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Magnetic Resonance Imaging Findings in Patients with Tarsal Tunnel Syndrome

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Abstract

Tarsal tunnel syndrome (TTS) is a common entrapment syndrome whose diagnosis can be difficult. We compared preoperative magnetic resonance imaging (MRI) and operative findings in 23 consecutive TTS patients (28 sides) whose mean age was 74.5 years. The 1.5T MRI sequence was 3D T2* fat suppression. We compared the MRI findings with surgical records and intraoperative videos to evaluate them. MRI- and surgical findings revealed that a ganglion was involved on one side (3.6%), and the other 27 sides were diagnosed with idiopathic TTS. MRI visualized the nerve compression point on 23 sides (82.1%) but failed to reveal details required for surgical planning. During surgery of the other five sides (17.9%), three involved varices, and on one side each, there was connective tissue entrapment or nerve compression due to small vascular branch strangulation. MRI studies were useful for nerve compression due to a mass lesion or idiopathic factors. Although MRI revealed the compression site, it failed to identify the specific involvement of varices and small vessel branches and the presence of connective tissue entrapment.

Keywords: MR image, surgery, tarsal tunnel syndrome, nerve compression, plantar nerve

Introduction

Entrapment neuropathy of the posterior tibial nerve at the tarsal tunnel is called tarsal tunnel syndrome (TTS). Its symptoms are sole numbness, pain, and a cold sensation; they affect the patient's quality of life.[1-5] Symptomatic TTS due to space-occupying lesions such as ganglions or schwannomas is identified on diagnostic images. Idiopathic TTS elicited by physiological changes is diagnosed when the disease is attributable to adhesions due to trauma, distortion of an artery, dilation of a vein, or hypertrophy of the flexor retinaculum.[1,2,6] Entrapment is often idiopathic.[2,7,8] Electrophysiologic studies may render a TTS diagnosis; however, their diagnostic sensitivity is uncertain, and TTS cannot be ruled out when the findings are negative.[1,9-14] Consequently, there is no gold standard examination, and the diagnosis and treatment of TTS tend to be based on clinical findings.[6,10,14]

Doneddu et al.[10] suggested diagnostic imaging was more useful for diagnosing TTS than other nerve entrapments, e.g., carpal tunnel syndrome, that can be evaluated in both electrophysiological- and diagnostic imaging studies. High-resolution ultrasound and magnetic resonance imaging (MRI) are used to identify space-occupying lesions and anatomical findings in the tarsal tunnel.[6,15-18] High-resolution ultrasound studies are less costly than MRI but require reading by experienced pathologists. Under certain conditions, MRI findings can be reproduced easily and evaluated objectively.

Elsewhere,[18] we suggested the potential value of MRI for the visualization of nerve compression in patients with idiopathic TTS. We compared operative- and preoperative

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MRI findings in TTS patients in the current study.

Materials and Methods

This study was performed according to the tenets of the Declaration of Helsinki and was approved by the ethics committee of Chiba Hokuso Hospital, Nippon Medical School (No. 947). All patients provided prior written informed consent for the surgery. Written informed patient consent for inclusion in this study was waived due to its retrospective nature but an opt-out option was available on our hospital's homepage.

Between November 2019 and October 2021, we operated 24 consecutive TTS patients (29 sides). One patient was excluded from this study due to the earlier implantation of a pacemaker. The other 23 patients (28 sides) underwent preoperative MRI studies. They were 12 males and 11 females (average age 74.5 ± 7.8 years, range 54 to 86 years); the affected side was unilateral in 18 and bilateral in 5 patients; 13 lesions involved the right- and 15 on the left side. All patients presented with TTS symptoms such as numbness, pain, coldness, or a foreign-body sensation. On 25 sides, we detected a Tinel-like sign at the tarsal tunnel. We measured the sensory nerve conduction velocity at the tarsal tunnel; a positive finding was recorded when the terminal latency of the abductor hallucis muscle exceeded 5.8 ms and the difference in the side-to-side amplitude was more than 50%.[7,19]

