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Research Article

Is denervation surgery possible in the treatment of hallux rigidus? An anatomic study of cadaveric specimens

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ABSTRACT

Objective: The aim of this study was to provide anatomic considerations in the first metatarsophalangeal joint (FMPJ) innervation and to evaluate the feasibility of the denervation surgery in the treatment of hallux rigidus.

Methods: In this cadaveric study, 14 fresh frozen cadaveric transtibial amputation specimens was used. For nerve dissection, dorsal and plantar longitudinal incision centered over the FMPJ were performed. Deep peroneal and dorsomedial cutaneous nerves were dissected in the dorsal aspect of the joint. Medial plantar nerve branches, medial and lateral hallucal nerves, were dissected in the plantar aspect of the joint. The presence, number, and location of articular branches to the FMPJ capsule were recorded. Dorsal and plantar incision length for proper dissection were also recorded.

Results: Nerve dissection of the 14 specimens revealed the following number of articular branches from the relevant nerves: 14 from dorsomedial cutaneous nerves, 11 from deep peroneal nerves, 6 from medial hallucal nerve, and 5 from lateral hallucal nerve. Dorsal incision mean length was 60.53 (range, 42.48–85.12) mm, and the plantar incision mean length was 88.08 (range, 77.32–111.21) mm.

Conclusion: Evidence from this study has shown that partial dorsal denervation of the FMPJ may be a technically feasible procedure along with the presence of superficially easily dissected nerves with relatively small incision.

Level of Evidence: Level 5

Introduction

Hallux rigidus is one of the most common forms of degenerative arthritis of the foot and ankle.[1] The main findings of hallux rigidus are pain, limitation of the joint's range of motion and progressive osteophyte formation at the first metatarsophalangeal joint (FMPJ).[2,3] Arthrodesis of FMPJ is the most commonly preferred surgical treatment modality, especially in advanced cases.[4] Although, it is highly effective for pain control, arthrodesis is associated with drawbacks such as loss of joint motion, diminished gait efficiency, limitations in sports and shoe choice.[5,6]

Peripheral articular denervation has been proposed as an alternative treatment for degenerative arthritis. The concept of denervation was originally proposed in 1933 by Camitz for the treatment of chronic hip arthritis.[7] There are several advantages of denervation over arthrodesis or arthroplasty. For example, joint integrity is preserved, muscle function remains unaffected, no implants/foreign materials are required, postoperative immobilization is not necessary, operation can be performed simultaneously with other operations, the method is technically simple, inexpensive, and with low risk, all alternatives such as arthrodesis or arthroplasty remain possible for future and the results can be reliably anticipated by preoperative nerve block tests.[8] In previous studies, denervation surgery has been shown satisfactory clinical results in the treatment of painful arthritis of the wrist, metacarpophalangeal joint, patellofemoral joint, facet and sacroiliac joints, midtarsal and tarsometatarsal joints and the ankle.[9-14]

An anatomical study about innervation of the foot joints was published by Gardner and Gray in 1968. In their study, they defined FMPJ innervation that was supplied by several nerve's articular branches. Dorsal innervation supplied by articular branches of Dorsomedial Cutaneous Nerve (DMCN) medially and Deep Peroneal Nerve (DPN) articular twigs laterally. Plantar innervation was supplied by articular branches of medial plantar nerve medial and lateral hallucal branches (Figure 1).[15]

To the best of our knowledge, there has been no study evaluating the innervating of FMPJ and the feasibility of surgical denervation. The aim of this study is to examine the innervation of FMPJ and to evaluate the feasibility of surgical denervation using standard surgical approach.

