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ORIGINAL INVESTIGATION

Location of motor branches of tibialis posterior muscle and its relation in treatment of spastic equinovarus foot: a cadaveric study

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Abstract
Background and objectives: Nerve block or neurolysis is an important approach in the treatment of spastic equinovarus foot. To illustrate the accurate location of the nerve branch to the tibialis posterior muscle (TP) in clinical practice, 21 adult cadavers were dissected and 14 complete both lower limb specimens were obtained. A total of 28 lower limbs were included.
Methods: We measured the length of the motor branch nerve (LM) of the tibialis posterior muscle, the length of the fibula (LF), the vertical distance (D1) from the midpoint of LM to the fibula tip as well as the horizontal distance (D2) from the midpoint of LM to the inner edge of the fibula.
Results: The LM was higher (35.74 ± 7.28 mm) in male than in female (30.40 ± 6.88 mm) specimens but there was no significant correlation between LM and gender ($p > 0.05$). Additionally, among male specimens, the LM on the right side was longer than that on the left ($p \leq 0.05$) while among female specimens, the D1 on the left side was longer than that on the right ($p \leq 0.05$). The LF in male specimen was significantly longer than that in female ($p \leq 0.05$). The midpoint of the nerve to the motor branch of the tibialis posterior muscle was about 50 mm distal to the fibular head and 10 mm at the inner edge of the fibula.
Conclusion: Using this coordinate, the midpoint of the nerve branch to the TP could be accurately located.

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Introduction

Spastic equinovarus foot (SEF) is a frequent deformity, with an estimated incidence of between 18–56%, among patients suffering from spastic hemiplegia following a stroke.[1,2] The condition is characterized by spasticity of the triceps surae and tibialis posterior muscles (TP).[3–6] Various approaches have been applied in the treatment of SEF including: physiotherapy, muscle stretch training, use of orthosis, alcohol or phenol neurolysis, botulinum toxin injection, selective neurotomy, tendon transfer, and Achilles tendon lengthening. Effective neurolysis involving the use of phenol or alcohol requires the accurate location of the motor nerve branches of the triceps surae and TP muscle responsible for SEF. Botulinum toxin, phenol or alcohol injection can be used in the treatment of spastic clubfoot, and the treatment effect can be maintained for 6 months, so it is an ideal treatment choice.[7]

Anatomically, the TP muscle originates from the posterior fibula, the posterior tibia and the interosseous membrane, below the soleus muscle line. The attendant tendon is subdivided into anterior, middle, and posterior parts, ending at the sole of the foot.[8] The main function of the TP muscle is to maintain the medial arch of the foot and to make the foot varus.[9]

Several studies have been conducted on the motor nerve branches of the triceps surae muscle but, in contrast, not much attention has been given to studying the location of the motor branches of the TP muscle.[10–13] Nihal and colleagues used the tip of the fibular head as the location of the tibial nerve branch. The position of the tibial nerve from the tibial nerve to the tibial posterior muscle was 7.6 cm away from the tip of the fibula, the length of the branch was 7.8 cm, and the average terminal branch was 3.7 branches.[14] However, it is difficult to apply it in clinical practice. Bodily and colleagues[15] used the tibial plateau as a reference point to determine the location of the origin of muscular motor branches in the posterior compartment of the leg. It is difficult to accurately locate the motor branch of posterior tibial muscle due to the lack of specific location of tibial plateau. Baroncini and colleagues[16] measured the distance from the femoral tibial joint line of the knee joint to the origin point of the posterior tibial nerve branch of the tibial nerve. Because it is difficult to reach the posterior popliteal fossa of the knee joint, the anterior knee joint line as a reference, clinical application is more difficult. Because the motor branches of soleus and tibialis posterior muscles are too small to be identified in imaging, we must use related muscles to locate these branches indirectly. The motor branches of posterior tibialis muscle are located at the starting point of posterior tibial muscle. These localization methods are difficult to be accurately applied in clinic. The purpose of this study was, therefore, to find a simple and reliable method of locating the motor branch (LM) of the TP using adult cadaveric specimens.

