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Volume 35, Issue 6
September 2015
Pages 457–462
Clinical Article

The ultrasonographic evaluation of hemodynamic changes in patients with diabetic polyneuropathy after tarsal tunnel decompression

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First published:
3 August 2015 Full publication history

DOI:
10.1002/micr.22467 View/save citation

Abstract

Background

Nerve decompression procedures have shown to have promising roles in patients with diabetic polyneuropathy. It is known that not only nerves but also arteries pass through the same compressed anatomical tunnels. The aim of the study is to reveal whether the surgical decompression procedures have a positive effect on hemodynamic and morphological parameters of the arterial structures passing through these anatomic tunnels.

Methods

Twenty-seven patients who underwent posterior and anterior tarsal tunnel release procedures were retrospectively scanned for preoperative and 3 months postoperative arterial Doppler ultrasound imaging. The preoperative and third month postoperative measurements were compared for flow pattern of artery, flow lumen diameter, pulsatility index (PI), resistance index (RI), and flow volumes by evaluating the hemodynamic and morphological parameters of dorsalis pedis (DPA) and tibialis posterior arteries (TPA).

Results

For TPA, mean PI values were 5.76 ± 2.78 preoperatively, 7.17 ± 3.08 postoperatively. Mean RI values were 0.94 ± 0.04 preoperatively and 0.89 ± 0.05 postoperatively. For DPA, mean PI values were 5.06 ± 2.14 preoperatively and 6.35 ± 2.31 postoperatively. Mean RI values were 0.93 ± 0.05 preoperatively and 0.86 ± 0.06 postoperatively. When the results are analyzed for both of the arteries, PI values were significantly increased; RI values were significantly decreased when the preoperative measurements were compared with the postoperative measurements ($P < 0.05$).

Conclusion

According to these results, it can be suggested that the nerve release procedures have a positive effect on the hemodynamic and morphological parameters of the arteries as they pass through the anatomical tunnels as well as its positive effects on the neurological functions of the entrapped nerves. Microsurgery 35:457–462, 2015.

Diabetic foot infections and related foot amputations are a major cause of morbidity in diabetic patients. Ischemia of the extremity as a result of atherosclerosis and diabetic vasculopathy, and diabetic peripheral neuropathy are main causes of diabetic foot ulcers.[1] In various studies diabetic peripheral neuropathy is considered to be the main reason in the formation on diabetic foot ulcers.[2, 3]

The prevalence of peripheral neuropathy in diabetic patients is reported to be around 30%[4, 5]; however, it is reported to be as high as 82% in some studies, correlated with the duration of diabetes.[4-6] The neuropathy in diabetic patients affects both motor, sensory, and autonomic nerves. Sensory neuropathy is associated with loss of protective sensations (pain, pressure, and temperature).[1] Motor neuropathy is characterized by muscular weakness, atrophy and paresis; autonomic sympathetic neuropathy is characterized by decreased sweating (hypohydrosis/anhydrosis) and alterations in microvascular circulation.[1, 7] These changes together with recurrent minor trauma and defective perception of pressure sensation of foot may eventually lead to diabetic foot ulcers.[1, 7]

Chronic compression of the peripheral nerves in the anatomical tunnels through which they pass are observed because of the pressure increase as a consequence of metabolic dysfunctions in diabetic patients.[3, 8, 9] The conversion of glucose to sorbitol and the final increase in the intracellular osmotic pressure by sorbitol causes an increase in the intraneural water content which becomes evident as “nerve edema”.[10-12] Nerve edema is thought to cause nerve entrapment in the anatomical tunnels that are enclosed by nonexpendable rigid walls that directly cause a pressure increase throughout the tunnel.[13]

In several studies, lower extremity nerve decompression procedures have shown to improve the nerve functions of diabetic patients.[14-17] It is reported that as a result of the improvement in the protective sensation in these patients after release procedures, ulceration, and amputation could be prevented and hospitalizations because of diabetic foot ulcers could be decreased.[18] In addition to these findings, there are also studies suggesting that the surgical decompression of the tarsal tunnel may also improve microcirculation.[3] Yet, there are no studies to date that evaluate the changes in the arteries of the entrapped area adjacent to the involved nerves.