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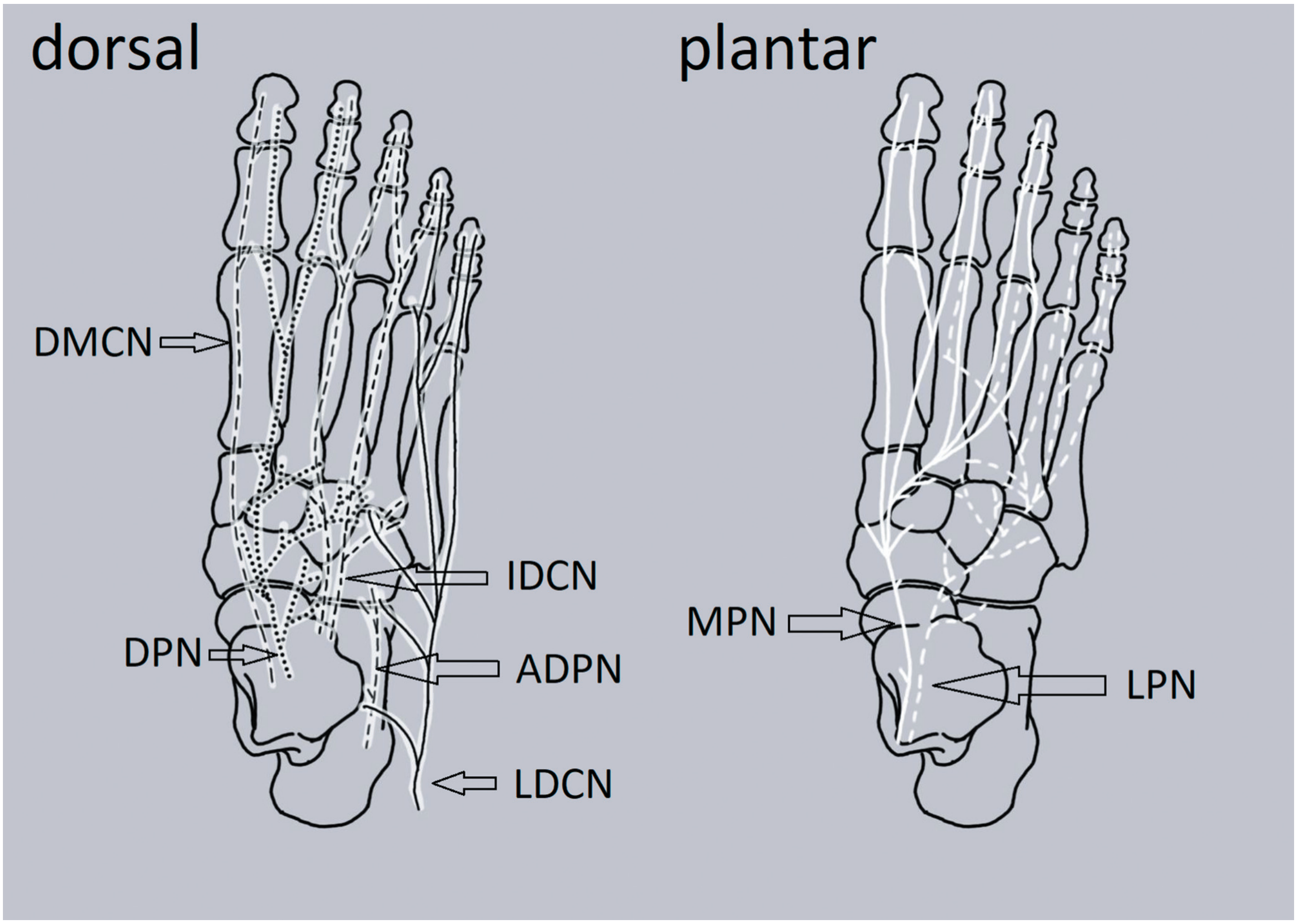

Figure 1. Schematic representation of dorsal and plantar innervation of the foot joints, redrawn according to the study of Gardner and Gray.[15]
DMCN, Dorsomedial Cutaneous Nerve; DPN, Deep Peroneal Nerve, IDCN; Intermediate Dorsal Cutaneous Nerve; ADPN, Accessory Deep Peroneal Nerve; LDCN, Lateral Dorsal Cutaneous Nerve; MPN, Medial Plantar Nerve; LPN, Lateral Plantar Nerve.

Materials and Methods

In this study, 14 fresh frozen cadaveric transtibial amputation specimens from 14 cadaver were selected and stored at −20 °C. The specimens were thawed at room temperature and prepared. Of the 14 specimens, nine were right feet and five were left. Eleven of the specimens were of male and three were of female. The mean age at death was 66 (range, 52–75) years.

Dorsal and plantar longitudinal incisions which centered on the FMPJ were used for nerve dissection. The deep peroneal nerve, dorsomedial cutaneous nerve and articular branches of these nerves were dissected from the dorsal incision. Medial and lateral hallucal nerves and the articular branches of these nerves were dissected from the plantar incision. The nerves were identified proximally, and the nerves and their branches were carefully dissected in a proximal to distal direction by 4.5X loupe magnification. All dissections were carried out by same experienced foot and ankle surgeon.