Methods

A total of 21 adult cadaver specimens soaked in 10% formalin were collected from the Department of Anatomy, Qingdao University. The inclusion criteria involved the cadavers having complete lower limbs and no trauma or deformity in the lower limbs. Cadavers were excluded if they lacked one or both calves, if calves had features of previous calf injuries, if there were noticeable deformities of the calves or ankles, or if there was evidence of previous surgery. Some 14 cadavers, with a total of 28 legs, were eventually included in the study. The gender distribution was 8 male and 6 female cadavers. The specimens were placed in the prone position on the anatomical table with the knee joint flat and straight, in an extended position. An incision was made on the posterior median section of the calf, from the top of the popliteal fossa to the back of the ankle. The skin and subcutaneous tissue were cut open to expose the triceps surae muscle. The Achilles tendon was then cut off at the distal end and the triceps surae muscle turned to the proximal end and removed to carefully expose the posterior deep chamber while minimizing interference to the deep tissue. The tibial nerve, popliteal artery and vein, as well as the distal posterior tibial artery and vein were exposed from the proximal end. The medial edge of the lateral fibula and the full length of the fibula (LF) were similarly exposed. The length of the fibula was measured and recorded. To the TP muscle and the entry point to the TP muscle were located and dissected carefully under a 4-fold microscope, avoiding traction of the nerve. An electronic digital Vernier caliper (Sino-foreign joint venture Jingjiang measuring tools Co., Ltd., accuracy of 0.01 mm, corrected reading before use), was used to measure the length of the nerve branch of the TP muscle, marked as LM. The length of the fibula was marked as LF. The vertical distance from the midpoint to the nerve branch of the TP muscle to the fibula tip was marked as vertical distance from the midpoint of the motor branch of the tibial nerve supplying the TP to the fibula tip (D1). The horizontal distance from the midpoint of the nerve branch of the TP muscle to the inner edge of the fibula was marked as horizontal distance from the midpoint of the motor branch of the tibial nerve supplying the TP to the inner edge of the fibula (D2). Pictures (camera model, Sony α-77) of the images were also captured. This study was approved by the Ethics Committee of the Affiliated Hospital of Qingdao University (Fig. 1).

Statistical analysis

All measured data was expressed as mean $\pm$ standard deviation ($X \pm s$). Comparison between groups was performed using the Student's *t*-test for independent samples while correlation analysis between variables was performed using the Pearson test. Differences between entities were considered statistically significant when the value of $p \leq 0.05$.

Results

In all specimens, the nerve branch of the TP muscle of the tibialis posterior muscle was found to originate from the fibular side of the tibial nerve trunk distal to the fibular head. The LM was 35.74 $\pm$ 7.28 mm in male and 30.40 $\pm$ 6.88 mm in female specimens; the difference in length was, however, not statistically significant ($p > 0.05$). Equally, the values obtained for D1 (47.57 $\pm$ 8.65 mm in male and 51.98 $\pm$ 12.92 mm in female) and D2 (10.93 $\pm$ 3.31 mm in male and 11.14 $\pm$ 2.84 mm in female)