Lower extremity arteries can be assessed by Doppler ultrasound flow imaging, conventional and subtraction arteriography, CT-angiography, and MR-angiography.[19] Doppler ultrasound flow imaging is an easy to use, reproducible, cheap, and a noninvasive method for qualification of patients for different treatment modalities and for the evaluation of the response to the treatment.[19]

In this study, we aimed to evaluate the effects of the surgical decompression procedure to release the tibial and deep peroneal nerves on the hemodynamic and morphological parameters of the adjacent vascular structures, namely the "posterior tibial artery" and "dorsalis pedis artery".

PATIENTS AND METHODS

Hundred and eight patients operated between 2010 and 2014 for lower extremity nerve release procedure were retrospectively reviewed. Twenty seven of those patients with complete preoperative and 3 months postoperative Doppler ultrasonography (USG) records were included in the study. Among the 27 patients included to the study, 19 were male and 8 were female, and the mean age was 61.9 years (min 43–max 78 years), the mean duration of diabetes was 13.4 years (min 9–max 18 years), the mean body mass index (BMI) was 29.76 ± 4.72 kg/m^2, and the mean HbA1c values 74.4 ± 5.3 mmol/mol. Surgical nerve decompression procedure performed on left side in 12 and on right side in 15 patients. The patients with complicated wound healing (infection, dehiscence etc.) of the surgical areas were excluded from the study.

Surgical Procedure

Selection criteria for surgical nerve decompression procedures were lower extremity polyneuropathy because of diabetes mellitus, validation of the diagnosis of polyneuropathy with electrophysiological tests, no prior history of lower extremity amputation because of diabetic foot, positive Tinnel sign, biphasic or triphasic flow pattern in the arteries of lower extremity, no lymphatic or venous obstruction in the lower extremity, no immunodeficiency state, no rheumatologic disease or collagen tissue disorder, no plegia in the lower extremities, no cigarette smoking history, and no renal failure. Patients who met these criteria were selected for the nerve releasing procedure. Bilateral lower extremity arterial Doppler USG performed routinely to all patients in the preoperative period. Surgical procedures were performed according to the surgical principals described by Dellon[20] under spinal anesthesia and tourniquet application.

Release of Tibial Nerve and Its Branches at Medial Ankle (Posterior Tarsal Tunnel)

A curvelinear longitudinal incision placed over the area in the midway between medial malleolus and Achillies tendon. Flexor retinaculum was dissected and cut to release underlying tibial nerve. Distally lateral and medial branches were released by cutting the ligaments overlying the branches of the tibial nerve (Fig. 1)

Figure 1.

Open in figure viewer

Intraoperative view of the tibial nerve release in the posterior tarsal tunnel.

Release of Deep Peroneal Nerve over the Dorsum of the Foot (Anterior Tarsal Tunnel)

A 2.5–3 cm incision was made over the dorsum of the foot in the 1st metatarsal space. Extensor retinaculum was incised and deep peroneal nerve was dissected. The extensor hallucis brevis tendon was elongated with partial tenotomy to prevent entrapment of the underlying deep peroneal nerve (Fig. 2)

Figure 2.

Open in figure viewer

Intraoperative view of the deep peroneal nerve release in the anterior tarsal tunnel.

Surgical nerve decompression of the common fibular nerve at the level of the fibular neck was performed as the third step of the lower extremity nerve release procedure.

The preoperative and 3 months postoperative bilateral arterial Doppler USG results of 27 patients were retrospectively documented and analyzed. Postoperative measurements were collected when the patients visit 3 months after the surgery before the operation for the contralateral extremity.

The USG examinations were performed by a Doppler scanner (Logiq E9, GE, Healthcare) 4–10 Mhz linear probe.

The preoperative and 3 month postoperative measurements were compared for flow pattern of artery (FPA), flow lumen diameter (FLD), pulsatility index (PI), resistance index (RI), and flow volumes (FV) by evaluating the hemodynamic and morphological parameters of dorsalis pedis and tibialis posterior arteries.

