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Original article

Tibialis posterior transfer for foot drop due to central causes: Long-term hindfoot alignment

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ABSTRACT

Background: Tibialis posterior transfer (TPT) is the treatment most widely used to palliate foot drop due to dorsiflexor palsy. TPT has been extensively studied in patients with peripheral neurological causes of foot drop. In contrast, data are scarce on central foot drop, in which TPT is often blamed for causing flattening of the arches. The primary objective of this study was to assess the impact on foot alignment of TPT in patients with central foot drop. The secondary objective was to determine whether TPT combined with other surgical procedures improved gait.
Hypothesis: TTP can induce flattening of the medial arch of the foot.
Patients and Methods: We retrospectively identified 13 patients managed with TPT (1 foot per patient). Mean follow-up was 65 months (range, 12–108 months). The causes were stroke ($n = 5$), head injury ($n = 3$), spinal cord injury ($n = 2$), cervical spondylotic myelopathy ($n = 1$), cerebral palsy ($n = 1$), and a brain tumour ($n = 1$). The clinical assessment focused chiefly on forefoot alignment and footprint parameters. The following variables were collected from weight-bearing radiographs: Djian-Annonier angle, Méary-Toméno angle, lateral arch angle, and calcaneal pitch angle in the sagittal plane; talo-metatarsal angle in the transverse plane; and rearfoot valgus angle in the coronal plane.
Results: Of the 13 feet, 6 had normal footprint parameters and 7 pes cavus. There were no cases of flatfoot. Pronation deformities and supination deformities were each found in 2 patients. Comparing the radiographic parameters between the two feet in each patient identified differences only for the lateral arch angle and calcaneal pitch angle, which indicated pes cavus on the operated side (operated side: 142.7° [range, 136°–156°], $p = 0.041$; and 24° [range, 14°–33°], $p = 0.028$, respectively).
Discussion: In contrast to the working hypothesis, we found no evidence of progression to valgus flatfoot after TPT transfer performed to treat central foot drop.
Level of evidence: IV, retrospective study with no control group.

1. Introduction

Tibialis posterior transfer (TPT) via the inter-osseous route, first described by Mayer [1], is the reference standard surgical treatment of dorsiflexor palsy responsible for foot drop. Several techniques have been reported [2–7]. The volume and fibre length of the tibialis posterior are similar to those of the tibialis anterior (TA) [8]. Most studies of TPT outcomes have focused on patients with peripheral neurological causes of foot drop. Information is scarcer for central foot drop, in which the outcomes of TPT are less predictable [9]. Given that the tibialis posterior is the main source of support to the medial arch, transferring it might induce valgus flatfoot, a deformity reported in patients with tibialis posterior dysfunction or rupture [10–13]. However, there is little reference to valgus flatfoot in case-series studies of TPT in adults. Furthermore, to our knowledge, post-TPT functional outcomes have not been assessed during gait, although they may differ from outcomes measured with the patient supine.

The primary objective of this study was to assess the impact on foot alignment of TPT in patients with central foot drop. The secondary objective was to determine whether TPT combined with

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Table 1
Features in the study population and surgical procedures performed.

Patients	Age (years)	Sex	Side	Cause	Time since surgery (years)	Fixation site	Concomitant procedures
1	57	F	R	Tumour	3.9	PB	GnA lengthening
2	42	M	L	Stroke	3.6	TA	Achilles lengthening FDL tenotomy Gn + S neurotomy
3	37	F	L	SCI	9	?	Gn + S neurotomy
4	35	M	R	HI	6.4	TA	Achilles lengthening Gn + S neurotomy
5	35	F	L	Stroke	1	TA	Achilles lengthening FDL tenotomy Gn + S + TP neurotomy
6	57	M	R	CSM	4.5	TA	Achilles lengthening Gn + S neurotomy
7	37	M	R	HI	3.5	PB	Achilles lengthening FDL tenotomy Gn + S +TP neurotomy
8	46	M	L	Stroke	7	C	Achilles lengthening Gn neurotomy
9	55	F	R	HI	8.8	TA	Gn neurotomy
10	61	M	R	Stroke	8	PB	Achilles lengthening TP neurotomy
11	37	M	L	Stroke	8	C	Achilles lengthening Gn + S neurotomy
12	26	M	R	Cerebral palsy	6.3	PB	Achilles lengthening, Gn + S neurotomy
13	30	M	R	SCI	1	PB	Achilles lengthening FDL tenotomy FHL lengthening Gn + S + TP neurotomy
Total	42,7	9 M (69%)	8R (61,5%)	Stroke, *n* = 5 (38.4%) HI, *n* = 3 (23%) SCI, *n* = 2 (15.4%) CSM, *n* = 1 (7.7%) CP, *n* = 1 (7.7%) Tumour, *n* = 1 (7.7%)		TA, *n* = 5 (53%) PB, *n* = 5 (29.4%) C, *n* = 2 (11.7%)	