Approximately, 5 cm longitudinal skin incisions were made, which were centered on the FMPJ from both plantar and dorsal sides. The incisions were extended until adequate identification and dissection were achieved. The musculotendinous junction of Extensor Hallucis Brevis (EHB) muscle was used as a landmark to identify DPN proximally. The nerve was found beneath to EHB musculotendinous junction.[16] The Extensor Hallucis Longus (EHL) tendon was used as a landmark to identify DMCN proximally. The nerve was found at the medial side of EHL tendon.[17] Flexor Hallucis Longus (FHL) tendon was used as a landmark for Medial Hallucal Nerve (MHN) and Lateral Hallucal Nerve (LHN) dissections. The nerves were identified on the medial and lateral sides of the FHL tendon proximal to FMPJ, respectively. The dissections were terminated at the distal end of the FMPJ capsule. The presence and location of articular branches in the FMPJ joint were identified by the use of surgical loupes. A digital caliper was used for distance measurements (Insize® 1103-150, resolution: 0.01 mm, accuracy: ±0.02 mm). The measurements were recorded according to the *x–y* plane which was centered on FMPJ. After the measurements, all

HIGHLIGHTS

- Denervation surgery is an alternative treatment option for painful degenerative osteoarthritis.
- Dorsal sensorial nerves of the first metatarsophalangeal joint are superficial, easy to approach and identify through a standard dorsal incision.
- Partial dorsal denervation of metatarsophalangeal joint is technically feasible.

articular branches of the nerves were excised and sent to pathology laboratory for histological confirmation. Finally, the lengths of both incisions were measured and recorded.

Statistical analysis

Statistical analyses were performed by SPSS for Windows 15.0 software (SPSS, Inc., Chicago, IL, USA). Descriptive statistics were used to report the identification rates and capsular entry to joint center distance of the articular branches of the nerves. The Kolmogorov–Smirnov test was to verify the normal distribution and homogeneity of the dorsal and the plantar incision lengths. These data distributions were normal and compered using the student's *t*-test.

Results

In all specimens, a definite articular branch of DMCN was identified. The articular branch of the DPN was found in 11 (78.5%) of the 14 samples. Articular branches of the LHN were identified in five (36%) and MHN in six (42.9%) of all the specimens. Histological examination of the tissues confirmed that all of the samples identified as article branches of the nerves were nerve tissues (Figures 2 and 3).

All of the articular branches of the DMCN were located on the medial side of the FMPJ. In four samples (29%), capsular entry of the articular branches of the DMCN was located distal to the joint line and for the rest of all (71%) the entry points were located proximal to the joint line. All of the articular branches of the DPN were located on the lateral side of the FMPJ. In two samples (18%), capsular entry point of the articular branches of the DPN was located distal to the joint line and for the rest of all (82%) the entry point was located proximal to the joint line. The detail of the distance between capsular entrance of the articular nerves and the joint line is given in Table 1. The approximate capsular entry point of the articular branches of the dorsal nerves is shown in Figure 4.

All the identifiable articular branches of LHN and MHL were observed to be entering the plantar capsule proximal to the joint line. The entrance points of the plantar nerves were closer to center of the joint in the medial lateral plane than the dorsal nerves. The details are given in Table 1.

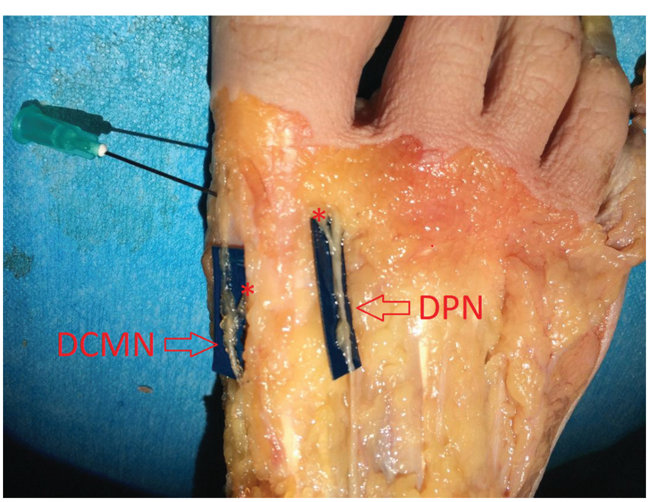

Figure 2. A left foot.
Notes: Skin and subcutaneous fat tissue were removed. Dorsal innervation of the first metatarsophalangeal joint. The capsular entrances of the articular branches are shown by asterisks. The hypodermic needle indicates the joint line.**Abbreviations:** DMCN, Dorsomedial Cutaneous Nerve; DPN, Deep Peroneal Nerve.

