Foot and Ankle Surgery 22 (2016) 196–199

Contents lists available at ScienceDirect

Foot and Ankle Surgery

journal homepage: www.elsevier.com/locate/fas

Interosseous membrane window size for tibialis posterior tendon transfer—Geometrical and MRI analysis

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ARTICLE INFO

Article history:
Received 7 June 2015
Received in revised form 18 August 2015
Accepted 10 September 2015

Keywords:
Tibialis posterior tendon transfer
Interosseous membrane
Drop foot
Tendon transfer
Tendon entrapment

ABSTRACT

Background: Tibialis posterior (TP) tendon transfer through the interosseous membrane is commonly performed in Charcot-Marie-Tooth disease. In order to avoid entrapment of this tendon, no clear recommendation relative to the interosseous membrane (IOM) incision size has been made.
Objective: Analyze the TP size at the transfer level and therefore determine the most adequate IOM window size to avoid muscle entrapment.
Methods: Eleven lower extremity magnetic resonances were analyzed. TP muscle measurements were made in axial views, obtaining the medial-lateral and antero-posterior diameter at various distances from the medial malleolus tip. The distance from the posterior to anterior compartment was also measured. These measurements were applied to a mathematical model to predict the IOM window size necessary to allow an ample TP passage in an oblique direction.
Results: The average tendon diameter (confidence-interval) at 15 cm proximal to the medial malleolus tip was 19.47 mm (17.47–21.48). The deep posterior compartment to anterior compartment distance was 10.97 mm (9.03–12.90). Using a mathematical model, the estimated IOM window size ranges from 4.2 to 4.9 cm.
Conclusion: The IOM window size is of utmost importance in trans-membrane TP transfers, given that if equal or smaller than the transposed tendon oblique diameter, a high entrapment risk exists. A membrane window of 5 cm or 2.5 times the size of the tendon diameter should be performed in order to theoretically diminish this complication.

1. Introduction

Tibialis posterior transfer was first reported by Ober in 1933 [1]. He described the circumtibial technique. This transfer allows the foot to recover (at least partially) its dorsiflexion motion in pathologies such as Charcot-Marie-Tooth, leprosy, mononeuropathy, common peroneal nerve injury, stroke, Duchenne muscular dystrophy [2–5,7], whenever the deformity is flexible.

Since its first description by Ober who transferred the tendon subcutaneously around the tibia, Mayer, who credited Putti [8], came up with another tibialis posterior transfer technique: through the interosseous membrane. Watkins popularized this procedure in 1955 [9] and proposed several variations and modifications. Despite several modifications of this technique [3,9–11], at the present time no clear information relative to the interosseous membrane window size is available in order to avoid some potential complications of this technique: adhesions or muscle-tendon entrapment at the transfer site [3,6,12–14].

The purpose of our research was to measure the tibialis posterior (TP) diameter at various locations throughout the leg and the distance from its original situation in the deep posterior compartment to its new expected position in the anterior compartment. From this information we would therefore determine the most appropriate size of the interosseous membrane incision (window) necessary to provide a safe tibialis posterior tendon excursion.

2. Methods

Eleven magnetic resonance (MRI) studies were analyzed from legs being studied because of a non-traumatic non-related diagnosis. Inclusion criteria were: skeletally mature, no evidence

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http://dx.doi.org/10.1016/j.fas.2015.09.001
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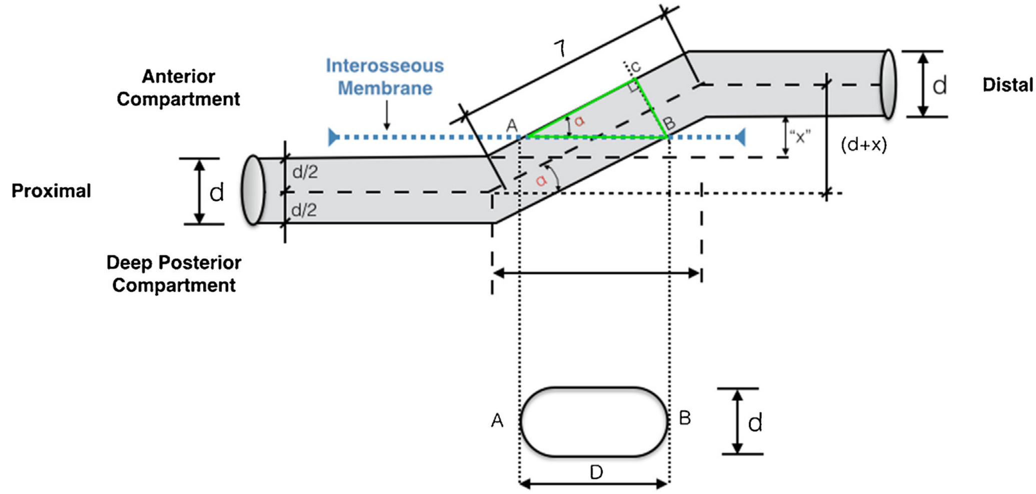

