

## Technique Protocol

# High volume injection (hydrodissection) for tarsal tunnel syndrome using peripheral nerve stimulation: treatment protocol

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### Abstract

Tarsal tunnel syndrome is a focal compressive neuropathy of the posterior tibial nerve or one of its associated branches. Brief mention is made in the literature of the use of corticosteroid injections for this condition. The basic technique of hydrodissection is used for other nerve entrapments and includes identifying the region of nerve compression, and the injection of a fluid medium to dissect between structures or fascial planes. We introduce our treatment protocol using a methylprednisolone/sterile water/ropivacaine hydrochloride injectate mix and peripheral nerve stimulation to perform hydrodissection technique for tarsal tunnel syndrome.

Level of clinical evidence: V (expert opinion).

**Keywords:** tarsal tunnel syndrome, compression neuropathy, high volume injection, hydrodissection, hydrodilataion, nerve stimulator

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### 1. Introduction

Abouelelaa and Zohiery (2012) define tarsal tunnel syndrome (TTS) as a focal compressive neuropathy of the posterior tibial nerve or one of its associated branches, individually or collectively. Keck (1962) and Lam (1962) separately described and named the condition in the same year though Von Malaise had previously discussed the same symptomatology in 1918. The presentation of TTS is an insidious onset of neuralgic heel pain, typically unilateral, aggravated by activity and relieved by rest. This may present as poorly localized paraesthesia, dysesthesia and/or hyperaesthesia radiating from the retro-malleolar region to the sole, heel or forefoot, or a combination of these areas (Brown et al, 2016; McSweeney & Cichero, 2015). In the later stages, wasting of the intrinsic muscles might be seen (Williams & Robinson, 2009). TTS may have multiple causes such as thickening of the flexor retinaculum, bone compression or intra-tunnel pathologies (such as flexor tenosynovitis), cysts and other soft tissue masses, accessory muscles or vein-related pathology (Fantino et al, 2020). Diagnosis is based on the clinical history and physical examination findings, including a positive Tinel sign at the tarsal tunnel, which can be confirmed with magnetic resonance imaging (MRI)

to identify space occupying lesions (SOLs) and nerve conduction studies (Urits et al, 2020). Ahmad et al (2012) and McSweeney and Cichero (2015) provide useful narrative overviews of the condition.

Brief mention is made in the literature of the use of corticosteroid injections (CSIs) for TTS (see Fig. 1) as part of an overall treatment strategy (Antoniadis & Scheglmann, 2008; Edwards et al, 1969; Ferkel et al, 2015; Furr-Stimming et al, 2016; Mondelli et al, 1998; Perera et al, 2017; Reilly, 2010, Sofka et al, 2001; Sun et al, 2020; Tallia & Cardone, 2003; Vilaça, 2019). These are level V studies (or lower) and have varying detail on the descriptive technique of the injection (see discussion section). Ahmad et al (2012) suggest that corticosteroid injections may be sufficient to reverse any intraneural oedema. Urits et al (2020) postulate that injection therapy can provide a bridge to surgery but notes that no randomized controlled studies have been conducted, possibly because of the low incidence of the condition and the high frequency of surgical release.

