JOURNEYING THROUGH ANKLE'S SECRET LABYRINTH

UNRAVELLING FOOT AND ANKLE TUNNEL SYNDROMES IN ATHLETES

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INTRODUCTION

In the world of ankle and foot health, nerve entrapments often linger in the shadows, frequently misdiagnosed or entirely overlooked. Yet, these intricate tunnel syndromes are more than just a footnote in the realm of sports medicine; they play a pivotal role not only in the careers of professionals but also in the daily lives of countless recreational athletes.

Tunnel syndromes of the foot and ankle encompass a group of neurologic conditions characterized by nerve compression within confined anatomical spaces. These syndromes can lead to different symptoms, affecting an athlete's performance, and quality of life, and requiring prompt diagnosis and management.

As peripheral nerves course from the spinal cord into the lower limbs, they pass natural tight passages that may lead to compression of the nerve. The symptomatology of nerve compression is dependent on the anatomy of the nerve at the level of nerve compression, meaning that symptoms may be sensory and/or motor loss.

When athletes present with sensorimotor issues, conducting a comprehensive clinical assessment before jumping into diagnostic tests is crucial. This is because similar symptoms can result from different underlying problems. Pain is a common symptom, and it can take the form of sharp, burning sensations with abnormal tingling in specific skin areas (called dermatomes) due to pressure on sensory nerve fibers or reduced blood supply. If motor nerves are affected, athletes might experience muscle weakness, then widespread, deep pain in muscle groups or joints, and nerve compression can lead to symptoms both near and far from the affected area (Burrus et al., 2015). Understanding these symptoms helps distinguish between sensory and motor nerve issues. While examinations like electrodiagnostic tests can be helpful, their accuracy relies on the person conducting the test and the specific nerve being examined. So, a thorough clinical evaluation, including patient history and physical examination, remains vital, with additional tests if needed.

The terminology used to describe these syndromes varies, but for clarity, we'll use the term "tunnel syndromes" in this article. Tunnel syndromes have multiple causes, including external nerve pressure (i.e. from a ganglion cyst), trauma, infections, metabolic disorders, vascular problems, anatomical variations, and certain physical activities (Pecina et al., 2001a).

This article provides a comprehensive overview of tunnel syndromes affecting the foot and ankle, discussing their anatomy, etiology, clinical presentation, and treatment options.

Sural nerve syndrome

The sural nerve is a primarily sensory nerve that can get trapped anywhere along the course of the nerve leading to discomfort in the calf, lateral ankle, and lateral foot, depending on the level of nerve involvement. It is most often seen in runners or athletes with repetitive ankle sprains (Burrus et al., 2015). Neurogenic pain is a common finding with a burning feeling, increased sensitivity in the skin, and sometimes symptoms mimicking Complex Regional Pain Syndrome (CRPS). The vulnerability of the sural nerve to compression or tension injuries is notable as it courses posteriorly along the lower leg and passes behind the lateral malleolus. Particularly, compression or distortion of the sural nerve tends to occur at the point where it penetrates the crural fascia, typically between the middle and distal thirds of the calf (Trescot, 2016).

Anatomy

The sural nerve has two main parts: one from the tibial nerve, known as the medial cutaneous sural nerve, and the other from the common peroneal nerve, called the ramus communicans of the lateral sural cutaneous nerve. However, in about 20% of cases based on studies using cadavers, there can be variations in how the sural nerve forms or where it goes (Garção et al., 2023). Generally, the origin is in the back of the knee, running between the calf muscles under a layer of connective tissue called the crural fascia. The nerve goes through this tissue in the middle to lower calf area, near a small vein called the small saphenous vein, and to the lateral side of the Achilles tendon. It connects with the common peroneal branch and goes behind the lateral malleolus, supplying sensation to the ankle joint, the back of the calf, and the lateral part of the heel and foot (Trescot, 2016).