Imaging was performed on a 1.5T MRI scanner (Brivo MR355, GE Healthcare Japan) using a 3-inch surface coil and a T2* fat suppression 3D sequence (TR: 44 msec, TE: 10 msec, slice thickness: 1.5 mm, matrix: 256 × 192, FA: 15°, FOV: 17 cm, BW: 15.63 kHz).[18] All scans were acquired simultaneously with both feet in neutral ankle position. We checked for the presence or absence of compression to the posterior tibial nerves (medial and lateral plantar nerves) and investigated factors responsible for TTS-eliciting. Nerve compression was recorded when at least 50% of the nerve diameter was compressed. Two experienced neurosurgeons (KK and RK) proficient in diagnosing and treating TTS and blinded to the surgical findings evaluated the MRI findings and compared them with the surgical records and intraoperative videos.

To evaluate the surgical outcomes six months postoperatively, we used the numerical rating scale (NRS); the scores assigned to the severity of persistent symptoms ranged from 0 to 10. Statistical analysis was done with IBM SPSS for Windows ver. 25.0 (IBM Corp., Armonk, NY, USA). For comparison studies, we employed the Wilcoxon signed-rank test; differences of $p < 0.05$ were considered statistically significant. All values are expressed as the mean ± standard deviation.

Results

MRI findings on the nerves and vessels in the tarsal tunnel

In order to visualize the nerves in the tarsal tunnel, axial images are useful.[20] The medial and lateral plantar nerves were slightly hyper-intense with our T2* fat suppression sequence. The posterior tibial artery and vein complex, located at a shallower layer than the nerves, were more hyper-intense than the nerves. The posterior tibial artery is usually seen as sandwiched by veins, and its course is tortuous. As it can be difficult to distinguish this artery from veins based on its intensity on single-slice images, we confirmed its tortuosity in 3 directions on consecutive slices.

Comparison of preoperative MRI- and intraoperative findings

On one of the 28 sides (3.6%), a ganglion was involved. The nerve was decompressed by removing the ganglion with the patient under general anesthesia. The diagnosis on the 27 other sides was idiopathic TTS based on both MRI- and surgical findings. On 18 sides, single-site nerve compression was identified, and two compression sites were observed on nine sides. Postoperatively the NRS in all patients fell from 6.8 ± 1.2 to 2.8 ± 1.4 ($p < 0.05$).

Among the 18 sides with single-site compression, 14 revealed well delineated tortuosity of the posterior tibial artery as the TTS-eliciting factor on MRI scans (Fig. 1). Surgery under a microscope was performed under local anesthesia. We made a 25-mm bow-like skin incision on the tarsal tunnel, opened the flexor retinaculum, and decompressed the nerve by repositioning the posterior tibial artery in the tarsal tunnel. We cauterized or cut small arterial branches and veins to move the vessel when needed. Surgical findings indicated nerve compression was due to arterial tortuosity; arterial pulsation was transmitted directly to the nerve in a hammer-like motion. To prevent recurrent nerve compression, we transposed the posterior tibial artery to the side of the medial malleolus. We sutured it to the superficial part of the flexor retinaculum using a 4-0 nylon suture.[7]

MRI failed to show the TTS-eliciting factor in 4 of the 18 sides with single-site nerve compression. Surgical findings indicated that a varix was involved on three sides (Fig. 2); the varix-bearing vessel and the affected artery were transposed for nerve decompression. Connective tissue entrapping the nerve on the 4th side with single-site nerve compression was cut for nerve decompression (Fig. 3).

Among nine sides with two compression sites, eight were compressed at both sites by the tortuous artery. On one side each, simultaneous compression at the proximal and distal portions of the tortuous artery was found. The compression sites were well delineated on MRI scans. On