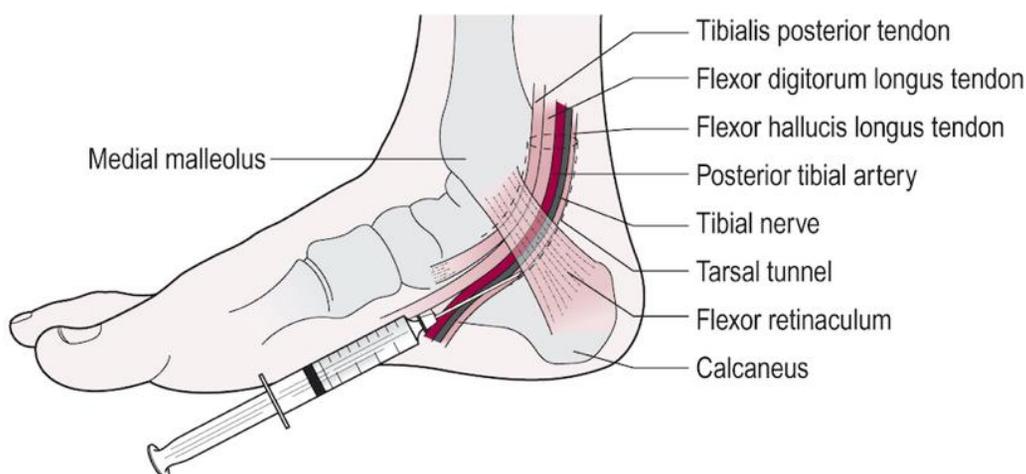


Figure 1: TTS injection (Reilly, 2010)

The basic technique of hydrodissection (high volume injection [HVI]) includes identifying the region of nerve entrapment or compression and the use of a fluid medium, usually local anaesthetic and/or saline, to dissect between structures or fascial planes (Beard & Gousse, 2018; Cass, 2016; Delzell & Patel, 2020; Lam et al, 2020). Pathological nerves can be identified by examination or ultrasound visualisation (Fernández-Gibello, 2019). Our team performs palpation-guided, ultrasound-guided and nerve stimulator-guided blocks for regional anaesthesia. We have performed TTS injections as detailed below using all these techniques but have found that the use of nerve stimulation to be the most effective for TTS hydrodissection. We present our treatment protocol for hydrodissection using a corticosteroid/local anaesthesia/sterile water mix.

### Anatomy

The tibial nerve (TN) is the major continuation branch of the sciatic nerve. After its division from the peroneal nerve above the popliteal fossa, the TN travels through the posterior

leg between the two heads of the gastrocnemius, supplying the muscles in the posterior compartment to reach the posteromedial ankle (Madani et al, 2020; Perera et al, 2017). It enters the tarsal tunnel (TT) - also known as the tibio-calcaneal tunnel, calcaneal tunnel or Richet's tunnel (Fernández-Gibello, 2019) - a fibro-osseous space located deep to the flexor retinaculum (FR) and postero-inferior to the medial malleolus. The FR (also known as the medial annular or lacinate ligament) is formed by two layers: a superficial and a deep layer, with an anteriorly oriented apex and an inferior base along the superior border of the abductor hallucis muscle (Fernández-Gibello, 2019). The contents of the TT from anterior to posterior are the tibialis posterior (TP) tendon, the flexor digitorum longus (FDL) tendon, the posterior tibial artery and two veins, the TN, and the flexor hallucis longus (FHL) tendon. The TN passes on the posterolateral side of the tibial vessels. The first branch off the TN is the medial calcaneal nerve (MCN) and is often spared in cases of TTS (Craig, 2010). The TN terminates by dividing into medial and lateral plantar nerves (MPN/LPN) (see Fig. 2) (Soneji & Peng, 2016; Urits et al, 2020).

The distal margin of the tunnel is referred to as the abductor canal or porta pedis: the door to the foot. It is narrow in width and merges with both the superficial and deep fascia of the abductor hallucis muscle (McSweeney & Cichero, 2015). The medial plantar neurovascular bundle penetrates the upper calcaneal chamber, and the lateral plantar neurovascular bundle penetrates the lower calcaneal chamber, which communicate with the intermediary central compartment of the sole of the foot (Sarafian & Kelikian, 2011).