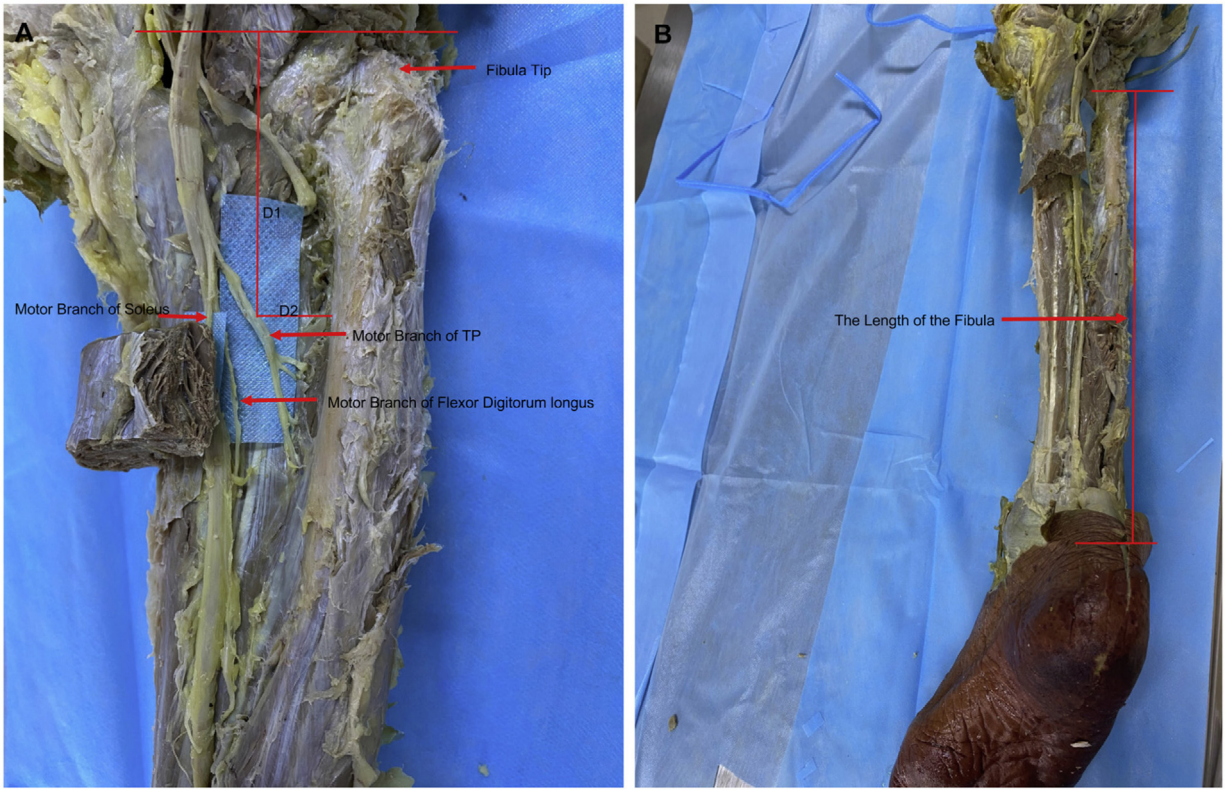

Figure 1 A, Image of motor branches of the tibial nerve supplying the TP muscle. B, Length of the fibula. The red dot is the midpoint of the trunk of the motor branch of the tibial nerve innervating the TP. D1 represents the distance between the superior edge of the tip of the fibula and the midpoint of the main motor branch of the tibial nerve that supplies the TP; D2 represents the distance between the midpoint of the main motor branch of the tibial nerve supplying the TP and the inner edge of the fibula.

Table 1 Comparison of LM, D1 and D2 values between Male and Female specimen.

	Female (n = 12)	Male (n = 16)	t	*p*
LM	30.40 ± 6.88	35.74 ± 7.28	1.968	0.60
D1	51.98 ± 12.92	47.57 ± 8.65	-1.085	0.29
D2	11.14 ± 2.84	10.93 ± 3.31	-0.18	0.86
LF	340.58 ± 14.91	377.32 ± 37.71	-3.18	0.004

Note: Values are in mm and represent the mean ± SD.
LM, Length of the motor branch of the tibial nerve of the tibialis posterior muscle; LF, Length of the fibula; D1, Vertical distance from the midpoint of the motor branch of the tibial nerve of the tibialis posterior muscle to the fibula tip; D2, Vertical distance from the midpoint of the motor branch of the tibial nerve of the tibialis posterior muscle to the inner edge of the fibula.

Table 2 Comparison of LM, D1 and D2 values between left and right sides of female specimen.

	Left (n = 6)	Right (n = 6)	t	*p*
LM	30.35 ± 7.81	30.44 ± 6.56	-0.021	0.98
D1	59.91 ± 9.91	44.06 ± 10.88	2.639	0.025
D2	10.21 ± 3.05	12.08 ± 2.53	-1.156	0.275
LF	338.00 ± 16.15	343.17 ± 14.57	-.58	0.573

Note: Values are in mm and represent the mean ± SD.
LM, Length of the branch nerve to the tibial nerve of the tibialis posterior (TP) muscle; LF, Length of the fibula; D1, Vertical distance from the midpoint of the branch nerve of the TP to the fibula tip; D2, Horizontal line from the midpoint of the nerve branch to the tibial nerve of the TP to the inner edge of the fibula.

did not differ significantly ($p > 0.05$). The LF was higher in male (377.32 ± 37.71 mm) compared to that in female (340.58 ± 14.91 mm) specimens, $p < 0.05$ (Table 1).

