Clinical Research

Ultrasound-Guided Proximal and Distal Tarsal Decompression

An Analysis of Pressures in the Tarsal, Medial Plantar, and Lateral Plantar Tunnels

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Abstract: **Objectives.** *To analyze the reliability of measurements of tarsal tunnel and medial and lateral plantar tunnel pressures before and after ultrasound-guided release. Measurements taken were guided by ultrasound to improve reliability. This novel approach may help surgeons make surgical decisions. The second objective was to confirm that decompression using ultrasound-guided surgery as previously described by the authors is technically effective, reducing pressure to the tarsal and medial and lateral plantar tunnels.* **Methods.** *The study included 23 patients with symptoms compatible with idiopathic tarsal tunnel syndrome (TTS). The first step was to measure intracompartmental pressure of the tarsal tunnel, medial plantar tunnel, and lateral plantar tunnel preoperatively. The second step was ultrasound-guided decompression of the tibial nerve and its branches. Subsequently, pressure was measured again immediately after decompression in the 3 tunnels.* **Results.** *After surgery, the mean values significantly dropped to normal values. This represents a validation of effective decompression of the tibial nerve and its branches in TTS with ultra–minimally invasive surgery.* **Conclusions.** *The ultrasound-guided surgical technique to release the tibial nerve and its branches is effective, significantly reducing pressure in the tunnels and, thereby, decompressing the nerves.*

Level of evidence: *Level IV*

Keywords: minimally invasive; tarsal tunnel syndrome; musculoskeletal; ultrasound-guided surgery

> "Constant pressure on the nerve may produce pressure radiation with tingling and numbness, known as the Valleix phenomenon."

Introduction

Tarsal tunnel syndrome (TTS) is a peripheral neuropathy caused by entrapment of the tibial nerve, in the flexor retinaculum in the ankle, and its branches, in the deep fascia of the abductor in the rearfoot.[1-4] The first description of tarsal tunnel is attributed

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to Richter in 1897.[5] The prevalence of TTS described in the literature is lower than that for other compressive neuropathies, although some authors consider it to be underdiagnosed or occasionally misdiagnosed as plantar fasciitis.[6-8]

Compression of the tibial nerve and its branches may be a result of extrinsic causes, such as sequelae of fractures, ankle sprains, flat feet, valgus ankle, overweight and systemic diseases such as rheumatoid arthritis, hyperlipidemia and diabetes, among other causes, or intrinsic causes, such as injury causing a reduction in the nerve space in the tunnel (ganglions, nerve tumours, perineural fibrosis, lipomas, and accessory tendons or muscles).[1,7,9,10] Estimates suggest that the cause is unclear in 20% of patients, with symptoms of TTS being idiopathic in origin. In such cases, the cause is thought to be biomechanical alteration of the rearfoot valgus, causing tension and compression of the nerve, leading to increased pressure in the compartment, thereby producing neural ischemia.[4,11-15]

Pollock and Davis[16] described the clinical syndrome for the first time in 1932, whose course involves pain, burning sensation, paraesthesia, and heaviness in the sole of the foot. Lengthy walks or standing often exacerbate symptoms.

There is currently no reliable test for diagnosing TTS. Diagnosis usually involves correlation of clinical history, imaging tests, and electromyography (EMG).[17-19] Physical examination may reveal painful points on the tibial nerve and its branches at the flexor retinaculum.[1,4] The forced foot eversion and flexion maneuver can exacerbate symptoms, and on rare occasions, the pain may radiate toward the calf.[7,20]

The Hoffman-Tinel test may be positive in more than half of patients with this condition.[7,10,21] Constant pressure on the nerve may produce pressure radiation with tingling and numbness, known as the Valleix phenomenon.[7,9,20] It is positive in about a third of cases. EMG and nerve conduction studies may provide results but frequently produce false negatives.[1,4,22] Schon et al[23] showed that the EMG is unreliable in confirming diagnosis of compression of the tibial nerve and its branches.