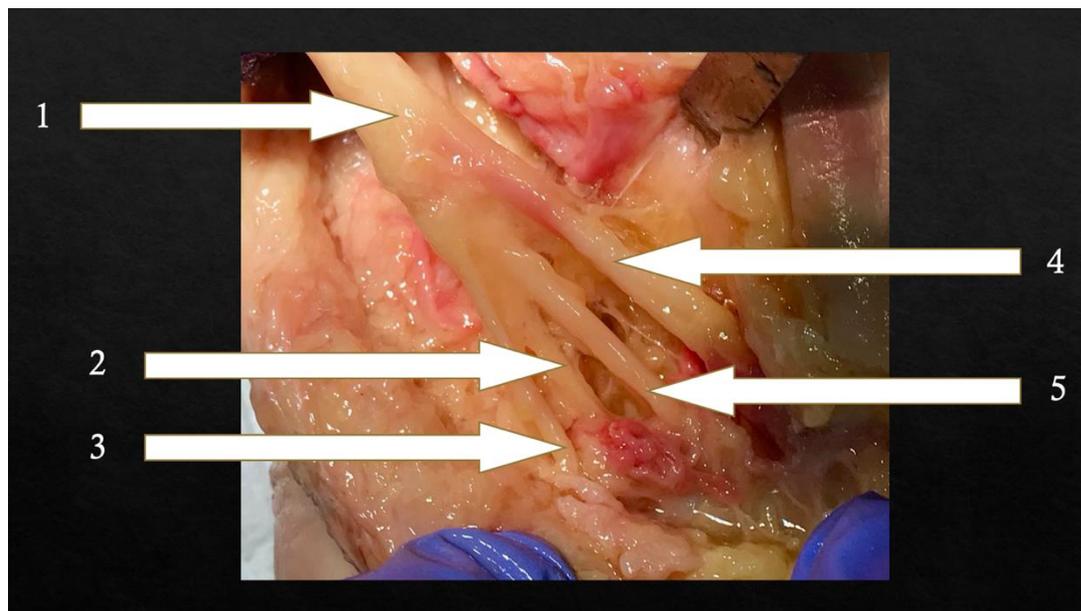


Figure 2: cadaveric anatomy of the postero-medial compartment, left foot.  
Legend: 1 TN, 2 ICN, 3 MCN, 4 MPN, 5 LPN (dissection by Mr G. Flanagan)

The MPN accompanies the medial plantar artery lying on the lateral side of the vessel. It passes deep to abductor hallucis and sends a digital nerve to the medial side of the 1<sup>st</sup> toe and three branches to supply adjacent sides 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>, and 4<sup>th</sup> toes. The LPN passes forward with the lateral plantar artery and lies on the medial side of the vessel reaching the lateral side of the

foot at the base of the 5<sup>th</sup> metatarsal. It splits into a superficial and deep branch. The superficial divides to supply the lateral side of the 5<sup>th</sup> toe and the adjacent sides of the 4<sup>th</sup> and 5<sup>th</sup> toes. The deep branch accompanies the lateral plantar artery and supplies, with the superficial branch, all the remaining small muscles on the sole of the foot (Percival, 2001).

### Nerve stimulators

Action potentials are generated when a stimulus of a sufficient intensity leads to depolarisation of the nerve membrane of excitable cells, such as peripheral nerves (Malamad, 2019). A peripheral nerve stimulator (PNS) is an artificial means of generating an action potential. These devices work by supplying electrons to depolarise the nerve. The number of electrons supplied per stimulus equals the current output of the nerve stimulator. The greater the current output the greater the potential for the nearby nerve to become depolarised thus evoking contraction of the muscle supplied by that particular nerve. As the needle to nerve distance decreases depolarisation will occur at progressively ampage (in a non-linear manner) from lower current outputs (Metcalf, 2010). PNS's were the primary nerve-seeking device in the decades preceding widespread use of ultrasound (US) guidance. With the introduction of US, however, the role of nerve stimulators has changed for many clinicians from nerve seeking to monitoring needle-nerve contact or intraneural needle tip placement (Ip & Tsai, 2021).