M: male; F: female; L: left; R: right; HI: head injury; SCI: spinal cord injury; CSM: cervical spondylotic myelopathy; CP: cerebral palsy; TA: tibialis anterior; TP: tibialis posterior; C: cuboid; PB: peroneus brevis; GnA: gastrocnemius aponeurosis; FDL: flexor digitorum longus; FHL: flexor hallucis longus; Gn: gastrocnemius; S: soleus.

other surgical procedures improved gait. The working hypothesis was that TTP could induce flattening of the medial arch of the foot.

2. Patients and Methods

2.1. Inclusion and exclusion criteria

The study patients were managed at the Lille university hospital in Lille, France, between 1995 and 2012. To be eligible, patients had to meet the following criteria pre-operatively: age older than 18 years; weakness of the foot dorsiflexors due to an acquired central neurological abnormality; absence of visible tibialis anterior recruitment during walking; and permanent hindfoot varus, including during the stance phase, ascribable to forces applied by the tibialis posterior muscle. Only patients with a follow-up of at least 9 months since TPT were included. We excluded patients with midfoot and hindfoot arthrodesis, hindfoot varus present only during the swing phase and ascribable to tibialis anterior muscle activity, or visible tibialis anterior muscle recruitment during walking.

Of 23 identified patients meeting the inclusion criteria, 3 had died, 2 declined to participate in the study, and 5 had been lost to follow-up, leaving 13 patients for retrospective review. Table 1 reports the main patient characteristics and intra-operative data.

2.2. Surgical procedures

TPT via the inter-osseous route was performed under general anaesthesia in all 13 patients. The tibialis posterior tendon was cut at its distal insertion site or in the medial retro-malleolar groove, depending on the length needed for the transfer. The tendon was then re-routed to the anterior compartment through the inter-osseous space after full-width inter-osseous membrane resection, proximal to the superior extensor retinaculum. The tibialis posterior tendon was then attached to either the tibialis anterior tendon (as described by Pulvertaft) or the lateral edge of the foot around the peroneus brevis tendon or via trans-osseous anchors implanted in the cuboid bone. The choice between these two sites was governed by the existence of lateral instability due to weakness of the accessory peroneal muscles.

Concomitant surgical procedures on tendons or nerves were performed as appropriate, notably in the posterior leg compartment if spasticity or tendon retraction contributed to the functional impairments. These procedures were as follows: selective neurotomy of the motor nerve branches to the gastrocnemius muscles ($n = 11$), of the superior nerve to the soleus muscle ($n = 11$), or of the posterior tibial nerve ($n = 4$); Achilles tendon lengthening ($n = 10$); lengthening of the gastrocnemius aponeurosis ($n = 1$); intramuscular lengthening of the flexor hallucis longus ($n = 2$); and flexor digitorum tenotomy ($n = 4$).

A resin boot cast was worn for 5 weeks. After removal of the cast, rehabilitation therapy was provided in a rehabilitation centre for at least 1 month, followed by rehabilitation therapy by a community-based physiotherapist.

2.3. Assessment methods

To achieve our primary objective, we assessed foot alignment both clinically, based on visible deformities in the horizontal plane (pronation-supination) and on footprint parameters, and

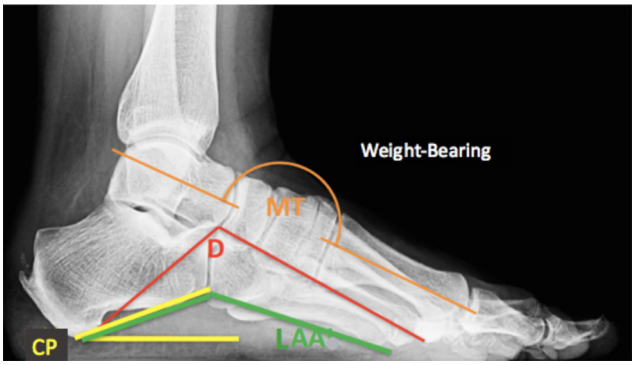

Fig. 1. Angles measured on the lateral weight-bearing radiograph. MT: Méary-Toméno angle; D: Djian-Annonier angle; LAA: lateral arch angle; CP: calcaneal pitch.