As summarized in Table 2, no significant differences were found between the left and right sides among female specimens in the values of LM, D2 and LF. To the contrary, the D1 was longer on the left compared to the right side ($p < 0.05$). Considering male specimens, the only significant differences recorded between the left and right sides was in the value of LM ($p < 0.05$). For the other parameters: D1, D2 and LF, the differences between left and right sides did not meet the threshold to be considered statistically significant (Table 3). Further analysis failed to show a relationship between LF and either LM, D1 or D2 (Table 4).

Discussion

Patients who have suffered from a stroke episode are at risk of developing SEF.[17] With SEF, affected patients often must contend with curtailed walking speed and distance. More-

Table 3 Comparison of LM, D1 and D2 values between left and right sides in male specimen.

	Left (n = 8)	Right (n = 8)	t	*p*
LM	31.52 ± 6.32	39.97 ± 5.73	-2.802	0.014
D1	51.31 ± 9.16	43.83 ± 6.68	1.866	0.083
D2	10.28 ± 3.89	11.59 ± 2.71	-0.782	0.447
LF	376.28 ± 38.40	378.38 ± 39.62	-0.108	0.916

Note: Values are in mm and represent the mean ± SD.
LM, Length of the branch nerve to the tibial nerve of the tibialis posterior (TP) muscle; LF, Length of the fibula; D1, Vertical distance from the midpoint of the branch nerve of the TP to the fibula tip; D2, Horizontal line from the midpoint of the nerve branch to the tibial nerve of the TP to the inner edge of the fibula.

Table 4 Pearson correlation test of LM, LF, D1 and D2 between genders.

	Female (n = 12)	Male (n = 16)	*p*
LM	30.40 ± 6.88	35.74 ± 7.28	0.067
D1	51.98 ± 12.92	47.57 ± 8.65	0.097
D2	11.14 ± 2.84	10.93 ± 3.31	0.243
LF	340.58 ± 14.91	377.32 ± 37.71	

Note: Values are in mm and represent the mean ± SD.
LM, Length of the branch nerve to the tibial nerve of the tibialis posterior (TP) muscle; LF, Length of the fibula; D1, Vertical distance from the midpoint of the branch nerve of the TP to the fibula tip; D2, Horizontal line from the midpoint of the nerve branch to the tibial nerve of the TP to the inner edge of the fibula.

over, there is functional restriction of the affected foot that may impair the ability to execute normal daily activities.[18] Most patients, especially those who present with early phase spasticity, can respond to physiotherapy, muscle stretch training, and neurolysis using substances such as alcohol, phenol, or injection with botulinum toxin.[19,20] The main side effect of alcohol or phenol neurolysis is hypoesthesia, with an incidence of 2–32%. However, it has the advantages of no immune response and lower price compared with botulinum toxin.[21]

Oral drug therapy, like the use of baclofen, although employed in the treatment of extensive spasm, has registered poor efficacy dotted with unpleasant side effects. This has made it unsuitable for the treatment of focal SEF. On the other hand, spasticity (≥ 6 months) is often associated with muscle and tendon contracture and require tendon lengthening surgery.

Although potentially helpful, ultrasound-assisted block of the main trunk of the tibial nerve can lead to the loss of plantar sensation. Consequently, patients may lose balance, further aggravating postural and walking capabilities, increasing risks of falls. Applying selective motor branch blockade significantly reduces this risk. The precise and selective blockade of the LM of the TP muscle can clarify the role of the nerve in causing foot varus. In addition, it can provide important information in guiding the treatment of SEF. For foot varus caused by TP muscle spasticity, neurolysis, or neurotomy of the motor branches of this muscle can be performed to relieve the spasticity.[22]