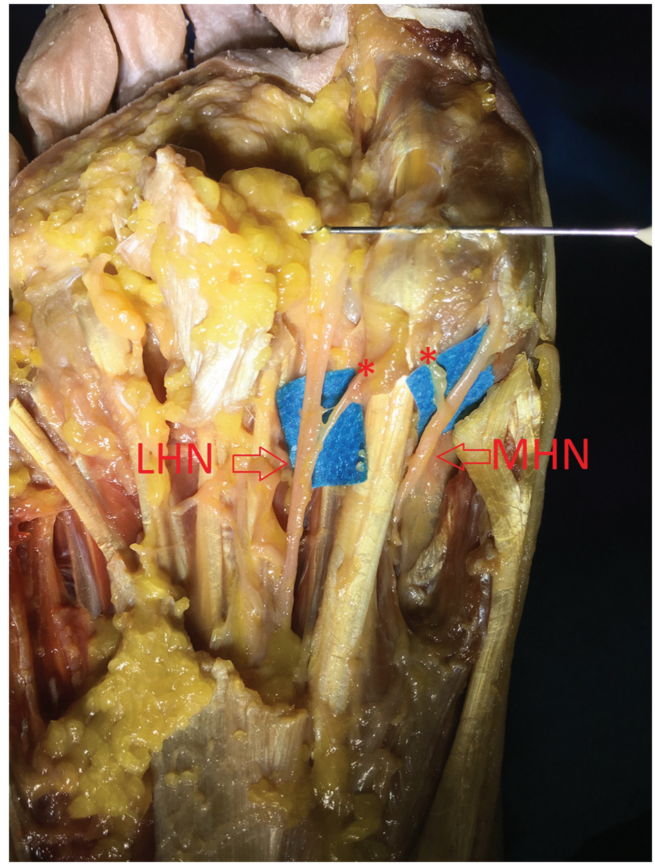

Figure 3. A left foot.
Notes: Skin, subcutaneous fat tissue, and plantar fascia were removed. Plantar innervation of the first metatarsophalangeal joint. The capsular entrances of the articular branches are shown by asterisks. The hypodermic needle indicates the joint line. LHN, Lateral Hallucal Nerve; MHN, Medial Hallucal Nerve.

The mean length of the incision for adequate nerve dissection is longer on the plantar side ($P = 0.001$). Plantar incision length mean was 60.53 (±16.53, range, 42.21–90.72), while the mean dorsal incision length was 88.08 (±11.23, range, 75.43–111.23) mm. The details are given in Table 1.

Discussion

To the best of our knowledge, there has been no anatomical study on the innervation of FMPJ. The results of this study confirmed that the partial dorsal denervation of FMPJ is feasible due to the fact that the dorsal sensitive nerves are superficial, easy to identify and reach via standard dorsal surgical approach.

In 1968, Gardner and Gray published a study about the innervation of foot joints, in which five fetal feet were examined. They stated that FMPJ innervation supplied by articular branches of DPN, DMCN and medial plantar nerve hallucal branches. However, there was no detailed information about the percentage of the presence of articular branches in their study.[15] In this study, the articular branches of DMNC were identified in all samples. It was 78.5% for DPN, 42.9% for medial hallucal nerve and 36% for lateral hallucal nerve. The anatomical variations might be the reason for the absence of articular branches of the nerves in each sample. And also, we think that the use of standard surgical approach, rather than anatomical dissection approach for identification of the nerves, may be another reason. In