## 2. Search Strategy

For this paper, the authors performed a literature search around injection therapy for TTS. We adopted a strategy that involved searching for research evidence via three different sources:

1. Electronic databases - healthcare databases advanced search (HDAS)
2. Google scholar
3. Reference lists

Databases: AMED (Allied and Complementary Medicine, 1985 - present), CINAHL (Cumulative Index to Nursing and Allied Health Literature: 1981 - present), Embase (Excerpta Medica Database, 1974 - present), MEDLINE (Medical Literature Analysis and Retrieval Online, 1946 - present). Additionally, NYSORA (New York School of Regional Anaesthesia) and hand searches of the Journal of Foot and Ankle Surgery, the Journal of Foot and Ankle Research (unlimited to date restriction) were searched. Keywords used were: 'tarsal tunnel syndrome', (with searches limited to humans) with Boolean operators AND for 'injection' OR 'hydrodissection'. See reference list.

## 3. Technique

As indicated above, our team performs palpation-guided (see Figs. 3 and 4), ultrasound-guided and nerve stimulator-guided high-volume injections prior to surgery; and after conservative measures have been tried and failed, or are not indicated.



Figures 3 and 4: palpation-guided HVI injection at the porta pedis (here with a 10ml syringe)

The basic technique for HVI performed under aseptic non-touch technique (ANTT) using PNS is presented in table 1 below, based on the regional anesthetic block technique of Metcalfe (2010). The injectate is comprised of 40mg of methylprednisolone mixed with 10ml 0.75% ropivacaine hydrochloride and 10ml of sterile water (see Fig. 5) to a total of 20ml. 10ml 0.5% levobupivacaine hydrochloride can be substituted for ropivacaine hydrochloride. The use of sterile saline reduces the overall anaesthetic dose given.



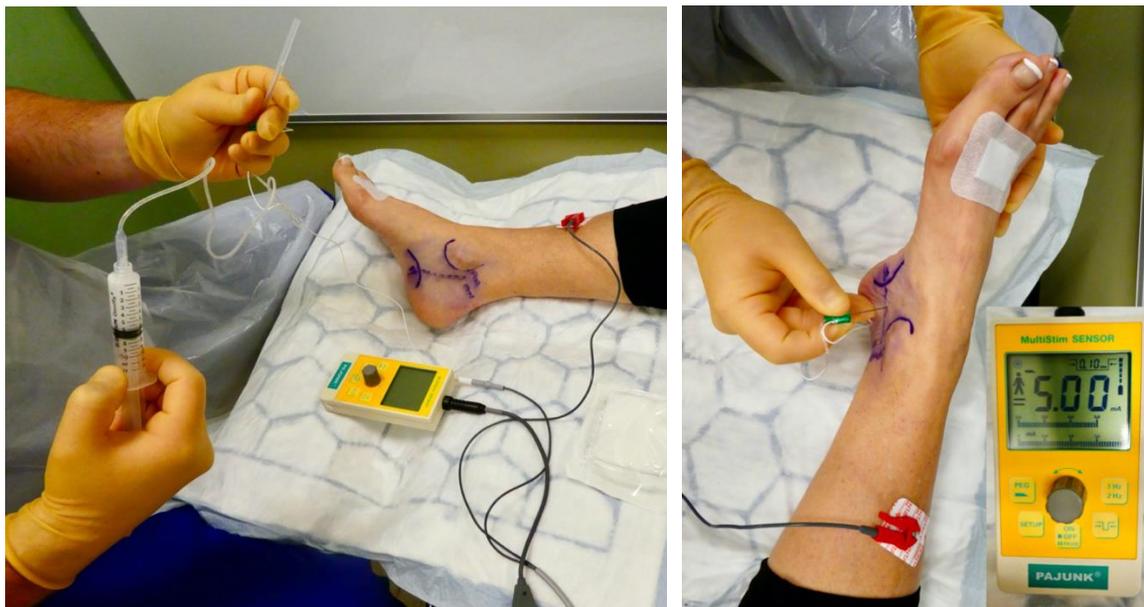
Figure 5: methylprednisolone, sterile water and 0.75% ropivacaine hydrochloride injectate mix