The selective blockade of the nerve branch of the TP muscle requires that it should be accurately and precisely located. This way, it can be useful in the diagnosis or treatment of spasticity arising from the TP muscle. In a study by Apaydin and coworkers, the average distance between the entry point of the nerve branch of the TP and the tip of the fibula was 7.6 cm.[22] In contrast, our study, in which we followed the midpoint of the motor branch of the TP muscle, obtained a much lower value (male 47.57 mm, female 51.98 mm). In another study, Picelli and colleagues used an ultrasound technique to measure the distance between the nerve branch of the TP and the tip of the fibula.[4] The distance of 4.3 cm which they obtained more closely approximates the result of the current study as compared to the earlier findings by Apaydin et al. However, it is important to note that in their work, Picelli and colleagues did not indicate the exact location of the motor branch of the tibial nerve. In another study, Deltombe et al applied the computed tomography (CT) coordinate system to locate the motor nerve branches of the TP muscle in adult hemiplegic patients. And their study determined the location of the motor nerve branches to the soleus and tibialis posterior muscles in relation to anatomic surface landmarks for selective motor branch blocks and neurolytic procedures. And the result shows that the mean coordinates ± standard deviation for the soleus motor branch were 10 ± 5 mm (vertical), 17 ± 9 mm (horizontal), and 30 ± 4 mm (deep); for the tibialis posterior motor branch they were 45 ± 6 mm (vertical), 17 ± 8 mm (horizontal), and 47 ± 4 mm (deep). These coordinates allowed people to perform selective motor blocks without CT scan.[23] Other researchers have defined the precise locations of the muscular branches and motor points of triceps surae muscles in relation to the bony landmarks.[24]

Deltombe and Gustin's measurement with CT found that the nerve branch of the TP muscle was located 47 ± 4 mm deep.[3] On the other hand, Picelli et al found a depth of the tibialis posterior motor branch was 42 ± 8 mm by using ultrasound measured.[4] The observations by these researchers can thus provide a suitable reference for clinical operation. The main purpose of the current study was to provide a reference for the localization of the motor branch block or neurolysis of the tibial nerve of the TP. In clinical practice, it is necessary to include the electrical stimulation technique to determine the location of the nerve. Since the thickness of superficial structures of the body surface vary greatly, the measurement of depth may also vary similarly. We, therefore, recommend using electrical stimulation during motor branch blockade of the tibial nerve to compensate for the limitations of this two-dimensional localization. Obesity has a great influence on the depth, and hence localization, of the nerve branch of this muscle. For some obese patients, the inner edge of the fibula is difficult to reach, and therefore localization using ultrasound is preferable. The findings of this study provide a basis for ultrasonic localization of the motor nerve branch of the tibial nerve that supplies the TP muscle.

Since the specimens in our study were soaked in formalin, making it difficult to obtain the height accurately, we measured and expressed the length of the fibula as a ratio. Thus, the LM, the D1, and the D2 were not related to the length of

the fibula. In our study, the average length of the LM of the TP was 35.74 mm in men and 30.40 mm in women. Injection at the midpoint of the motor branch can prevent alcohol or phenol from spreading to the main trunk of the tibial nerve. This can help avoid the negative effects of impairing sensation of the sole of the foot and the walking capabilities of the patient. This assertion, however, needs to be confirmed by further clinical research.

Our study, although providing important insights into the localization of the LM of the TP, is beset by some limitations which require consideration. First, as the cadaver specimens were soaked in formalin, the tissues may have been dehydrated and denatured; this could potentially affect the accuracy of measured values. Secondly, although great care was taken during the procedure, the removal of superficial tissue structures may still affect the position of the nerve. It is critical to retain the integrity of the tissue around the tibial nerve and minimize the impact on the position of the tibial nerve and its branches. For clinical validation, it is necessary to confirm the location of the LM of the TP by electrical stimulation; this can make up for the shortcomings of this anatomical study. Third, it is impossible to measure the depth of the motor nerve branches of the tibial nerve in the current study due to procedural limitations that required the removal of superficial tissue structures. Therefore, this study can only locate the motor branches of the tibial nerve in two dimensions.

Conclusion

Treatment of TP spasticity using injection with botulinum toxin or neurolysis of motor branches is beset by the need for high technical skills. This study has demonstrated that it is feasible to locate the motor branch nerve of the TP whose blockade can help to relieve spasticity in the treatment of spastic equinovarus foot. Further validation of this approach should provide a clinically viable intervention in managing this condition.

Conflicts of interest

The authors declare no conflicts of interest.

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