Table 1. Summary of the Study

	DMCN		DPN		MHN		LHN		Incision Length	
Specimen No.	**PDD**	**MLD**	**PDD**	**MLD**	**PDD**	**MLD**	**PDD**	**MLD**	***D***	***P***
1	5.84	3.65	−6.03*	7.67	5.28	2.85	7.14	3.37	50.23	82.31
2	−8.99*	4.33	5.46	9.34	–	–	6.37	2.44	80.13	101.65
3	−4.22*	4.78	5.86	5.66	–	–	–	–	45.67	75.87
4	4.37	5.23	–	–	9.27	1.34	12.93	3.48	60.56	94.52
5	6.1	2.2	−2.34*	13.44	–	–	–	–	56.34	89.69
6	4.7	4.62	3.97	3.73	–	–	5.88	2.35	49.45	97.48
7	7.92	3.65	0.54	8.44	–	–	–	–	78.32	87.82
8	7.96	2.52	2.45	9.21	3.13	2.67	–	–	42.48	99.51
9	8.72	1.92	6.44	5.34	–	–	–	–	64.72	77.32
10	5.48	2.63	2.53	3.97	4.59	1.85	–	–	49.85	82.81
11	−1.67*	1.43	–	–	6.61	3.45	–	–	90.72	111.21
12	10.28	2.77	0.78	9.33	3.72	1.87	–	–	51.65	78.21
13	3.12	1.34	–	–	–	–	4.71	2.53	85.12	75.43
14	−2.24*	2.23	2.56	2.44	–	–	–	–	42.21	79.32
Mean ± SD	3.38 ± 5.59	3.09 ± 1.27	2.02 ± 3.71	7.14 ± 3.23	5.43 ± 2.23	2.33 ± 0.78	7.4 ± 3.21	2.83 ± 0.54	60.53 ± 16.53	88.08 ± 11.23

Note: All values are given in millimeters.
*Negative values indicate the distal of the joint line.
DMNC, Dorsomedial Cutaneous Nerve; DPN, Deep Peroneal Nerve; MHL, Medial Hallucal Nerve; LHL, Lateral Hallucal Nerve; PDD, Proximal-Distal Plane Distance to Joint Line; MLD, Medial-Lateral Plane Distance to Joint Line; D, Dorsal; P, Plantar; SD, Standard Deviation.

Figure 4. A left foot.
Notes: The approximate capsular entry point of the dorsal articular branches. The red dot indicates the center of the joint. The yellow asterisks indicate the capsular entry of the deep peroneal nerve and the green asterisks indicate the capsular entry of the dorsomedial cutaneous nerve.

this study, we used the standard surgical approach because one of the aims of this study is to evaluate the feasibility of surgical denervation in addition to the evaluation of FMPJ innervation.

Findings of this study demonstrated that total denervation of FMPJ joint is not feasible. There are several reasons for this. First, it is technically demanding to dissect plantar nerves, the plantar nerves are located deeply, and longer surgical incisions are needed for dissection. Also, identification rates of the articular branches of the plantar nerves were lower than the dorsal nerves. Identification of the dorsal nerves articular branches were easier by relatively smaller incisions because of the superficial course the nerves. The dorsal articular branches of the nerves were found in most of the samples in this study. Therefore, we think that partial dorsal denervation of FMPJ is technically feasible.

Partial joint denervation surgery was first described for the hip joint which was then followed by the knee.[18,19] But partial joint denervation surgery was popularized by Dellon's studies. Dellon described partial denervation first for the wrist, then for the knee, the shoulder, the sinus tarsi and the carpal-metacarpal joint.[20–24] In these studies, satisfactory results were reported by partial joint denervation in patients with degenerative osteoarthritis. The early symptoms in hallux rigidus are related to the dorsal side of FMPJ. A painful dorsal prominence and restricted dorsiflexion of the joint are the most common clinical symptoms.[25] Dorsal cheilectomy is a good surgical option with satisfactory clinical results in early stage of the disease.[26,27] Although progression of the arthrosis can be observed radiologically in many patients after cheilectomy, this does not seem to affect the clinical outcomes.[28] We think that, after retracting the DMNC and DPN, circular dissection of the FMPJ capsule from the surrounding soft tissues before the capsular incision can be enough for dorsal denervation. The current study demonstrated that dorsal denervation can be done without any additional effort during the standard surgical procedure.

There are some limitations of our study. The first limitation is that we had a small number of cadaveric legs. The use of additional specimens would potentially increase the impact of this study. Second, as with any cadaveric study, we cannot make definitive claims as to how this procedure translates into clinical practice. Randomized prospective studies are needed to answer questions such as the clinical effects of this procedure on FMPJ diseases or whether partial denervation is sufficient. Our aim is to be a reference to future clinical studies.

In conclusion, this cadaveric study demonstrated that partial dorsal denervation of FMPJ is technically feasible rather than total denervation and it can be combined with dorsal cheilectomy.

Ethics Committee Approval: Ethical approval was not necessary because the data were obtained from cadaveric specimens and did not involve any interactions with human or animal subjects.

Informed Consent: N/A.

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Conflict of Interest: The authors declare that they have no conflict of interest.

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