STEP	PROCESS
<b>STEP 1</b>	Equipment: <ul style="list-style-type: none"> <li>• ANTT equipment (gloves, skin disinfectant, dressing, etc)</li> <li>• Injectate drawn into a 20ml syringe</li> <li>• ECG pad(s)</li> <li>• Nerve stimulator and leads (see Fig. 6)</li> <li>• Pole (insulated) needle (see Fig. 7)</li> </ul>
<b>STEP 2</b>	Position the patient and ensure the equipment is close at hand ready connected (see Fig. 8). Mark up the points of maximal tenderness (PMTs) – proximal, mid or distal (esp. at the porta pedis) of the tarsal tunnel. Skin preparation is performed using chlorhexidine or iodine according to local policy.
<b>STEP 3</b>	Introduce the pole needle through the skin with nerve stimulator off using aseptic non-touch technique (see Fig. 9).
<b>STEP 4</b>	Advance the needle toward the nerve with the nerve stimulator output set at 5mA (see Fig. 9, inset). As one approaches the nerve, motor stimulation is seen by contraction of the toes.
<b>STEP 5</b>	The output is gradually reduced whilst gently moving the needle to achieve maximal motor response with minimal unit output - approximately 0.5mA (see Fig. 11).
<b>STEP 6</b>	Aspirate to ensure that the needle is not intra-vascularly placed, prior to injecting 5-7ml solution as a bolus.
<b>STEP 7</b>	Repeat pro re nata (PRN) to all PMTs. This might be one to four infiltrations dependent on the individual presentation. As per our typical regional blockade technique, the patient is given general information on rest, avoidance of driving, and departmental contact details in the case of clinical emergency (syncope, bleeding, pain, etc).

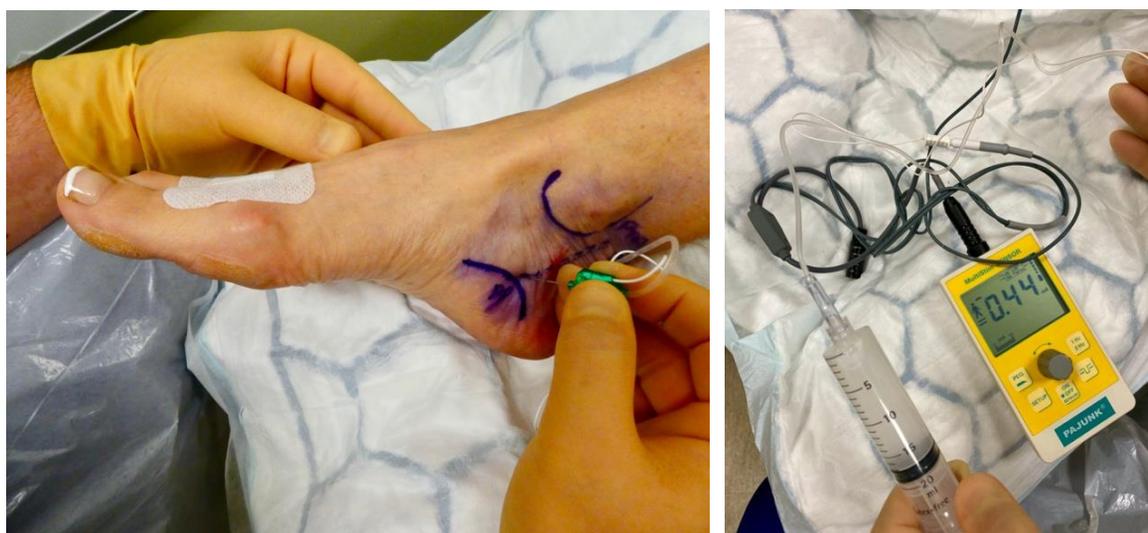
Table 1: basic technique for use of a PNS adapted from Metcalfe (2010)



Figures 6 and 7: Pajunk PNS and pole needle



Figures 8 and 9: patient positioning and needle entry to PMT  
(nb the 2<sup>nd</sup> toe metatarso-phalangeal joint required a CSI for a separate pathology)



Figures 10 and 11: TTS HVI technique using PNS

#### 4. Discussion

Ahmad (2012), Doneddu et al (2017), Lau and Stavrou (2004) and Williams and Robinson (2009) consider that TTS is a rare condition, but one that is regularly under-diagnosed, and can lead to a range of symptoms affecting the plantar margins of the foot. Its rarity has not been our experience. As experienced clinicians in the management of heel pathology we see TTS overlapping with - or misdiagnosed for - many cases referred in with an apparent

presentation of plantar fasciopathic heel pain. This is recognised by others who discuss the triad combination of plantar fasciitis, posterior tibial tendon dysfunction and TTS (Labib et al, 2002).