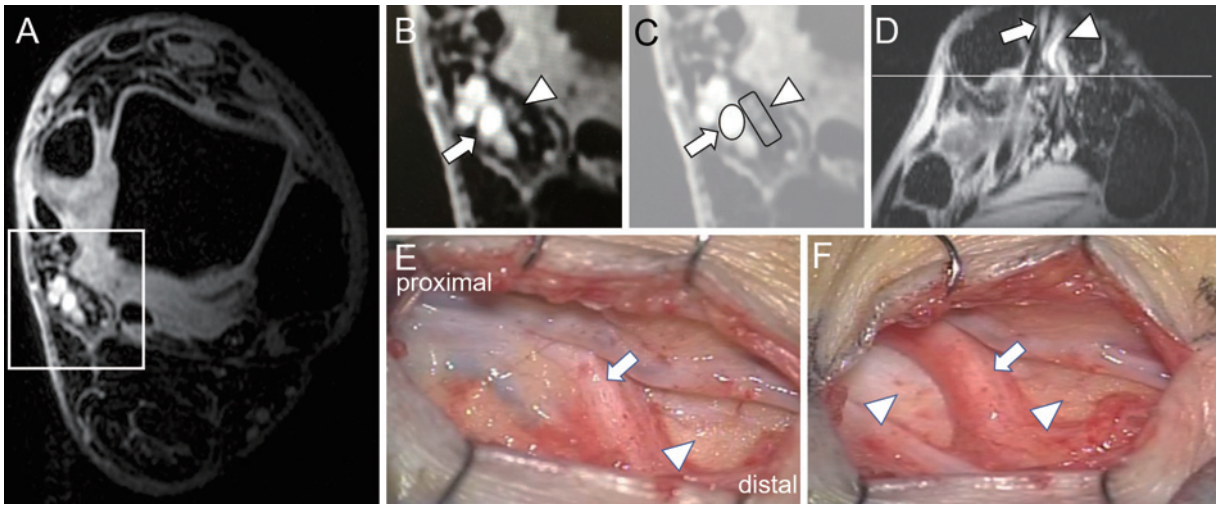

Fig. 1
A-D T2 fat suppression MR images. The axial image (B) shows that 53.6% of the nerve diameter (arrow head) is compressed by the posterior tibial artery (arrow).
A Axial image; the rectangle indicates the range of B and C.
B, C Enlarged axial image.
D Sagittal image.
(E, F) Intraoperative photographs of left-sided tarsal tunnel syndrome. The tortuous artery (arrow) compresses the nerve.