The results were statistically analyzed with Statistical Package for the Social Sciences 15.0 for Windows (SPSS Inc., Chicago, IL, USA) by using paired sample t test for parametric data and Wilcoxon two sample test for nonparametric data. Categorical data was analyzed with χ^2 test. $P < 0.05$ was considered to be statistically significant.

RESULTS

Posterior Tibial Artery

When preoperative FPA results were evaluated 25 patients had triphasic and 2 patients had biphasic flow pattern; whereas in postoperative third month evaluation 24 patients had triphasic and 3 patients had biphasic flow pattern. Mean FLD values were 2.45 ± 0.60 mm preoperatively and 2.54 ± 0.58 mm 3 months postoperatively. Mean PI values were 5.76 ± 2.78 preoperatively, 7.17 ± 3.08 3 months postoperatively. Mean RI values were 0.94 ± 0.04 preoperatively and 0.89 ± 0.05 3 months postoperatively. Preoperative Mean FV values were 19.40 ± 5.84 mL/minute preoperatively and 22.74 ± 7.07 mL/minute 3 months postoperatively (Table 1, Fig. 3).

Figure 3.

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Comparison of preoperative and postoperative Doppler USG measurements and indexes of TPA.

Figure 4.

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Comparison of preoperative and postoperative Doppler USG measurements and indexes of DPA.

Table 1. The Preoperative and 3 Months Postoperative Doppler USG Results of the Posterior Tibial Artery

	Preoperative	Postoperative	*P*
Mean flow lumen diameter (mm)	2.45 ± 0.60	2.54 ± 0.58	<0.05
Mean pulsatility index	5.76 ± 2.78	7.17 ± 3.08	<0.05
Mean resistance index	0.94 ± 0.04	0.89 ± 0.05	<0.05
Mean flow volume (ml/min)	19.40 ± 5.84	22.74 ± 7.07	<0.05

When the results are statistically analyzed there were no significant difference for FPA, whereas FLD, PI, and FV values were found to be significantly increased postoperatively, and RI values were found to be significantly decreased when the preoperative measurements were compared with the 3 months postoperative measurements ($P < 0.05$).

Dorsalis Pedis Artery

When preoperative FPA values are evaluated, 23 patients had triphasic and 4 patients had biphasic flow pattern; whereas 3 months postoperatively 22 patients had triphasic and 4 patients had biphasic flow pattern. One patient has developed stenosis of the DPA. Mean FLD values were 1.74 ± 0.42 mm preoperatively and 1.88 ± 0.42 mm 3 months postoperatively. Mean PI values were 5.06 ± 2.14 preoperatively and 6.35 ± 2.31 3 months postoperatively. Mean RI values were 0.93 ± 0.05 preoperatively and 0.86 ± 0.06 3 months postoperatively. Mean FV values were 6.35 ± 2.31 mL/minute preoperatively and 8.59 ± 3.56 mL/minute 3 months postoperatively (Table 2, Fig. 4). When the results are statistically analyzed there were no significant difference for FPA; FLD, PI, and FV values were significantly increased; RI values were significantly decreased when the preoperative measurements were compared with the 3 months postoperative measurements ($P < 0.05$).

Table 2. The Preoperative and 3 Months Postoperative Doppler USG Results of the Dorsalis

Pedis Artery

	Preoperative	Postoperative	*P*
Mean flow lumen diameter (mm)	1.74 ± 0.42	1.88 ± 0.42	<0.05
Mean pulsatility index	5.06 ± 2.14	6.35 ± 2.31	<0.05
Mean resistance index	0.93 ± 0.05	0.86 ± 0.06	<0.05
Mean flow volume (ml/min)	6.35 ± 2.31	8.59 ± 3.56	<0.05

When patients are evaluated for neurological symptoms there was improvement in 25 patients (92.5%).