Reviewing the local anatomy, four fibrous septa emerge from the interior surface of the flexor retinaculum. They each create an independent channel that allows leg structures to transition to foot structures. The third channel from medial to lateral contains the nerve and vascular structures (Lau & Stavrou, 2004). Singh and Kumar (2012) described the dorsal extension of the medial border of the plantar fascia (i.e., the deep fascia of the abductor hallucis muscle) as the medial septum. All these serve as barriers for accurate needle placement. Further, there is significant variability of the local anatomy. Dellon and Mackinnon (1984) describe a high neuro-anatomical variability of the tibial nerve and its branches. Moroni et al (2019) have mapped the tarsal tunnel with regard to Baxter's neuropathy of the inferior calcaneal nerve (ICN). Awadelseid (2019) found that the course of the medial calcaneal nerve (MCN) is also subject to variability, with many branching pattern variations, specifically concerning origins, numbers, and levels of branching. These variations lead to different distribution of patho-sensory display which then presents a diagnostic challenge to the clinician.

A solid anatomical understanding and thoughtful approach is therefore required for injection therapy (Hansford et al, 2019). Iborra et al (2019) found that high resolution US could delineate the anatomic course of the nerves and vessels in the medial ankle but note that the experience and skills of the examiner, and quality of the US machine, are important. This is where we feel PNS offers an alternative for providing feedback on nerve location. Further, we find that approximately 80% of entrapment occurs more distally in the tarsal canal at the porta pedis. Although TTS classically refers to the proximal tarsal tunnel, Lau and Stavrou (2004) note that failure to take the existence of the distal tarsal tunnel into account can lead to poor results with therapy.

Buchanan et al (2014) showcased a right medial and lateral plantar nerve hydrodissection - US-guided - with 100% symptom relief but relatively little attention and even less detail appear in the literature regarding injection techniques. Doty et al (2006) and Kapoor (2017) describe PNS TTS injection techniques. Mondelli et al (1998) treated nine patients with TTS with local steroid injections, with good results shown in 6 patients. Sobey and Franklin (2016) describe an ultrasound-guided tibial nerve block for definitive treatment of TTS in a paediatric patient. Sofka et al (2001) describe in the injection of posterior TTS using ultrasonographic guidance for therapeutic treatment of tarsal tunnel cysts compressing on the TN. Reilly's earlier work (2010) for CSI is presented in table 2. Tallia and Cardone (2003) provide one of the more detailed accounts of the injection technique:

*“with the patient in the lateral recumbent position with the affected foot down, the maximal point of tenderness is identified. 2cm proximal to the this a 25g needle is inserted at an angle of 30 degrees to the surface of the skin and directed distally. The final needle depth will be determined by the amount of subcutaneous tissue. The physician should aspirate before injecting to ensure that the needle is not in an artery or a vein and 0.5ml of Celestone or 0.5mL or Solumedrol is slowly injected”.*