radiographically. Weight-bearing radiographs were used to measure four parameters in the sagittal plane, i.e., the Djian-Annonier angle, Méary-Toméno angle, lateral arch angle, and calcaneal pitch (Fig. 1); the talo-metatarsal angle in the transverse plane; and the rearfoot valgus angle in the coronal plane (Fig. 2a and b). To reach our secondary objective, we collected the following parameters: ranges of passive and active foot dorsiflexion in the supine position with the knee extended and flexed at 90°, measured using a goniometer; dorsiflexor strength graded according to the Medical Research Council (MRC) system [14]; whether a foot-drop device or orthopaedic shoe was worn before and/or after TPT; maximum dorsiflexion range during the swing phase when walking barefoot measured on videos recorded by two synchronised cameras, in the coronal and sagittal planes, respectively; and Global Assessment Scale (GAS) score for the overall change induced by TPT, which can range from −4 (severe worsening) to +4 (complete elimination of symptom) [15].

2.4. Statistical analyses

Categorical variables were described as number (%) and continuous variables as mean (range). For comparisons of pre-operative vs. post-operative data and of data on the operated vs. contralateral sides, we applied Wilcoxon's test for continuous variables and McNemar's test for categorical variables. All statistical analyses were done using SPSS version 20.0 software (IBM Corp., Armonk, NY, USA). Values of $p \leq 0.05$ were taken to indicate significant differences.

3. Results

The study included 13 patients, whose main features are listed in Tables 1 and 2. Mean follow-up was 5.5 years (range, 1–9 years).

3.1. Clinical and radiographic data on foot alignment

The evaluation of forefoot alignment during weight bearing in the coronal plane identified pronation deformity in 2/13 (15.4%) feet after TTP. The tibialis posterior tendon had been fixed to the tibialis anterior tendon in 1 of these patients and to the peroneus brevis in the other. Pronation deformity was not found in any of the feet on the non-operated side. Supination deformity was identified in 2/13 (15.4%) operated feet, both of which had been managed by tibialis posterior tendon attachment to the lateral edge of the foot.

The footprint parameters indicated pes cavus deformity in 7/13 (53.8%) feet on the operated side. The deformity was grade 1 in 5/7 (71%) feet and grade 3 in 2/7 (29%) feet. No cases of pes cavus deformity were found on the non-operated side. There was a single case of grade 1 flatfoot on the non-operated side. Thus, the footprint parameters were normal in 6/13 (46%) feet on the operated side and 12/13 (92%) feet on the non-operated side. No cases of flatfoot were identified on the operated side.