The value of other tests is still being studied or depends on the expertise of the physician. For instance, magnetic resonance imaging (MRI) scans could have a diagnostic value by identifying signs compatible with plantar muscle atrophy.[24] MRI can reveal space-occupying lesions, such as a tumor, cyst, or varicosity.[25]

Measuring pressure in the tarsal tunnel below the flexor retinaculum and medial and lateral plantar tunnels, under the hallucis abductor, is a test that could provide a reliable diagnosis.[14] Pressure in the tarsal tunnel compartment was first measured by Kumar et al[13] in 1988 in living patients. Measurements were taken in the neutral position and with plantar and dorsal flexion of the ankle, obtaining values of 4 to 7 mm Hg, 10 to 15 mm Hg, and 15 to 20 mm Hg, respectively, using a water manometer.

In 1990, Trepman[4] measured tarsal tunnel pressures in cadavers, taking the measurements in neutral, supination, and pronation positions in the ankle and foot, obtaining the highest measurement in pronation, with a mean value of 32 ± 5 mm Hg (2-60 mm Hg). Rosson et al,[14] in 2009, performed measurements on cadavers in the tarsal tunnel and medial plantar and lateral plantar tunnels for different positions of the ankle and knee, obtaining the highest values with pronation. The values with cadavers were 1 to 33 mm Hg for the tarsal tunnel, 5 to 50 mm Hg for the medial plantar tunnel, and 0 to 56 mm Hg for the lateral plantar tunnel. With this study, Rosson et al[14] corroborated that, in compressive neuropathy of the tarsal tunnel, not only should the tibial nerve in the tarsal tunnel be decompressed, but also the lateral plantar and medial plantar tunnels for the lateral plantar and medial plantar nerve, respectively, because pressures are very high, even higher than in the tarsal tunnel, and patients with suspected TTS have higher pressures than those measured in the anatomical parts.[14] Both Rosson et al[14] and Trepman[4] used the same device, made by Stryker (Stryker 295 IntraCompartmental Pressure Monitor System, Quick Pressure Monitor Set, Stryker, Kalamazoo, MI).

The main objective of our study was to analyze the reliability of measurements of tarsal tunnel and medial and lateral plantar tunnel pressures before and after ultrasound-guided release. Measurements were taken during visits under ultrasound guidance to provide greater reliability. The authors understand that this has not been published before and could help surgeons in making a surgical decision. The second objective was to confirm the hypothesis that decompression using ultrasound-guided surgery as described by the authors in 2018 is technically effective, reducing pressure to the tarsal tunnel and medial and lateral plantar tunnels.[26]

Materials and Methods

This prospective, observational study was performed in accordance with the principles of the 1964 Declaration of Helsinki (2013 revision). All participants gave separate written informed consent in addition to standard surgical consent.

The study included 23 patients with symptoms compatible with idiopathic TTS. Of the 23 patients, 14 were women and 9 men, with an average age of 54 years and an average course of 31 months. The inclusion criteria were a clinical history of compressive neuropathy and a clinical examination positive for Hoffman-Tinel signs and Valleix phenomenon in all tunnels involved in the study. EMG studies were not considered a diagnostic criterion because these studies may provide abnormal results and frequently produce false negatives.[1,4,22] In those patients suffering from manifestations of symptoms compatible with proximal nerve lesions, such as spinal or other injuries, specific manual orthopedic tests and complementary tests such as MRI and EMG should be considered. The study used an E-CUBE 15 US machine with an L8-17X multifrequency linear transducer (Alpinion Medical System, Bothell, WA), the 295

Figure 1.

295 IntraCompartmental Pressure Monitor System (Stryker Instruments, Kalamazoo, MI).

IntraCompartmental Pressure Monitor System (Stryker Instruments, Kalamazoo, MI; Figure 1).

Ultrasound was used in each step of the study—for preoperative measurement during the visit, for surgery, and measuring pressure after surgery, where it ensured that the needle was inserted in the tunnel being studied and not elsewhere. The first step was to measure intracompartmental pressure of the tarsal tunnel, medial plantar tunnel, and lateral plantar tunnel during visits. Following Trepman[4] and Rosson et al,[14] the Stryker intracompartmental pressure monitor was used along with its specific consumables.

Unlike other studies, our measurements were ultrasound guided (Figure 2A) in the 3 tunnels studied: the tarsal tunnel (Figure 2B) at the flexor retinaculum for the tibial nerve, and in the distal tarsal tunnel, at the deep fascia of the hallucis abductor, in both the medial plantar tunnel, for the medial plantar nerve (Figure 2C), and the lateral plantar tunnel, for the lateral plantar nerve (Figure 2D).

