fibers that help in vigorous propulsion and jumping when knee is extended[17].

• As the TA is inserted on to the calcaneum, it acts on the knee, ankle and the subtalar joint. The tendon also supinates the foot with plantar flexion as the axis of subtalar joint runs medially and upward from the posterolateral corner of the calcaneum.[18] This is the cause for non-uniform stress transfer to insertional site[19].

• The force acting on the TA is about seven times the body weight while running.

• The fibers of gastrocnemius are attached laterally and those of Soleus medially in the calcaneum which is due to the rotation of the limb bud during development[20].

Tendoachilles Rupture

Ruptures of the Achilles tendon have been increasing in number and more common in sedentary person in developed countries and barefoot walkers in developing countries, such as farmers, who walk on uneven surfaces. Tendinopathy of the Achilles tendon is common both in athletic and non-athletic individuals. Two main theories have been proposed based on the etiology of ruptures, namely The Mechanical Theory and The Degeneration Theory[36].

Mechanical Theory

McMaster postulated that a healthy tendon would not rupture even if it is subjected to severe strain. Barfred[37] investigated a hypothesis and stated that if straight traction was applied to the tendon, the chance of rupture would be distributed equally to all parts of the muscle, tendon, bone complex whereas if oblique traction was applied, the chance of rupture seen completely in the tendon. With supination, there is elongation of fibers on the convex aspect before the concave side is strained. Hence this hypothesis shows that risk of rupture of the tendon is greatest when it is loaded obliquely with maximum muscle contraction when the initial tendon length is shortened. This situation and factors are present in certain sports requiring rapid push- off. Intrafibrillar sliding[38] is the process by which tendons are initially damaged at the submicroscopic fibrillary level. This may apply to the tendons that rupture without previous degenerative changes.

This process may occur a few seconds before macroscopic slippage of collagen fibers, this implies tendons unaffected by degenerative changes may also rupture due to the accumulation of fibrillar tissue. This will support the theory of complete rupture being due to multiple micro ruptures and the tendon reaching a critical endpoint prior to rupture.

Degeneration Theory

This theory explains the rupture of chronic degenerated tendon with an excessive load being applied, which may not cause harm to a healthy tendon. These degenerative changes can occur due to chronic overloading with microtrauma, drug therapy and can also be associated with autoimmune diseases. The ratio of CollagenType I and Type II is altered compared to a normal healthy tendon[39]. In the case of overuse tendinopathies like in athletes and workers, damage or chronicstress on tendon may lead to microtears, which are healed with changes in cellular composition cannot withstand chronic loading. Spontaneous rupture of Achilles tendon occurs with systemic disorders such as autoimmune disorders[40], genetic collagen disorders[41], infectious diseases[42], neurological conditions[43], and metabolic conditions like hyperlipidaemia[44].

Tendinopathy

One of the most important causes of rupture of the Achilles tendon in India is elderly people with a habit of barefoot walking on the uneven surface in the agricultural background. Hyper-pronation is the commonest malalignment of the ankle. In athleteswith Achilles tendinopathy, limited subtalar joint mobility and limited range of motion of the ankle joint were more frequent findings. The cause for "whipping action" on the Achilles tendon is excessive movement of the hindfoot in the frontal plane, along witha lateral heel strike with excessive compensatory pronation, that predisposes to tendinopathy.

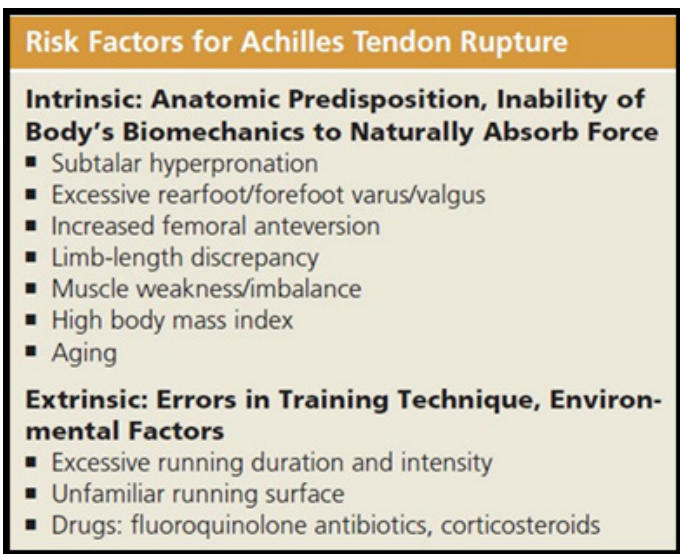

Figure 3. Risk Factors for Tendoachilles Rupture[45]