DISCUSSION

In patients with diabetic neuropathy, lower extremity nerve decompression can be performed by releasing common peroneal nerve at fibular neck, superficial peroneal nerve at anterolateral calf, deep peroneal nerve on the dorsum of foot, tibial nerve and its branches at medial ankle, lateral femoral cutaneous nerve at the level of inguinal ligament-anterior superior iliac spine, and common digital plantar nerves at second to fourth intermetatarsal spaces.[13] These procedures were reported to have role in ameliorating nerve functions, preventing ulcerations and amputations by restoring the protective sensation in lower extremity, decreasing hospitalization because of foot infections.[14-18]

In diabetic patients with peripheral polyneuropathy, chronic compression of the tibial nerve occurs in the posterior tarsal tunnel whereas chronic compression of the deep peroneal nerve occurs in the anterior tarsal tunnel. Posterior tibial and dorsalis pedis arteries accompany these nerves in these anatomical tunnels.[20, 21] Rosson et al. reported that the pressure in the posterior tarsal tunnel increased in patients with diabetic and idiopathic tarsal tunnel syndrome and these increased pressures were decreased after the release procedures.[9] It is hypothesized that in patients with diabetic neuropathy, the vascular structures adjacent to the chronically compressed nerves could also be affected because of the compression. The results obtained from our study- the decrease in RI values of PTA and DPA- were also in parallel with these findings.

Reiber et al. reported that in 35% of diabetic patients who developed foot ulcers, the cause was peripheral ischemia because of proximal artery disease.[22] In a controlled study evaluating the Doppler results of the arteries of feet by Leoniuk et al., vessel diameters and wall thicknesses of PTA and DPA were found to be increased but FLD values were not found to be increased in patients with early stage of type 2 diabetes.[19] In the same study it was found that there was a positive correlation between the levels of HbA1c and RI and there was a negative correlation between the intensity of trophic skin changes and PI.[19] In our study, the decrease in postoperative RI values of PTA and DPA and the increase in values of PI suggest that nerve decompression improves the blood flow through the involved vessels. This, in turn, is thought to contribute to the prevention trophic skin changes and foot ulcers.

In a study by Blount et al., seven patients with tarsal tunnel syndrome, three of whom were diabetic, sympathetic nerves were shown in the epineurium of tibial nerve in five patients and when epineurectomy was applied to the tibial nerve, blood flow may increase because of the effect of local sympathectomy.[23] In a study with 20 diabetic patients by Trignano et al., after tarsal tunnel release, improvement in peripheral microcirculation was denoted.[3] The findings of our study also support similar findings.

In the literature, Doppler ultrasound flow imaging is the most common method for evaluating the arteries of lower extremities.[19] Janssen et al. declared that PI is the best method for the evaluation of critical limb ischemia in patients with diabetic polyneuropathy.[24] All Doppler USG measurements were performed as routine distal lower extremity arterial examination over certain predefined anatomical points. For posterior tibial artery the midpoint between medial malleolus and Achilles tendon and for the dorsalis pedis artery the point on the midline of 1st web, 4 cm proximal to the 1st MTP joint was used with a standardized leg position and room temperature for all patients. Even though these points refer to specific and standardized points of measurement, the USG probe was redirected and moved slightly to determine the clearest view of the examined artery. These manipulations may lead to minor deviations and distortions, thereby causing suboptimal results in measurements. Considering the restrictions of Doppler USG in determination of blood flow, further studies evaluating the effects of nerve release procedures particularly on the lower extremity microvascular circulation by methods such as laser Doppler, transcutaneous oxygen pressure (TcPO2), and thermal cameras are required.

In our study, Doppler USG follow-up data is limited to 3 months postoperatively. A longer Doppler USG follow-up may provide us with more valuable data about the long term effects of nerve release procedures on arterial blood flow in distal lower extremity. The long term follow-up may also be complicated in these diabetic patients with the patients' progressive vascular disease process which manifests itself as decrease in blood flow, may hinder the positive effects of the nerve release procedures.

CONCLUSION

In patients with diabetic polyneuropathy, after the release procedures performed in the anatomical tunnels through which the nerves pass, hemodynamic and morphological parameters of the adjacent arteries that pass through the same tunnels are improved. Therefore the decrease in the development of diabetic foot ulcers after nerve release procedures could be because of the improvement in hemodynamic and morphological parameters of the adjacent arteries besides neurological benefits observed in these patients.

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