Fig. 1. If we superimpose our tendon transfer to a scalene triangle "ABC" (green color), the longest side (AB segment) represents the hypotenuse or the oblique tendon diameter; the other minor sides represents the cathetus, the shorter cathetus (BC segment) represents the transverse tendon diameter; being "alpha" (α) the angle formed by the AB and AC segments. Abbreviations: d = tendon smaller diameter, D = tendon larger diameter. (For interpretation of the color information in this figure legend, the reader is referred to the web version of the article.)

of previous skeletal injury, tumour or Tibialis posterior tendon disease. Tibialis posterior measurements were made in axial views of the legs, using commercially available radiological software (Agfa Healthcare N.V. Mortsel, Belgium, 2014) obtaining the medio-lateral and antero-posterior diameter at various distances from the tip of the medial malleolus (10 cm, 12 cm and 15 cm). The 3 different measurement locations were chosen according to different surgical technique descriptions [1,3,4,9–11,15,16] and were performed by one orthopaedic surgeon trained in magnetic resonance imaging measurements. The mediolateral and antero-posterior diameters were averaged to obtain a combined diameter of the musculotendinous unit.

With these results, a geometric analysis was performed to determine the diameter of the tibialis posterior musculotendinous unit when placed in an oblique angle. The tendon obliquity was determined by the distance necessary to transfer the tendon from the posterior to the anterior compartment and by the transposed tendon length. The distance between compartments was calculated in MRI, measuring the distance from the TP anterior border to 5 mm anterior to the interosseous membrane ("x" in Fig. 1). The transposed tendon length was assumed from the senior author's empirical experience.

This oblique diameter is necessary larger than the transverse diameter and corresponds to the minimum window size in the interosseous membrane in order to avoid entrapment. Descriptive statistics were performed, and a confidence interval was calculated to estimate the minimum and maximum musculotendinous unit diameter and distance from the posterior to the anterior compartment.

3. Results

We reviewed 11 leg MRI. All patients were physically active (recreational sports) and had a median age of 34 years (range 16–55), with a gender distribution of 6 male and 5 female. The combined diameter (95% confidence interval) of the tibialis posterior unit at 10 cm proximal to the tip of the medial malleolus was 16.65 mm (15.35–17.96), at 12 cm was 17.82 mm (16.40–19.25), and at 15 cm was 19.47 mm (17.47–21.48) (see Table 1 for complete set of results). The distance between the original position of the tibialis posterior unit to its new expected position in the anterior compartment (anatomic location of tibialis posterior tendon to the antero-lateral border of the tibia) was (including confidence interval) at 10 cm: 12.27 mm (10.71–13.83), at 12 cm:

Table 1
Tendon diameter on MRI at various distances from the tip of the medial malleolus.