Histopathological study of debrided tendons from the patients who have been undergone surgical management has shown lack of inflammatory response, mucoid degeneration, and collagen disorganization. Pain is the cardinal symptom of tendinopathy. It generally occurs at the beginning and at the end of the training session, along with a period of diminished discomfort in between. As the pathogenesis progresses, pain may occur during exercise, and, in severe cases, it may interfere with daily living activities. In the acute period, the tendon is diffusely oedematous and swollen,

and on palpation, tenderness is usually greatest 2 to 6 cm proximal to the tendon insertion. In chronic cases, exercise-induced pain is the cardinal symptom, but crepitation and effusion diminish. In chronic cases a tender, nodular swelling is usually present and is believed to signify tendinosis. The diagnosis of Achilles tendinopathy is mainly dependent on a careful history taking and a thorough clinical examination. Diagnostic imaging may be required to confirm doubtful cases or to exclude other musculoskeletal disorders, such as Os trigonum syndrome, tenosynovitis or dislocation of the peroneal tendons, tenosynovitis of the plantar flexors, an accessory soleus muscle, tumours of the tendon, and neuroma of the sural nerve. Based on the location of inflammation, tendinopathy is classified as InsertionalTendinitis and Non-Insertional Tendinitis.

Insertional Tendinitis: Occurs due to a large exostosis at posterosuperior aspect of calcaneal tuberosity, known as Haglund's deformity and is associatedwith retrocalcaneal bursitis.

Non-Insertional Tendinitis: Occurs in the relatively avascular zone which is 2-6cm from the insertion site and is the most common site of inflammation and degeneration.

Presentation And Diagnosis

The Achilles tendon is the most common tendon to rupture in the body. The frequency of Achilles tendon rupture has increased significantly with an increasing emphasis on fitness in middle-aged adults and increased sports activities in athletic individuals, increase in awareness of health condition.

The two mechanisms of injury are Direct and Indirect. Direct injury involves a blow to the posterior ankle, a crush injury, or a laceration with a sharp instrument. Indirect injury consists of a non-contact injury occurring because of dorsiflexion or overload on the Achilles tendon. This is mostly seen during unexpected or violent dorsiflexion of the ankle as in stepping in a pothole or while walking on uneven surface. The most common mechanism of indirect injury is forceful pushing of the affected legviolently during sporting activities.

The patient typically presents with pain in the affected ankle, on the posterior side and in the case of chronic rupture, with difficulty in walking and climbing stairs. On history they may often indicate the sudden onset of pain associated with an audible click while walking or while training, which is followed by an inability to bear weight, and difficulty in walking. Patients with a chronic Achilles tendon rupture also have a typical history, that they often recall very minor a no trauma at all. Their primary complaint is difficulty in daily activities. A common scenario, especially in the Indian setting, appears to be an open tendoachilles injury due to foot getting caught in lavatory pans[46].

Examination reveals diffuse bruising and edema, with a palpable gap felt alongthe course of the tendon. The usual site of rupture is 2-6 cm from the insertional site. A study done by Young Hwan Park et. al[47] found that the average was about 6.4cm from the insertion site using MRI.

Clinical Tests

Thompson test: Also called as the Calf squeeze test was discovered by Thompson[48], 5yrs after Simmonds[49]. With the patient in prone position and knee flexed to 90 degrees, or with the flexed leg and knee supported on the couch and ankle cleared off the couch, the examiner squeezes the fleshy, bulky part of the calf. Normally, due to deformation of the Triceps surae, it causes bowing away from Tibia, resulting in Plantar flexion of the ankle. Whereas this movement is absent where there is discontinuity in the tendon due to its rupture and is compared with the other normalside.

Knee flexion test: With patient in prone position, he is asked to flex his knee while observing his ankles. The affected side goes into passive dorsiflexion while thenormal side remains neutral.