Etiology

Although not commonly mentioned as a primary cause of leg pain from exercise, there have been documented cases of nerve compression due to various factors like growth, scar tissue, ganglia, surgery, and vein inflammation. Tight-fitting ski boots or casts can also contribute to this problem. The crural fascia, a layer of connective tissue, can play a double role by pressing on the nerve. Activities like running or track sports can stretch the nerves at this level. Likewise, repeated injuries that twist the ankle can cause fibrous changes and trap the nerve. In severe cases, when the fascia locks the nerve in place, extreme twisting of the foot can lead to a traction injury (Mccrory et al., 2014).

Figure 1: Point of maximal tenderness of sural nerve.

Clinical symptoms and signs

Patients often describe feelings of sharp pain or abnormal sensations that match the skin area served by the sural nerve. However, there might not always be clear physical signs. Interestingly, this nerve-related pain is often confused with Achilles tendon issues, leading many athletes to consult sports physicians, thinking they have recurring Achilles tendon problems (Abbas et al., 2023). Unfortunately, clear neurological signs are not always present.

A physical examination typically reveals tenderness and potential swelling in the calf or in the region behind and below the lateral malleolus. (Figure 1)

Passive inversion of the ankle can induce pain within the sural nerve distribution. Symptoms can be triggered by plantar flexion and inversion of the foot (Pomeroy et al., 2015). Changes in sensitivity, either reduced or increased, might be noticed on the lateral part of the foot and ankle. Tinel's test, a percussion nerve test to elicit numbness and/or pain, doesn't usually help diagnose sural nerve issues. However, applying localized pressure can worsen sensory symptoms, indicating the possible problem location, known as the Hoffman-Tinel's sign (Trescot, 2016). Scratch collapse test may also be positive.

Electromyography, might provide useful information, but only a minority of patients show slower nerve conduction (Matsubara et al., 2023). When considering a diagnosis, it's important to also think about other conditions that can trap the sciatic nerve.

Treatment

Sometimes, simple approaches like using cold therapy and anti-inflammatory medications can help with nerve inflammation. However, it's essential to get rid of anything that might be irritating the nerve, such as specific types of ski boots or cycling shoes. Physical therapy can also be useful for loosening up and breaking down scar tissue.

Ultrasound-guided injections for the sural nerve can be done at different points along its path. Most often, they're given near a tough tissue area close to where the gastrocnemius muscle meets the Achilles tendon, roughly 10–15 cm above the lateral malleolus, or just above or behind it.

Identifying the root cause of nerve compression is crucial for successful treatment. When the underlying issue is addressed and removed, the nerve can often regenerate on its own, and the symptoms can improve. If conservative treatments don't work over a long time, surgery may be considered. If the nerve is compressed because of things like ganglions, Baker's cysts, or scar tissue, removing these can help the nerve heal. In cases where the nerve is trapped within scar tissue, it might need to be moved to a healthier spot. Also, if the nerve seems to get stretched when the ankle and foot move, a neurectomy might be considered.

Anterior tarsal tunnel syndrome (ATTS)

The deep peroneal nerve (DPN) is one of the main branches of the common peroneal nerve (CPN). Problems with the DPN can be seen in runners, football players, ballet dancers, and basketball players. Ankle sprains are generally common, and there is a connection between recurring ankle sprains and entrapment of the DPN at the level of the anterior tarsal tunnel.

Anatomy

The DPN innervates the muscles in the anterior lower leg, including the tibialis anterior, extensor digitorum longus, peroneus tertius, and extensor hallucis longus. It also provides sensation to the first and second toes. The DPN travels through a space called the anterior tarsal tunnel, which is extensor retinaculum above and the talus below.

Inside this tunnel, the DPN splits into two branches, innervating the extensor digitorum brevis, and providing sensation to metatarsophalangeal joints II-IV. It also helps with sensation in the ankle joint, which is crucial for ankle stability, and in the sinus tarsi. Additionally, the second branch follows along the dorsalis pedis artery and gives sensation to the big toe and the second innermost toe. It ends in the skin between these toes, providing feeling to the webspace in that area (Figure 2) (Becciolini et al., 2021).