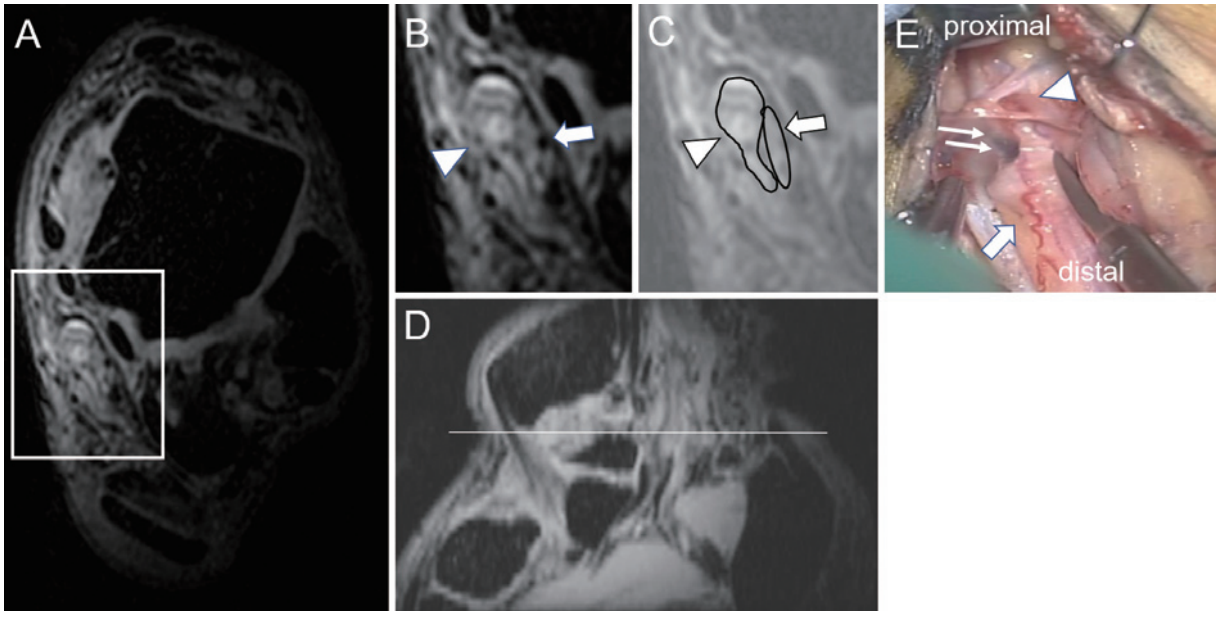

Fig. 2
A-D T2 fat suppression MR images. The axial image (B) shows that the nerve (arrow) is compressed but details on the compression factor (arrowhead) are not clearly visualized. The nerve diameter is reduced by 60.5%.
A Axial image; the rectangle indicates the range of B and C.
B, C Enlarged axial image.
D Sagittal image.
E Intraoperative photograph of left-sided tarsal tunnel syndrome. Nerve compression (arrow) is attributable to varix (thin arrows). The arrowhead points to the posterior tibial artery.

the 9th side, MRI suggested nerve compression by the tortuous artery at two sites. Intraoperative findings revealed that a vascular branch strongly strangulated the distal nerve. The tortuous tibial artery compressed the proximal

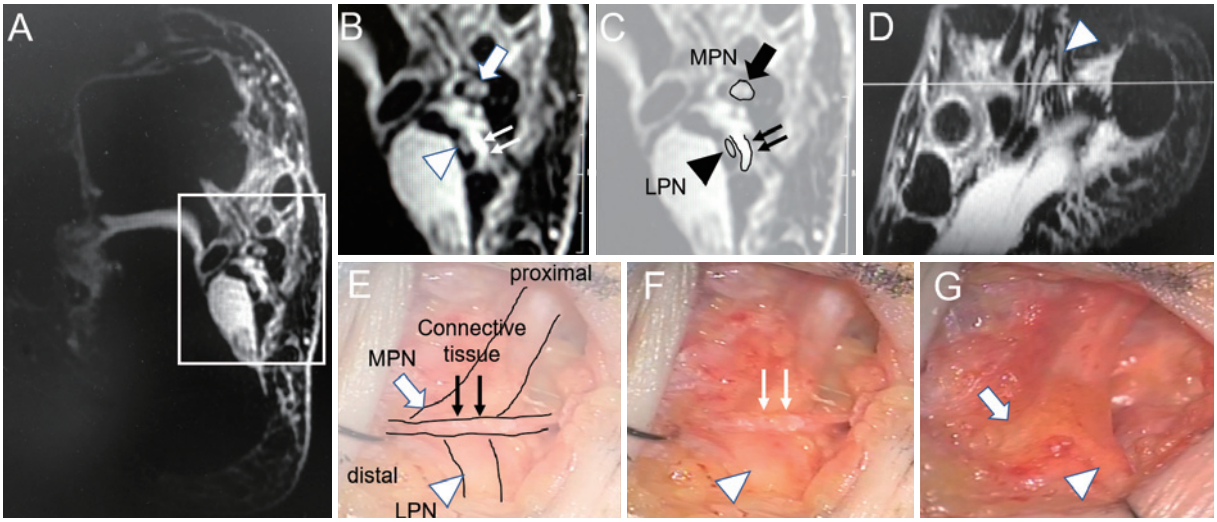

Fig. 3

A-D T2 fat suppression MR images. While the axial images (B, C) show that the lateral plantar nerve (LPN, arrowhead) is compressed, the site of compression is not clearly identifiable (thin arrows). The arrow points to the medial plantar nerve (MPN). The nerve diameter is reduced by 67.4%.

A Axial image; the rectangle indicates the range of B and C.

B, C Enlarged axial image.

D Sagittal image.

E-G Intraoperative photographs of right-sided tarsal tunnel syndrome. The LPN (arrowhead) is entrapped by connective tissue (thin arrows in E and F). (G) The arrowhead points to the decompressed LPN, and the arrow points to the MPN.

Table 1 Factors eliciting nerve compression and their detection by MRI#

	Compression factors	
MRI useful (n = 23, 82.1%)	ganglion	(n = 1)
	idiopathic	(n = 22)
	arterial tortuosity	(n = 14)
	proximal and distal arterial tortuosity	(n = 8)
MRI partially useful* (n=5, 17.9%)	idiopathic varix and arterial tortuosity	(n = 3)
	connective tissue strangulation	(n = 1)
	proximal arterial tortuosity and distal strangulation by a vessel branch	(n = 1)

#The numbers refer to sides (n = 28).