Once the needle was in the compartment, as confirmed by ultrasound, the pressure monitor was set to zero, 0.1 mL of saline solution was injected into each compartment, and the measurement was taken. While doing this, it is essential not to lift or exert pressure on the probe, thereby ensuring that it does not exert pressure on the tissues, which would increase the pressure reading in the tunnels when injecting saline solution.

The position of the ankle and foot were measured in pronation, as described by other authors in their studies,[4,14] because this is the position in which pressure is highest and which simulates the patient standing. The measurement of the pressure would have been more real with the patient in a standing position. We made some attempts with patients, but it was not possible because this situation caused pain and fear to the patients and, therefore, they did not place the total load of their weight on the foot. The range of motion differed between patients, but the differences in pressures for every patient were significant and clearly recorded.

The second step was ultrasound-guided decompression of the tibial nerve and its branches using the technique described by the authors, in which in the distal tunnel, the deep fascia of the hallucis abductor muscle is released at 2 separated tracks—one for the medial and one for the lateral plantar nerve—rather than releasing the septa between them, following the steps of our previously described technique.[26]

Subsequently, pressure was measured again immediately after decompression in the 3 tunnels, obtaining very promising results that confirm the study hypothesis: the ultrasound-guided surgical technique described by Iborra et al[26] is reliable for decompression of the tibial nerve and its branches.

Results

In the following, we discuss the results obtained.

Predecompression Measurement

The mean result of the compartmental measurement before surgery was 59 mm Hg (39-78 mm Hg) for the tarsal tunnel. At the distal tarsal tunnel for the medial plantar tunnel, a mean of 95 mm Hg (74-132 mm Hg) was obtained. Measurement at the lateral plantar tunnel obtained a mean of 102 mm Hg (79-141 mm Hg; Table 1).

All patients underwent ultrasound-guided surgery of the proximal and distal tarsal tunnels, releasing the flexor retinaculum and deep fascia of the hallucis abductor for the medial and lateral tunnel.[26] The measurement was repeated after surgery (Figure 3).

Postdecompression Measurement

The mean results of postsurgery compartment measurement were 0.3 mm Hg (0-2 mm Hg) at the tarsal tunnel, 8 mm Hg (5-13 mm Hg) for the medial plantar tunnel, and 9 mm Hg (3-15 mm Hg) at the lateral plantar tunnel (Table 1).

Discussion

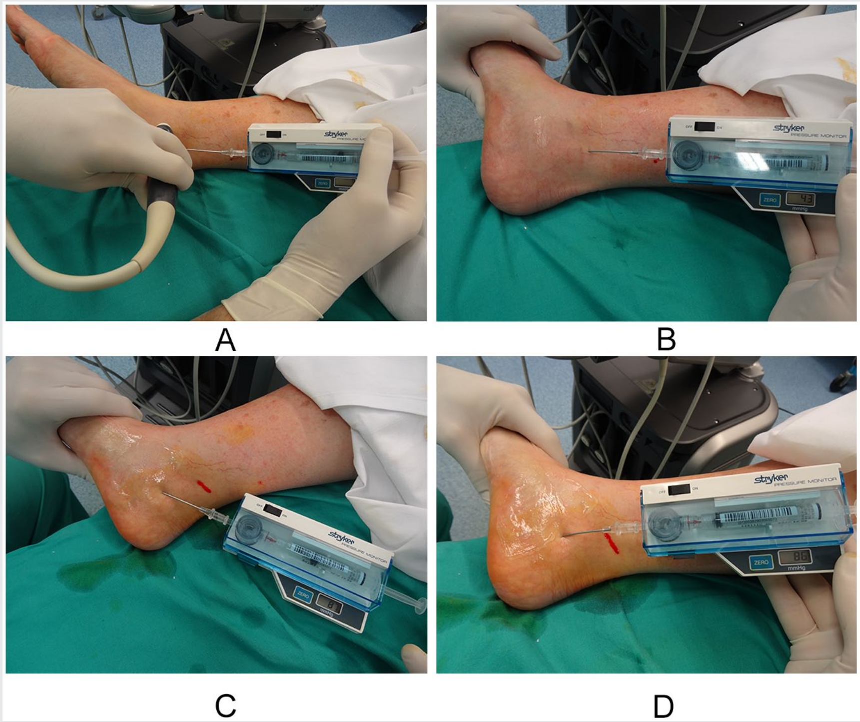
Compressive neuropathy of the tibial nerve and its branches is difficult to diagnose. It is highly dependent on the experience of the specialist[7] because there is no test that reliably diagnoses the condition, making clinical examination and history vitally important. Neurophysiological studies are unreliable and produced false negatives.[22]