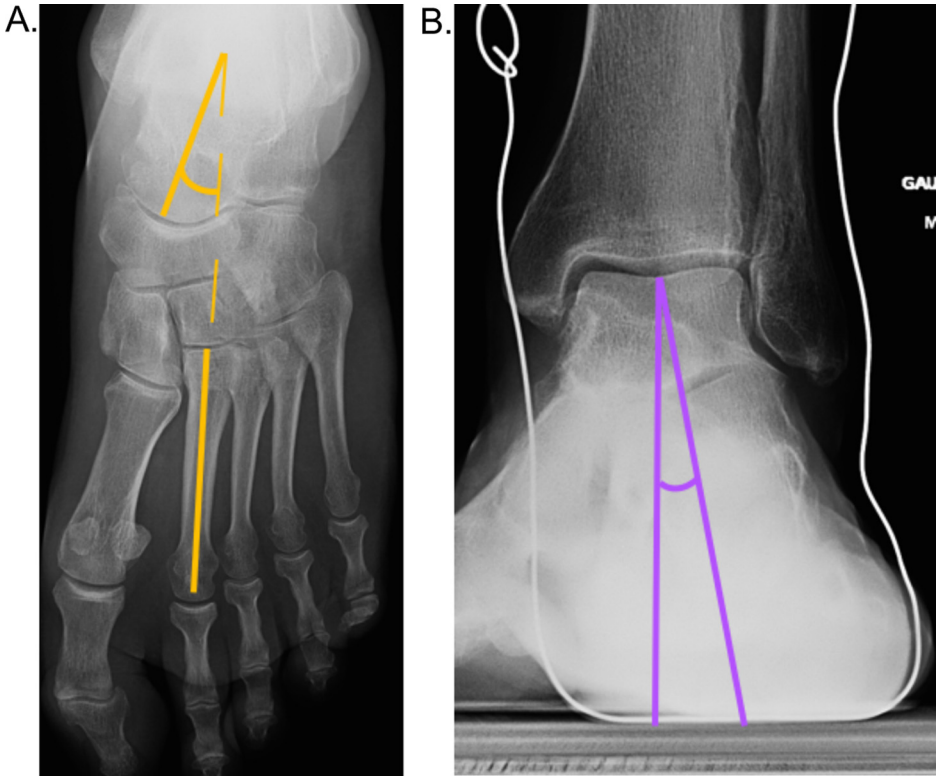

Fig. 2. A. Talo-metatarsal angle measured on the antero-posterior weight-bearing radiograph. B. Rearfoot valgus angle measured on the Méary view with a wire circling the heel.

Table 2
Main factors that affect the efficacy of tibialis posterior transfer.

Patients	Deficiencies				Marche		Foot alignment	Patient satisfaction
	Dorsiflexion strength (/5)	Active dorsiflexion arc in the supine position (°)	Weaned off foot drop orthosis	Weaned off orthopaedic shoe	Active dorsiflexion arc during gait (°)	Contact with ground		GAS [15]00
1	3	15	Fully	/	5	Sole	N	3
2	0	0	Fully	/	0	Sole	PC	3
3	2	18	Partially	Fully	2	Heel	PC	2
4	0	0	Fully	/	5	Sole	N	2
5	4	10	Non-user	/	5	Sole	PC	3
6	2	0	Fully	/	0	Sole	PC	3
7	0	0	Non-user	/	0	Sole	N	2
8	0	0	Non-user	Fully	0	Sole	PC	3
9	2	5	Rigid	/	0	Toes	N	0
10	0	0	Fully	/	0	Toes	PC	2
11	1	10	Fully	/	5	Sole	N	4
12	0	0	Fully	Fully	0	Sole	PC	4
13	5	40	Non-user	/	10	Heel	N	2

N: normal alignment; PC: pes cavus; GAS: global assessment scale.

Table 3
Comparison of the radiographic parameters on the operated and non-operated sides.

		Operated sideMean (range)	Non-operated sideMean (range)	*p* value
Sagittal plane	Djian-Annonier angle (°)	116.75 (105–127)	118.83 (105–132)	0.697
	Toméno-Méary angle (°)	6.7 (0–15)	6.25 (0–12)	0.937
	Calcaneal pitch (°)	24.83 (14–33)	21.58 (13–27)	0.028
	Lateral arch angle (°)	142.67 (131–156)	147 (129–156)	0.041
Hindfoot	Valgus	7.2° (3–15)	7.8 (3–13)	0.858
	Varus ($n = 1$)	2°	5°	
Horizontal plane	Talo-metatarsal angle (°)	16.75 (−6–39)	15.82 (−10–31)	0.925

Table 3 shows the comparisons of the radiographic parameters. The only significant differences were for calcaneal pitch and lateral arch angle on the operated vs. the non-operated sides ($p = 0.028$ and $p = 0.041$, respectively), indicating a tendency to posterior pes cavus and increased lateral arch height on the operated side.

3.2. Motion-range and strength analysis – filmed gait analysis

Mean passive dorsiflexion on the operated side was 15° (0°–30°) with the knee extended and 23.1° (10°–30°) with the knee flexed. Of the 13 patients, 11 (85%) were able to actively dorsiflex the foot, achieving a range of −3.2° (−5° to 20°) with the knee extended and 5.3° (5°–20°) with the knee flexed; mean MRC dorsiflexion strength was 2.9/5 (Fig. 3) reports the measured dorsiflexion strength values.