<b>Anatomy</b>	The <i>tarsal canal</i> is located behind and under the medial malleolus and becomes the <i>tarsal tunnel</i> as a result of the flexor retinaculum (lacinate ligament) passing over the structure and creating a closed space. The flexor retinaculum blends with the plantar fascia. Tension on the plantar fascia (pronation) may affect the tension on the retinaculum and alter the volume of the tunnel. Four fibrous septa emerge from the interior surface of the flexor retinaculum. The third channel, counting from medial to lateral, contains the nerve and vascular structures. The (bifurcated) nerve enters the foot at the abductor canal, traditionally referred to as the <i>porta pedis</i> .
<b>Pathology</b>	Tarsal tunnel syndrome describes an entrapment or compressional neuropathy of the tibial nerve in the posterior medial compartment of the foot. Signs and symptoms include paraesthesia in the sole of the foot and Tinel's sign elicited by tapping of the course of the nerve. A positive outcome may be seen from diagnostic nerve studies. Use of steroid injection, must, as always, be used as part of an overall treatment plan and is also used with respect to the underlying cause. For instance, tarsal tunnel can present secondary to hyper-pronation or trauma and the underlying cause should always be addressed where possible.
<b>Equipment</b>	2.5 or 5mL syringe using a 25mm (1 inch) 23G (blue) needle.
<b>Drug(s)</b>	40mg of methyl-prednisolone mixed with local anaesthetic.
<b>Positioning</b>	The patient is positioned sitting up or supine, depending on patient preference.
<b>Technique</b>	Typically, there is a point of maximum tenderness. My preference is for 30-40mg of methyl prednisolone injected into the point of maximum tenderness. Visualise the course of the posterior tibial tendon which should be avoided.
<b>Comments</b>	Warn the patient that they will develop numbness in the plantar foot.

Table 2: standard TTS CSI technique (Reilly, 2010)

McSweeney and Cichero (2015) note that while there are many intervention strategies for treating TTS there is limited robust evidence to guide the clinical management of this condition. They posit that the role of conservative versus surgical interventions at various stages of the disease process remains unclear, and there is a need for a structured, stepwise approach in treating patients with this condition, based on derived empirical evidence. Routinely, our team employ conservative therapies before recommending a surgical solution and PNS-guided, high volume (hydrodissection) injection therapy has proved a useful adjunct on top of basic conservative care.

As indicated in the acknowledgements, we thank our colleague, George Flanagan, for bringing the PNS-guided technique to our attention. We understand that this technique has been performed by all the podiatric surgeons in the UK for some time, but we are not aware of it being recorded elsewhere in the literature. Inspired by the work of Chan et (2008), we follow their HVI protocol for Achilles tendon injections and add corticosteroid to the local anaesthetic injectate. We hypothesise that this augments pure hydrodissection by adding an anti-inflammatory effect. We have been regularly performing TTS hydrodissection for the last three years and have been impressed by the outcomes. We are not aware of any complications (such as neurapraxia or local anaesthetic toxicity) occurring in our caseload. Consequently, the numbers of surgical decompressions we perform has reduced. We acknowledge this is a level 5

article with limited data to support our protocol. Indeed Cass (2016) states that despite the widespread use of hydrodissection techniques, there is a paucity of high-quality data to determine its effectiveness with most available research consisting of case reports or retrospective studies. While the available research demonstrates that HVIs could be effective, there is often lack of control group, randomization or blinding. Having developed the technique to a level we feel confident to present in this paper, our aim going forward is to produce a prospective case series with pre- and post-intervention pain scores, which we envision will be the subject of a further publication. After that more rigorous scientific inquiry would be necessary.

This article provides the treatment protocol we use for TTS, but we have also used it on isolated Baxter's neuropathy and MCN entrapment, with fair to good results (see Fig. 12). Further instructional videos can be found on YouTube/Podsurgeon.



Figure 12: MCN steroid injection (<https://www.youtube.com/watch?v=YakmljH7qwA>)

## 5. Conclusion

TTS is an underdiagnosed and overlooked cause of heel pain, with most cases in our experience located more distally in the porta pedis. Use of corticosteroid injections has been reported by various authors but with no high-level investigation. Hydrodissection is done for a number of nerve entrapments and here we introduce our version of a treatment protocol using a HVI technique, in combination with peripheral nerve stimulation, as a conservative treatment approach to this somewhat troublesome condition. Our aim is to design future higher powered perspective studies to produce more quantitative outcome data.

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## 7. Declarations

**Author Contributions:** IR conceived the aim and format of the paper. IR performed the literature search and produced the first draft. Both authors made substantial contributions to the final version.

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