Pressure in the proximal compartment (tarsal tunnel) and distal compartments (medial and lateral plantar tunnels) is a test that could provide a more reliable diagnosis. Measurement of the tarsal tunnel and medial plantar and lateral plantar tunnel compartments has been studied by several authors concluding that the position of maximum compression in the proximal and distal tarsal tunnel is with the foot in a maximally pronated position.

According to Kumar et al,[13] normal figures for the tarsal tunnel range from 15 to 20 mm Hg. Other authors report values of up to 32 mm Hg (Trepman[4]) or 33 mm Hg (Rosson et al[14]). However, measurement was not uniform in these studies, and ultrasound was not used to increase reliability in positioning the measurement needle. Furthermore, only the study by Kumar et al[13] used patients, whereas the other 2 studies were on fresh cadavers. Despite these limitations, 33 mm Hg may be taken as a maximum pressure parameter for the proximal tarsal tunnel

Figure 2.

Ultrasound-guided measurement (A), measurement in the tarsal tunnel under the flexor retinaculum (B), measurement in the medial plantar tunnel (C), and measurement in the lateral plantar tunnel (D).



over which the nerve could be suffering compression. For the distal tarsal tunnels, the authors found only the Rosson et al[14] study, performed on cadavers, marking a normal pressure range of 5 to 50 mm Hg for the medial plantar tunnel and 0 to 56 mm Hg for the lateral plantar tunnel. Therefore, a maximum normal pressure in the medial plantar tunnel and lateral plantar tunnel of 50 and 56 mm Hg, respectively, may be considered as a starting reference point.

In our study, the mean measurement in all patients was 59 mm Hg (39-78 mm Hg) for the proximal tarsal tunnel (tibial nerve). The measurements were taken with pronation position of the foot and ankle but were much higher than the 33 mm Hg described by Trepman[4] and Rosson et al.[14] For the medial plantar tunnel (medial plantar nerve), the mean pressure was 95 mm Hg (78-132 mm Hg), well above the 50 mm Hg measured as normal by Rosson et al. For the lateral plantar tunnel (lateral plantar nerve), the mean pressure was 102 mm Hg (79-141 mm Hg), well above the 56 mm Hg measured as normal by Rosson et al. After surgery, the mean values dropped to 0.3 mm Hg (range 0-2 mm Hg) in the proximal tarsal tunnel, 8 mm Hg (5-13 mm Hg) in the medial plantar tunnel, and 9 mm Hg (3-15 mm Hg) in the lateral plantar tunnel.

In our opinion, this study provides the following:

- an additional tool for diagnosing a complex condition, which is possibly underdiagnosed and undertreated;
- a precise diagnostic tool, in real patients, to measure pressure in the proximal and distal tunnels, under ultrasound guidance. To the best of our knowledge, this is the first study to measure distal, medial and lateral tunnel pressure in real patients under ultrasound guidance; and
- a validation of effective decompression with ultra–minimally invasive surgery of the tibial nerve and its branches in TTS using the described technique.

Some of the limitations to our study are as follows:

1. Further studies such as this are needed to determine a range of normality in normal and pathological pressures in real patients, always with the precision of ultrasound guidance in positioning the needle.
2. Intracompartmental pressures in real life may differ, depending on other factors, such as standing time, walking or staying still, and footwear, but pressures before and after surgery and the values obtained confirm a pathological preoperative state and decompression that is at least static and effective after surgery.

Table 1.