Etiology

Anterior tarsal tunnel syndrome can happen due to factors from inside or outside the foot. Internal factors: These are things within the foot, such as osteophytes, synovial pseudocysts, ganglions, unusual muscles, fractures, inflammation, neuromas, or aneurysms, that can reduce the tunnel's space. Most often, pressure from the extensor hallucis longus tendon or the inferior extensor retinaculum pressing

Figure 2: Interdigital webspace with sensory innervation from DPN.

on the deep peroneal nerve causes anterior tarsal tunnel syndrome.

External factors: Wearing tight shoes and high heels - the condition can worsen when the foot is in a plantarflexed position (Pecina et al., 2001b; Trescot, 2016).

Clinical symptoms and signs

ATTS typically leads to a mix of sensory and motor symptoms. Sensory symptoms include numbness or hyperesthesia, and motor symptoms include weakness in toe extension and fine toe movements, at times associated with muscle wasting in the foot. The pain connected to this syndrome often gets worse with physical activity and can persist even when you're at rest. Many people experience nighttime pain because the foot's position during sleep stretches the deep peroneal nerve. Athletes, especially soccer players (Ferkel et al., 2015), can develop similar symptoms due to repeated impacts on the top part of the foot. Trauma can also happen during activities like doing sit-ups with bars or having objects like keys pressing on the top of a running shoe.

To confirm the diagnosis, physicians often recommend electrodiagnostic tests, including electromyography (EMG) studies. These tests help distinguish anterior tarsal tunnel syndrome from other nerve issues like those involving the peroneal nerve or lower back (L5 nerve root) (Preston, 2021).

Tinel's sign is positive usually above extensor hallucis brevis muscle. To diagnose the entrapment of the deep peroneal nerve, we can use a test called the "squeeze test." This involves gently pressing the bones in the front part of the foot (metatarsal heads) together while gently squeezing the deep peroneal nerve from above and below.

Treatment

In the initial non-surgical treatment for ATTS, a comprehensive approach is used. This includes educating the patient, using medications, giving local steroid injections, doing physical therapy, and making lifestyle changes like choosing the right shoes and adjusting activities. The non-surgical plan involves resting, keeping the foot at a 90-degree angle to avoid nerve compression, using anti-inflammatory drugs, and possibly giving corticosteroid injections to relieve symptoms. For athletes who often have ankle sprains and reduced sense of joint position (proprioception), physical therapy can help strengthen the peroneal muscles and improve ankle joint awareness.

Sometimes, medications like anticonvulsants or tricyclic antidepressants can help with nerve inflammation and can be used alongside methods to reduce pressure. In severe cases, surgery might be considered to release the nerve at the entrance of the tunnel (DiDomenico & Masternick, 2006).

Tarsal tunnel syndrome (TTS)

The tibial nerve (TN) can get trapped in two specific locations as it gets close to the ankle. One of these is the tarsal tunnel (TT), which is also known as the tibiotalocalcaneal tunnel, or Richet's tunnel. This is where the TN goes beneath a band of tissue called the flexor retinaculum in the ankle. When the TN or its branches get compressed in this area, it's called tarsal tunnel syndrome (TTS). TTS is not very common compared to other nerve compression issues, but it often goes unnoticed and is sometimes wrongly diagnosed as plantar fasciitis (Doneddu et al., 2017).

Anatomy

The TT is a passageway in the posterior-medial region of the ankle, bordered by the medial malleolus, calcaneus, flexor retinaculum, and the surrounding soft tissues. Inside this tunnel, you find the tibial nerve and its branches, along with tendons from the tibialis posterior, flexor digitorum longus, and flexor hallucis longus muscles. (Singh & Kumar, 2012).

The tarsal tunnel is occupied by the posterior tibial artery and veins and the tibial nerve. At the level of the tarsal tunnel the nerve divides into the medial and lateral plantar nerves as well as the medial calcaneal branch that supplies the sensation to the medial aspect of the heel. The medial plantar nerve gives motor innervation to abductor hallucis, flexor hallucis brevis, flexor digitorum brevis muscles. The lateral plantar nerve gives off a mixed sensory-motor branch that passes in close relation to the plantar facial attachment to the calcaneum. This

Tunnel syndromes of the foot and ankle encompass a group of nerve compressions that lead to pain and loss of proprioception, affecting an athlete's performance, and quality of life.