*Compression was visualized, but TTS-eliciting factors were not.

portion of the nerve. The nerves with two compression sites were decompressed with our surgical procedures for idiopathic TTS.[7]

Identification on MRI scans of the factor(s) leading to nerve compression

As shown in Table 1, on 23 of 28 sides (82.1%), MRI detected the nerve compression sites and the factor involved in the compression. The scans aided surgical planning. Intraoperative videos revealed that neurovascular bands, vessel branches, and connective tissue were involved in nerve compression and that arterial tortuosity was most often implicated. Dissection of these structures was required for nerve decompression, and MRI scans failed to yield such detailed information. Although dual-site compression by the posterior tibial artery was visualized on MRI scans, they failed to identify the site eliciting the TTS symptoms. Therefore, we decompressed at both sites.

Varices (n = 3), connective tissue entrapment (n = 1), and small vascular branch strangulation (n = 1) were involved on the other 5 sides (17.9%); these details were not detectable on MRI scans.

Table 2 MRI findings on the tarsal tunnel on the unoperated side (n = 18)

Symptom	Compression due to:	
Similar to operated side (n = 4)	Arterial tortuosity	(n = 4) *
Milder than on operated side (n = 10)	Arterial tortuosity	(n = 7)
	Unknown	(n = 3)
Asymptomatic (n = 4)	Arterial tortuosity	(n = 2)

*Two sides featured two compression sites.

MRI findings on the tarsal tunnel on 18 unoperated sides

Among the 18 unoperated sides, 4 elicited the same degree of symptoms as the operated side. The tortuous posterior tibial artery exerted nerve compression; two patients presented with two nerve compression sites. Of these 18 sides, 10 produced milder symptoms than the operated side; nerve compression was involved on all 10 sides. The tortuous posterior tibial artery was implicated in nerve compression on seven sides. In three cases, MRI scans failed to reveal the compression-eliciting factor. On two of four asymptomatic unoperated sides, MRI showed nerve compression due to tortuosity of the posterior tibial artery (Table 2).

Discussion

Preoperative diagnostic imaging plays an important role in the surgical planning for TTS. Less invasive surgery to address TTS resulted in a success rate ranging from 44% to 96%.[1,9,10,12,21,22] The rate is affected by factors such as patient selection, symptom duration, electrophysiological findings, diagnostic inaccuracy, surgical technique, and the postoperative follow-up period.[1,9,10,12,23,24] Others[25,26] reported that surgical treatment failure was due to inadequate knowledge of the involved anatomy or incomplete surgical release.

The usefulness of MRI studies in patients with TTS due to space-occupying lesions has been documented.[6,12,14,20,27] Donovan et al.[20] found MRI useful for detecting trauma, space-occupying lesions, and foot deformities implicated in symptomatic TTS. However, they stated that no imaging abnormalities are observed in 40% of patients with clinical TTS (idiopathic cases). It has been suggested that in the absence of focal mass lesions, the nerve may appear normal in imaging studies. MRI is not useful for diagnosing idiopathic TTS directly, and it helps exclude space-occupying lesions.[6,12,28,29] Earlier, Frey and Kerr[30] reported that MRI yielded significant findings such as flexor hallucis tenosynovitis, varicosities, fracture/soft tissue trauma, and focal mass lesions in 88% of patients with TTS and that it was of value for the identification of its etiology and surgical planning. However, their MRI findings revealed changes in soft tissue lesions in the tarsal tunnel and did not address direct nerve compression.

Surgical findings suggested that the pathogenesis of idiopathic TTS may be mediated by a combination of several factors such as arterial vascular leashes, chronic scarring, chronic edema, and vascular loops other than varicosities.[1,24] Decompression of the flexor retinaculum by simple cutting is insufficient. The posterior tibial nerve and the posterior tibial artery and vein are located in a neurovascular band. In patients with idiopathic TTS, Kohno et al.[3] obtained good surgical results after neurovascular decompression. They freed the nerve from the posterior tibial artery and vein and inserted a fat-graft for cushioning and preventing adhesion between the vessels and the nerve. Intraoperatively, the decompressed appeared flat at the site of contact with the arteriovenous complex. Others[2,7,24,31,32] also focused on vascular compression in idiopathic TTS; they reported good surgical results after the nerve was released from the posterior tibial artery. These findings indicate that the posterior tibial artery is an important target for nerve decompression in patients with TTS.