Patient	Medial-lateral cross sectional diameter			Antero-posterior cross sectional diameter			Combined estimated diameter		
	10 cm	12 cm	15 cm	10 cm	12 cm	15 cm	10 cm	12 cm	15 cm
1	10.70	10.70	15.80	26.60	25.60	23.20	16.87	16.55	19.14
2	10.30	12.90	12.50	29.20	32.80	33.60	17.34	20.56	20.49
3	9.40	10.20	11.00	22.70	25.00	20.30	14.60	15.96	14.94
4	9.60	12.90	15.00	32.90	30.50	30.50	17.77	19.83	21.38
5	9.90	9.90	11.60	32.70	31.40	33.40	17.99	17.63	19.68
6	10.30	11.20	13.30	27.90	30.50	31.40	16.95	18.48	20.43
7	8.90	11.50	11.90	24.50	22.10	21.60	14.76	15.94	16.03
8	9.70	10.40	14.10	22.80	27.90	29.70	14.87	17.03	20.46
9	8.80	10.60	11.40	22.70	22.70	21.80	14.13	15.51	15.76
10	13.60	15.30	19.20	31.50	31.50	33.60	20.69	21.95	25.39
11	11.10	11.30	16.00	26.80	24.50	26.30	17.24	16.63	20.51
Mean	10.20	11.53	13.80	27.30	27.68	27.76	16.65	17.82	19.47
Std. Err.	0.4003	0.4803	0.7599	1.1804	1.1605	1.5856	0.5849	0.6402	0.8999
95% Conf. Interval.	9.31–11.10	10.46–12.60	12.10–15.49	24.66–29.93	25.09–30.26	24.23–31.29	15.35–17.96	16.40–19.25	17.47–21.48

Table 2
Distance between the original position of the tibialis posterior unit to its new expected position in the anterior compartment.

Patient	Anterior-posterior distance		
	10 cm	12 cm	15 cm
1	10.70	10.70	10.70
2	12.90	12.90	12.50
3	14.80	10.20	9.80
4	12.10	12.90	12.50
5	12.00	8.60	8.60
6	14.60	13.80	15.50
7	14.90	14.80	15.20
8	14.50	10.50	11.50
9	10.20	11.70	10.50
10	10.50	7.00	7.00
11	7.80	7.20	6.90
Mean	12.27	10.93	10.97
Std. Err.	0.7012	0.7812	0.8686
95% Conf. Interval.	10.71–13.83	9.19–12.67	9.03–12.90

10.93 mm (9.19–12.67) and 15 cm: 10.97 mm (9.03–12.90) (see Table 2 for complete set of results).

3.1. Geometric analysis

As the transferred tendon crosses obliquely through the interosseous membrane, the membrane window needed to allow its passage is much larger than the transverse tendon diameter. To know the angle of the transferred tendon, two variables have to be known. The first variable is the posterior to anterior compartment distance, i.e. the muscle starting and ending position in an axial view (axial translation). The second variable is the proximal to distal distance in which this translation will take place (in addition to the tendon combined diameter). With these 2 values, the tendon angle can be calculated using the trigonometric function "sine". The 95% confidence interval for the distance between compartments ranged from 9 mm to 13.8 mm. The total distance used for the transfer was assumed to be 7 cm from the senior author's empirical experience. Taking the anterior to posterior compartment distance (9–13.8 mm), the maximum combined tendon diameter (2.1 cm) and the total transferred tendon distance (7 cm), the estimated transferred tendon angle range is 25–30° (Fig. 1).

Knowing the angle and the combined diameter of the tibialis posterior unit, the oblique diameter or estimated window size can now be estimated. If we superimpose our tendon to a scalene triangle we get Fig. 1. We call this triangle "ABC", being the AB length equal to "*D*", triangle hypotenuse or oblique tendon diameter or estimated window size. The BC length is equal to "*d*", short cathetus or the transverse tendon diameter. If we call "alpha" (α) the angle formed by the AB and AC segments (SegAB, SegAC), the trigonometric function "sine" equals $\text{Sine}\,\alpha = d/D$ (opposite cathetus/hypotenuse) (Equation 1).

The short cathetus or "*d*" was measured in the patients MRI and reported as the combined diameter. The 95% confidence interval goes from 17 mm to 21 mm. We chose the maximum estimated value of 2.1 cm to perform calculations. Finally, in Equation 1, using an α value ranging from 25 to 30°, "*D*" or the estimated window size in the interosseous membrane equals to: $D = 2.1/\text{Sin}(\alpha^\circ) = 4.2–4.9$ cm.

The value of "*D*" in equation 1 increases by inverse proportion, i.e. the bigger angle we use, the smaller the oblique tendon diameter (or *D*) will be. Different examples are shown in Fig. 2 using alpha values of 20°, 25° and 30°.