Figure 3: Palpation of Tarsal tunnel.

nerve ultimately innervates the abductor digiti quinti muscle. Both plantar nerves end by forming the interdigital nerves, the medial plantar forming the branches to the medial three-and-a-half toes and the lateral plantar supplying the lateral one-and-a-half toes. The plantar nerves give the muscular innervation to all of the intrinsic foot muscles (McCrory et al., 2002; Rodríguez-Merchan & Moracia-Ochagavia, 2021).

Etiology

Compression of the tibial nerve and its branches can occur due to various factors, which can be categorized as external or internal (McSweeney & Cichero, 2015).

External factors include conditions like ankle fractures, sprains, foot deformities (like flat feet or abnormal foot positions), obesity, and systemic diseases such as rheumatoid arthritis, osteoarthritis, high cholesterol, or diabetes.

Internal compression can include ganglion cysts, inflammation or osteophytes causing compression in the TT.

TTS has been reported in cases involving specific conditions like tarsal coalitions (abnormal bone connections), fractures of the heel bone, and even in people wearing tight shoes. Interestingly, TTS is more common among dedicated runners, especially those with foot overpronation (Vasiliadis et al., 2021). Traumatic events, along with bleeding or scarring in the back of the ankle, can also trigger TTS. However, in a significant number of cases (about 20%), the cause of TTS remains unknown and is referred to as idiopathic.

Clinical symptoms and signs

The main symptom is pain and sensory symptoms (numbness/hyperesthesia), mostly in the dermatome of the medial plantar nerve, which includes the medial plantar surface and the first- to third toes. The symptoms can worsen at night or with prolonged periods of weight-bearing activity. Proximal radiation of pain may lead to misdiagnoses, such as sciatica or lumbosacral spine disorders.

Finding objective signs can be challenging, but loss of sensation, Tinel's sign, scratch collapse test may all contribute to suspecting the diagnosis. A physical examination might show swelling around or below the inner ankle (Figure 3). Specific maneuvers like foot eversion (pronation), dorsiflexion, and toe abduction can reproduce pain and paresthesia. Muscle problems are hard to detect with a simple examination since most patients can stand and walk without difficulty (Fortier et al., 2022).

The triple compression stress test (TCST), also known as the dorsiflexion/eversion test, is a test used to provoke symptoms in tarsal tunnel syndrome. To perform this test, the ankle is fully bent upward (dorsiflexed), the foot is turned outward (everted), and pressure is applied with your fingers over the tibial nerve to see if it causes tingling and pain. Research has shown that the TCST is a reliable test for diagnosing TTS, with a sensitivity of 85.9%, meaning it correctly identifies the condition in most cases, and a specificity of 100%, indicating it rarely produces false positives (Abouelela & Zohiery, 2012).

Diagnosing TTS requires a thorough evaluation, which can include various tests like X-rays, ultrasound, CT scans, MRI scans, and electromyography (de Souza Reis Soares et al., 2022; Manoharan et al., 2021; Patel et al., 2005; Samarawickrama et al., 2016). Other conditions like arch issues, Morton's metatarsalgia, lower back problems, heel pain, and plantar fasciitis need to be considered as differential diagnosis.

Treatment

Conservative treatment is often effective in managing TTS. The main goal is to relieve pain, reduce inflammation, and ease strain on the affected tissues. When nerve conduction through the posterior tibial nerve is excessively slow, conservative treatment may not work well.

To alleviate tarsal tunnel syndrome, several strategies can be employed (Nelson,

2021; Rodríguez-Merchan & Moracia-Ochagavia, 2021). First, activities can be adjusted to minimize strain on the affected area. Pain relief medications such as acetaminophen and NSAIDs can be used, and for neuropathic pain, medications like gabapentin, pregabalin, and tricyclic antidepressants may be prescribed. Additionally, physical and rehabilitation methods, including cryotherapy, supportive inserts, orthotic shoes, and various therapies, can help manage symptoms. Stretching exercises, muscle strengthening, kinesiology tape, orthopedic shoes, and night splints can provide relief. In cases of ganglion cysts, drainage under ultrasound guidance or steroid infiltrations may be considered as treatment options.