Our MRI studies and surgical findings also implicate the posterior tibial artery in nerve compression leading to TTS. The mean age of our patients was 74.5 years; in the elderly, worsening of arterial tortuosity due to atherosclerosis may lead to the development of TTS. Anatomically, the posterior tibial artery and the nerve are co-present in the same compartment as the neurovascular band.[2,3,7] In our TTS patients, surgical dissection of the vascular branch and the neurovascular band was required for nerve decompression from the tortuous artery, this information was not provided on MRI scans. Lopez-Ben[29] reported that imaging studies occasionally provided information on mass lesions and identified the entrapment site. During TTS surgery, we detected variceal involvement in nerve compression and one instance of nerve strangulation by small vessels. Although nerve compression was detectable on MRI scans, they did not provide these details.

Because talocalcaneal coalition may result in TTS due to prominent osseous excrescences into the tarsal tunnel, Alaia et al.[33] retrospectively inspected MRI scans to assess the presence of soft tissue disease in the tarsal tunnel of patients with talocalcaneal coalition. They reported abnormal nerve findings on 6 of 67 sides, although only one patient presented with clinical evidence of TTS, suggesting that the results were false-positive or indicative of subclinical TTS. Of our 18 patients who were subjected to unilat-

eral surgery, 14 reported bilateral symptoms. The other four sides were asymptomatic, although nerve compression in the tarsal tunnel was evident on two sides. We do not know whether the findings were false-positive or the degree of compression was subclinical. We suggest that the diagnosis of TTS should not be based on MRI findings alone and that such findings should be used to ascertain their consistency with neurological findings. Postoperatively all patients reported alleviation of their TTS symptoms, although the degree of relief was patient-dependent. Based on our findings, we can only conclude that preoperative MRI studies yield some useful information in patients with TTS.

Our retrospective study has some limitations. We cannot deny selection bias because all patients presented with nerve compression in the tarsal tunnel preoperatively. We did not exclude the possibility of false-positive findings; MRI studies on volunteers without TTS are needed to identify the false-positive rate. Also, our study population was small, and ours was a 1.5T MRI scanner. A 3.0T instrument may yield more information. We did not evaluate dynamic factors implicated in TTS, although ankle motion and aggravation elicited by walking have been reported.[2,10,16,23,34,35] We used a 3D T2* fat suppression sequence; the relationship between blood vessels and nerves may be clarified on Gd-enhanced MRI scans.

Our study included 23 TTS patients (28 sides) who underwent preoperative MRI studies. Of the 28 sides, 18 were on the unoperated side. Of these, 14 were clinically symptomatic, and four were asymptomatic. We think a comparison of electrophysiological- and MRI findings would have been of little value. Based on their systematic literature review of patients with lumbosacral nerve root compromise, Tawa et al.[36] reported the specificity of MRI findings for detecting radiculopathy is high, but their sensitivity is low. They suggested that diagnosticians should always correlate MRI findings with clinical symptoms and warned that caution is required for a diagnosis based on MRI studies alone. We suggest that this caution also applies to TTS.

Conclusion

Preoperative MRI studies were useful in TTS patients with mass lesions and in patients with idiopathic TTS. The nerve compression site was visualized on MRI scans; however, the involvement of varices, small vessel branches, and connective tissue entrapment was only confirmed during surgery. In order to determine the usefulness of MRI studies in patients with TTS, prospective studies on larger study populations are needed, and the rate of false-positive results must be determined.

Conflicts of Interest Disclosure

The authors declare they have no conflicts of interest and no commercial relationships and received no support from pharmaceutical or other companies. All authors are members of The Japan Neurosurgical Society (JNS) and have completed the Self-reported COI Disclosure Statement Forms available on the JNS members' website.

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