4. Discussion

There have been many description of the tibialis posterior transfer technique. Ober was the first to describe it [1], followed by

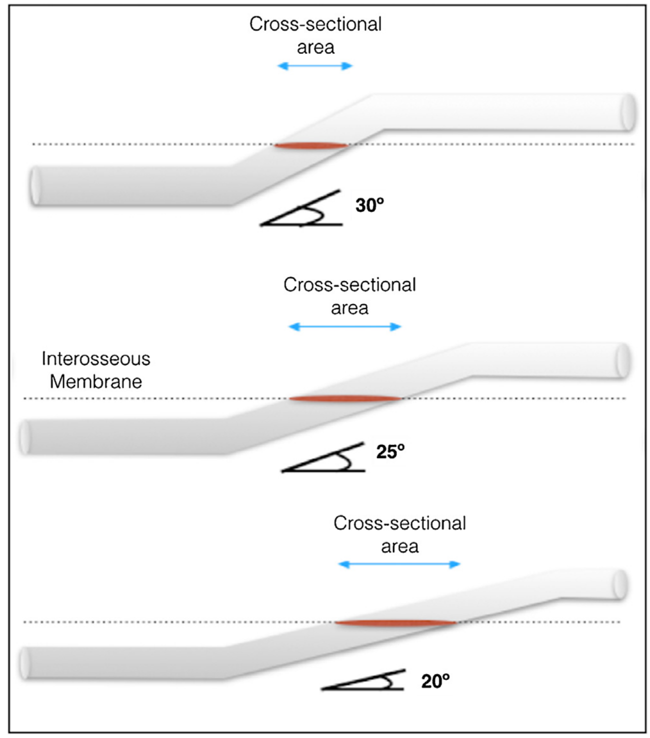

Fig. 2. Examples of alpha (α) values. The bigger angle (α) we use, the smaller the oblique tendon diameter (OTD) will be. If (α) = 30° then OTD = 4.2 cm; If (α) = 25° the OTD = 4.9 cm; and If (α) = 20° then OTD = 6.1 cm.

Putti who was the first to publish the trans-interosseous membrane transfer [8]. Many technique modifications have been published since that time (Watkins, Hsu-Hoffer, Myerson) [3,10,11,14], but no specific detail has been given to the interosseous membrane window size. The interosseous membrane is a strong fibrous tissue that extends from the tibia to the fibula throughout the whole leg, playing an important mechanical role. When performing the tibialis posterior transfer, if no appropriate membrane window is made, this strong tissue will most probably cause adhesions or muscle entrapment [3,6,12–14].

The surgical technique modifications [1,3,7–11,16] vary in the distance of the transfer from the ankle (10–15 cm proximally), but no further analysis has been given to the window size (length) in the surgical technique, even though it can be a source of complications, mainly tibialis posterior entrapment and adhesions. In the work done by van der Werf et al. [5] and Turner et al. [14], they described a 2 cm length incision at the interosseous membrane to allow tendon transfer. The Myerson modification [3], described a 2 cm membrane window length too, but added the concept that the tibialis posterior muscle belly should traverse the interosseous membrane, rather than the tendon, to avoid adhesions. The Hsu-Hoffer modification technique makes no comment on the interosseous membrane window length [2,11].

We found in our research that the maximum combined muscle diameter is 2.1 cm approximately when performing the transfer 15 cm proximal to the medial malleolus. The more distal the transfer, the smaller the combined diameter results (e.g. 16 mm of combined diameter when performed 10 cm proximal to the medial malleolus). Assuming a maximum estimated combined tendon diameter (2.1 cm), and the smallest transfer angle possible (25°) in order to maximally estimate the membrane window size, its length should measure approximately 5 cm. This window size probably allows a good muscle excursion, decreasing the entrapment risk. Normally, the membrane window size is taught to be 2–4 cm in length during orthopaedic residencies and foot and ankle fellowships and is probably what is mostly done worldwide. We believe that increasing this window size to 5 cm or to the value obtained by multiplying the tendon diameter by a constant of 2.5, could yield an improved excursion of the transfer and hopefully better outcomes.