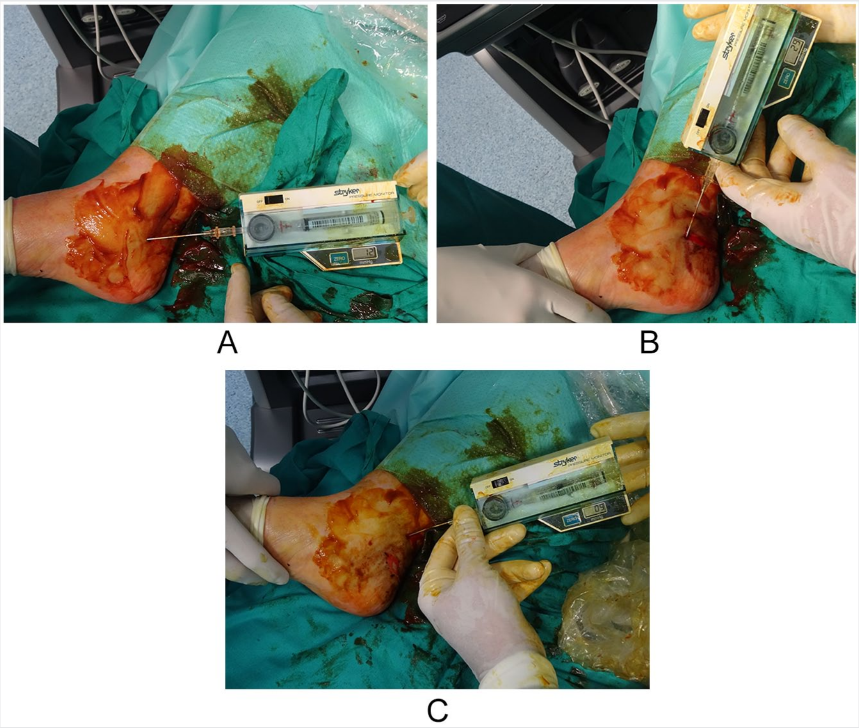
Predecompression (Pre) and Postdecompression (Post) Measurement (mm Hg).

Patient Number	Tarsal Tunnel (Pre)	Tarsal Tunnel (Post)	Medial Plantar Tunnel (Pre)	Medial Plantar Tunnel (Post)	Lateral Plantar Tunnel (Pre)	Lateral Plantar Tunnel (Post)
1	46	2	89	9	97	7
2	62	1	93	7	89	5
3	74	0	88	8	102	5
4	43	0	102	7	113	8
5	39	1	108	6	123	11
6	62	1	121	8	131	13
7	67	0	74	11	98	7
8	48	1	83	13	88	9
9	52	1	89	8	93	6
10	58	0	79	7	98	9
11	71	0	78	11	104	7
12	54	0	104	8	85	14
13	69	0	86	7	79	12
14	77	0	84	9	94	13
15	49	1	91	6	111	9
16	48	1	83	7	97	7
17	61	0	97	9	99	8
18	78	0	92	5	107	5
19	58	0	111	7	124	9
20	67	0	109	8	93	11
21	64	0	116	5	88	15
22	49	0	132	7	141	12
23	74	0	87	12	94	9
	59.56521739	0.391304348	95.47826087	8.043478261	102.0869565	9.173913043

There was no follow-up on pressure because the study required only confirmation of the effectiveness of the ultrasound-guided decompression technique in reducing pressures. It may be concluded, as with Rosson et al[14] in their open surgery study, that the ultrasound-guided surgical technique to release the tibial nerve and its branches is effective, significantly reducing pressure in the tunnels and thereby decompressing the nerves. Ultrasound could open the door to other valuable but as yet unknown tests, such as perineural infiltration, to alleviate symptoms or measurement of intracompartmental pressure with reliable positioning of the needle. The study of intracompartmental pressure appears to be a useful tool in diagnosing proximal and distal TTS,

Figure 3.

Ultrasound-guided postsurgery measurement of the lateral plantar tunnel (A), medial plantar tunnel (B), and tarsal tunnel (C).



and the results from this study support its routine use in clinical practice.

Declaration of Conflicting Interests

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Ethical Approval

Not applicable, because this article does not contain any studies with human or animal subjects.

Informed Consent

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Trial Registration

Not applicable, because this article does not contain any clinical trials.

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