Surgery for TTS is considered when conservative treatments fail, and the cause of the nerve compression is clear. In such cases, surgical outcomes are typically positive. The surgical procedure involves releasing the flexor retinaculum, which is a band-like structure near the inner ankle, from its attachment point near the medial malleolus down to the sustentaculum tali. Additionally, the deep fascia of the abductor hallucis muscle is cut to remove any potential compression on the nerve's end branches (Rodríguez-Merchan & Moracia-Ochagavia, 2021).

Jogger's foot

Compression of the medial plantar nerve (MPN) can occur near the navicular tuberosity as it passes through a bony, fibrous, and muscular tunnel between the navicular bone and the abductor hallucis muscle. This issue is often seen in middle-aged individuals who jog. People with this condition typically describe feelings of aching or shooting pain in the inner part of the foot's arch, especially when they're running (Vasiliadis et al., 2021).

Anatomy

The MPN, one of the two main branches of the tibial nerve, emerges below at the flexor retinaculum. It runs alongside the lateral side of the posterior tibial artery and travels near the quadratus plantae and abductor hallucis muscles initially. As it continues, it approaches the area known as the master knot of Henry (De Maeseneer et al., 2015). Along its path, the nerve moves along the inner edge of the flexor digitorum brevis muscle and then splits into different branches: the articular, muscular, and cutaneous branches. The cutaneous branches supply most of the skin on the front two-thirds of the sole and parts of the inner three and a half toes, including the big toe. The muscular branches go to the abductor hallucis, flexor hallucis brevis, flexor digitorum brevis, and first lumbrical muscles. The articular branches serve the joints in the tarsus and metatarsus.

Etiology

When runners have their ankles in a valgus (outward) position for extended periods, it can increase the risk of injuring the medial plantar nerve. This alignment puts more strain on the nerve, causing it to get stuck behind the bony bump on the inner side of the foot, called the navicular tuberosity. Additionally, turning the foot outward (eversion) stretches the nerve within a fibromuscular tunnel formed by the abductor hallucis muscle and the navicular tuberosity (Barrett et al., 2021). Repetitive stress on the nerve can lead to inflammation in the area where it's trapped.

Clinical symptoms and signs

Athletes with entrapment of the MPN often describe feelings of burning pain, tingling, and aching focused on the inner arch of the foot. These sensations tend to get worse during physical activities like running. Many experience tenderness at the navicular tuberosity along the inner arch. Some may also have reduced sensation in the sole of the foot near the big toe (Barrett et al., 2021).

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This discomfort can be made worse by using arch supports, running on uneven surfaces that increase the foot rolling inward (pronation), and wearing tight or narrow shoes that are laced tightly. It's worth noting that some patients might have a history of foot issues or previous surgery where the flexor hallucis longus (FHL) tendon was used for Achilles tendon repair.

During a gait analysis, it's common to observe foot supination, which helps relieve pressure on the arch of the foot. To identify any issues, it's crucial to carefully examine and feel along the entire tibial nerve, including its major branches.

Pain will be present over the MPN at the navicular tuberosity and Tinel's test positive at the same level (Trescot, 2016).

Treatment

Non-surgical treatments are typically effective in managing this condition. Key steps include discontinuing rigid high-arched orthoses and ensuring proper shoe design and fit, with necessary adjustments. It's recommended to avoid using arch supports in running shoes.

Modification of the training to avoid uneven surfaces and incorporating injections, often containing lidocaine and cortisone, for localized irritation and inflammation can be beneficial. Rest and limiting running distances promote healing, and anti-inflammatory medications are commonly prescribed.

In cases where conservative treatments prove ineffective, surgical intervention, specifically neurolysis, by releasing the fascia over the affected nerve in the most tender area.

Figure 4: Tenderness of the medial calcaneal tubercle.