The limitations of this research include the fact that patients heights were not considered (which could change the muscle diameter measurements) and that the muscles were evaluated in a relaxed state during the MRI. Regarding the latter, every muscle changes its form from a relaxed to a contracted state in vivo. In this analysis only the relaxed state was measured. This could mean that our results could be underestimating the real working muscle diameter. The anatomical variation between patients will introduce differences in every measurement, and only a small sample of this variation was obtained. Having said this, anatomical relationships should be maintained, and a 95% confidence interval was used to hopefully better represent a population. Another limitation refers to the surgical technique employed, as every surgeon will perform the transfer in a different way, varying the distance between incisions and therefore the length of the tendon transposed. A couple of assumptions had to be made too (for the sake of some calculations): assumptions included: a transferred tendon length of 7 cm and that the activity level of patients was average (more active patients would have had a larger muscle diameter and viceversa).

We think that our research approached a problem not previously discussed in the literature, where only expert recommendations are available. More investigations have to be performed in this topic to determine which way of transferring, i.e. circumtibial or trans-membrane, is the best depending on the function to be recovered and the muscular balance remaining. We suggest that everytime a trans-membrane transfer is chosen, an ample window of at least 5 cm or 2.5 times the tibialis posterior musculotendinous unit diameter should be performed. This is a recommendation and is not intended to replace the surgeons clinical and intraoperative tibialis posterior functional evaluation. Clinical studies are needed in order to prove any functional significance of these recommendations.

References

[1] Ober FH. Tendon transplantation in the lower extremity. New England J Med 1933;209:52–9.

[2] Hsu JD. Posterior tibial and anterior tibial tendon transfers for rebalancing the foot in neuromuscular disorders. Tech Foot Ankle 2009;8:172–7.

[3] Myerson M. Reconstructive Foot and Ankle Surgery, Chapter 16: Tendon transfers for management of paralytic deformity. Philadelphia: Elsevier Saunders; 2005.

[4] Steinau HU, Tofaute A, Huellmann K. Tendon transfers for drop foot correction: longterm results including quality of life assessment, and dynamometric and pedobarographic measurements. Arch Orthop Trauma Surg 2011;131:903–10.

[5] van der Werf GJIM, Tonino AJ. Transposition of the posterior tibial tendon in spastic equinovarus. Arch Orthop Traumatic Surg 1984;103:128–30.

[6] Wagenaar F, Louwerens JW. Posterior tibial tendon transfer: results of fixation to the dorsiflexors proximal to the ankle joint. Foot Ankle Int 2007; 28:1128–42.

[7] Wiesseman GJ. Tendon transfers for peripheral nerve injuries of the lower extremity. Orthop Clin North Am 1981;12:459–67.

[8] Mayer L. The physiological method of tendon transplantation in the treatment of paralytic drop-foot. J Bone Joint Surg 1937;19:389–94.

[9] Watkins MB, Jones JB, Ryder Jr CT. Transplantation of the posterior tibial tendon. J Bone Joint Surg Am 1954;36:1181–9.

[10] Gunn DR, Molesworth BD. The use of tibialis posterior as a dorsiflexor. J Bone Joint Surg Br 1957;39:674–8.

[11] Hsu JD, Hoffer MM. Posterior tibial tendon tendon transfer anteriorly through the interosseous membrane: a modification of the technique. Clin Orthop Relat Res 1978;131:202–4.

[12] Miller GM, Hsu JD, Hoffer M. Posterior tibial tendon transfer: a review of the literature and analysis of 74 procedures. J Pediatr Orthop 1982;2:363–70.

[13] Pappas AJ, Haffner KE. Cadaveric limb analysis of tendon length discrepancy of posterior tibial tendon transfer through the interosseous membrane. J Foot Ankle Surg 2013;52:470–4.

[14] Turner JW, Cooper RR. Anterior transfer of the tibialis posterior through the interroseous membrane. Clin Orthop Relat Res 1972;83:241–4.

[15] Chang TJ. The foot and ankle. Tendon transfer, Chapter 21. Lippincott Williams & Wilkins; 2005.

[16] Wiesel SW, Easley ME. Operative techniques in foot and ankle surgery. Chapter 126, Tendon transfer for foot drop. Philadelphia: Wolters Kluwer Health/ Lippincott Williams & Wilkins; 2010.