Needle test[50]: Hypodermic needle is inserted into skin of the calf just medial to the midline 10cm proximal to the insertion of TA. It is inserted in such a way that the tip is just within the substance of the tendon. Passive dorsiflexion and plantar flexion are done and the direction of needle is observed. On dorsiflexion, if the needle points distally and similarly if it points proximally on plantar flexion, it means that the tendon is intact.

Sphygmomanometer test[51]: The cuff is wrapped around the calf of prone positioned patient. Cuff is inflated to 100mm of Hg with foot in plantar flexion. The foot is now dorsiflexed with gentle pressure over the foot. The pressure rises to about 140mmHg indicating a continuity in the Achilles tendon

Matle test[52]: The foot on the affected side can be dorsiflexed more than the unaffected side passively due to loss of continuity of Musculotendinous unit.

Figure 4. Matle Test

Imaging Techniques

Radiography: Plain radiography of ankle shows loss in the regular triangular configuration formed Anterior to the Tendoachilles between posterior aspect of Tibia

and Superior aspect of Tendoachilles referred to as Kager's triangle[53]. It is less sensitive than USG and MRI.

Ultrasonography (USG): USG produces both Dynamic and Panoramic image of the tendon. The high-frequency probe of 7.5 to 10 megahertz provides the best resolution as they have a low focusing distance.[54] The longitudinal strands of collagen bundles in the tendon reflect the ultrasound beam. The probe must be held at right angles to the tendon to ensure the optimum amount of energy to be returned to the transducer.

The Abnormal Achilles tendon appears as a hypoechogenic, ribbon-like the image that is contained between two hyper echogenic images. When the tendon is relaxed the tendon fascicles appears as alternate hypoechogenic and hyperechogenic bands and are more compact than when the tendon is strained. Rupture of the Achilles tendon appears as an acoustic vacuum with thick irregular edges. Elastic properties of the tendon can also be studied by measuring the distance between the hypoechogenic and hyperechoic point and the calcaneus and how this distance changes with different forces exerted by the gastrocnemius-soleus complex. The Achilles tendon has the highest percentage of positive findings (75%)[55].

Magnetic resonance imaging (MRI): Normal TA is seen as an area of Low Signal Intensity on all pulse sequences and the tendon is well delineated by high signal intensity of the fat pad of Kager's triangle. Any increase in intra tendinous signal intensity should be considered as abnormal[24]. T1 weighted image sequence has a disruption in signal intensity in case of a tear while T2 weighted image shows increased signal intensity with edema and haemorrhage[56].

Treatment

Various treatment options include non-surgical/ conservative is associated with a significantly higher risk of re rupture compared to the surgical treatment[57]. The only risk which can be avoided with conservative treatment are: wound healing, wound infection and sural nerve damage. Serial casting with foot in plantar flexion helps in approximating the ends of the ruptured tendon.

Indications for surgery:

Surgical intervention has been yielding superior results in the treatment of TA tears. Aggressive post-operative protocols have demonstrated benefits of functional outcome in terms of function, patient satisfaction, acceptable complication rates, immobilization disease (Muscle atrophy, loss of strength, stiffness). Surgical intervention should be opted with caution in cases of:

- Diabetes
- Neuropathy
- Peripheral Vascular Disease
- Obesity
- Immunocompromised
- Age more than 60yrs[57].

Several suture and repair techniques are advocated to achieve the goal. The first suture technique for an end-to-end repair of the ruptured tendon was popularized by Bunnell and Kessler. Currently, more popular techniques include six strands suturing technique, suture wave technique, Krakow suture, and three bundle technique for acute repair of the ruptured tendon. In addition to this suturing technique, various suture constraints, several augmentation techniques have been described especially in chronic cases, which have elapsed more than 4-6weeks. Various methods available are Gastrocnemius Recession, Turndown Flaps; Tendon transfers/ augmentation with Flexor hallucis longus tendon, Peroneus brevis tendon, Flexor digitorum longus tendon, Fascia lata, and Allograft augmentation.

Conclusion

The achilles tendon is one of the most frequently ruptured tendons in the human body. Mechanical overuse, repetitive microtrauma, advancing age with poor blood supply in the area, causes weakening of the tendon and hence rupture. The concept of surgical repair in the ruptures are to restore the continuity of the tendon, such that the healing occurs in a physiological position allowing restoration of muscle/ tendon function is durable. The management differs in case of chronic tears where the ends of the ruptured tendons are degenerated.

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