Baxter's neuropathy

Heel pain is a prevalent issue in sports physician clinical practice, and one potential contributor to medial heel discomfort is the entrapment of the inferior calcaneal nerve (ICN), also known as Baxter's nerve. Alternatively referred to as the first branch of the lateral plantar nerve (FBLPN), deep calcaneal nerve, or the nerve to the abductor digiti minimi (quinti) muscle, ICN entrapment can exhibit similarities to or coexist with plantar fasciitis (Jaring et al., 2019), a condition now understood as stemming from degeneration due to repetitive microtrauma to the plantar fascia, compounded by acute and chronic inflammation. Baxter's nerve entrapment is believed to underlie as much as 20% of heel pain cases as Baxter showed in late 1980's.

Anatomy

The FBLPN has sensory and motor components that cover the calcaneal periosteum, long plantar ligament, lateral plantar skin, abductor digiti minimi, flexor digitorum brevis, and quadratus plantae. It usually starts near the tibial nerve's split or sometimes directly from the tibial nerve before the bifurcation. Entrapment points can occur at myofascial junctions, as well as where it passes in front of the calcaneal tuberosity.

Etiology

This condition can be caused by factors like muscle hypertrophy or a bone spur, as well as pronation of the rearfoot/midfoot complex, which pinches the nerve at a sharp turn. Entrapment of the nerve in the foot can result from various factors, including growths, tendon inflammation, muscle

Differentiating between Baxter's neuropathy and plantar fasciitis

This can be done by testing foot position and pain. When the foot is in a downward and inward position, applying pressure under the AbH is more likely to trigger symptoms in the patient. Also, when the foot and toes are bent upward (dorsiflexed), it puts tension on the plantar fascia, and tenderness is more pronounced when the fascia is stretched, suggesting it as a potential source of the patient's pain. Conversely, if tenderness increases when the fascia is relaxed, an underlying structure beneath the fascia, such as the ICN, is likely responsible for the symptoms (Trescot, 2016).

changes, bone spurs, injuries, and systemic conditions like diabetes (Moreno García et al., 2017).

Clinical symptoms and signs

This condition is characterized by persistent pain at the plantar medial heel, especially over the nerve. During a physical exam, palpating the heel's plantar medial area, particularly near the proximal abductor hallucis or plantar fascia, can reproduce nerve pain. The main sign of the nerve's entrapment is maximum tenderness where it's compressed between the tight deep fascia of the abductor hallucis muscle and the medial edge of the quadratus plantae (Pecina et al., 2001a). Tinel's test may be positive at this level. (Figure 4)

Patients with involvement of the ICN may have trouble in moving the little toe abduction. In cases where the medial calcaneal nerve is affected as well, there may be weakness in the abductor hallucis muscle (AbH).

The usefulness of electromyography (EMG) or nerve conduction velocity (NCV) studies for diagnosis is still a subject of debate (Preston, 2021).

Treatment

Conservative treatment is the first-line approach and often yields positive outcomes. It involves using heel cups or pads, occasionally with a heel lift in the shoes. A stretching routine that addresses both the Achilles tendon and the plantar fascia is recommended. NSAID may provide relief as well. Before considering surgery, local corticosteroid injections can be an option, serving both diagnostic and therapeutic purposes. If these measures provide limited pain relief, surgical decompression may be considered, but it's essential to have realistic expectations for the potential improvement (Rio Coles et al., 2021).

CONCLUSION

In conclusion, this comprehensive article sheds light on the intricate world of foot and ankle tunnel syndromes, which often afflict athletes and pose diagnostic and therapeutic challenges. These syndromes, characterized by nerve compression within anatomical spaces, can lead to a spectrum of symptoms, ranging from sensory deficits to motor impairments. Understanding the diverse etiologies, clinical presentations, and treatment options for tunnel syndromes is essential for clinicians dealing with athletes presenting neurovascular symptoms. A meticulous clinical evaluation remains paramount, enabling differentiation from other pathologies with similar symptoms. Conservative and surgical interventions should be tailored to address the underlying cause of nerve compression, emphasizing the importance of timely intervention to prevent irreversible nerve damage.

References

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