By filmed gait analysis, 7/13 (54%) patients had visible active dorsiflexion during the swing phase, with a mean motion arc of 5.3° (2°–10°); 3 (23%) patients were able to reach or go beyond the neutral position. Ground contact was with the sole of the foot in 9 (69.2%) patients, heel in 3 (23%) patients, and forefoot in 1 (7.8%) patient.

Of the 10/13 (69.2%) patients who wore an orthosis or orthopaedic shoe before surgery, 7 (77.8%), including all 3 orthopaedic shoe wearers, no longer did after surgery ($p = 0.021$). The mean GAS score was 2.9 (range, 2–4). No patient reported worsening (i.e., no patient had a negative GAS score).

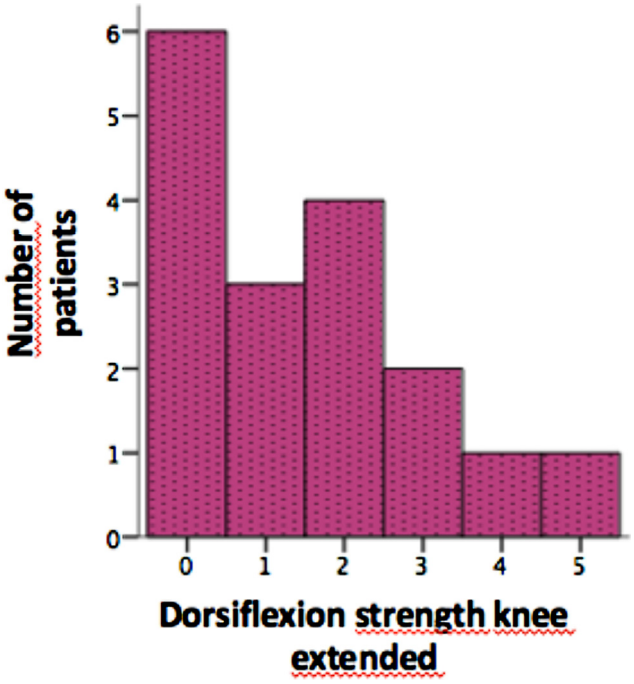

Fig. 3. Dorsiflexion strength with the knee extended as assessed using the Medical Research Council grading system.

4. Discussion

None of our study patients experienced arch collapse with valgus flatfoot after TPT. On the contrary, we identified a tendency towards the development of pes cavus deformity. Gait improved after surgery in most patients.

The tendency towards pes cavus after TPT is consistent with data reported previously by Gasq et al. [9]. In healthy individuals, valgus flatfoot has been reported in the event of tibialis posterior dysfunction. The tibialis posterior is the main stabiliser of the medial arch and normally counteracts the everting effect of the accessory

peroneal muscles. In patients with neurological abnormalities, valgus flatfoot has been reported chiefly in children [16–19], resulting in the practice of transferring only half of the tibialis posterior. However, the pathophysiology of foot deformities differs between children with cerebral palsy and adults with acquired neurological abnormalities. More specifically, children with cerebral palsy are more likely to exhibit hypertonia of the accessory peroneal muscles, which promotes the development of valgus flatfoot. Factors potentially involved in the development of pes cavus may include spasticity and/or retraction of the intrinsic plantar muscles, which may promote the development of posterior pes cavus; spasticity of the lateral intrinsic muscles or peroneus brevis resulting in lateral closure; and traction by the transferred tibialis posterior, particularly if it remains spastic, which may contribute to elevate the medial arch and promote the development of anterior pes cavus.

Forefoot deformities in the coronal and transverse plane were identified in some of our patients. The pronation deformities seen in 2 patients may have been related to tendon imbalance induced by the transfer, with a predominant effect of the foot evertors, and/or to spasticity of the foot evertors. The supination deformities, also seen in 2 patients, were consistent with residual tibialis anterior hyperactivity, intrinsic muscle hypertonia or residual retraction, and/or activity of the transferred tibialis posterior. Forefoot alignment in the coronal and transverse planes after TPT has not been described previously. This factor deserves attention, however, as it may adversely affect function.

The functional outcomes of the overall surgical management in our patients are encouraging. Patients who previously used an orthosis or orthopaedic shoe were usually able to dispense with the device after TPT. Furthermore, the level of patient satisfaction was high. During gait, although 92.2% of patients contacted the ground with the sole of the foot or heel, only half actively dorsiflexed the foot during the swing phase. In keeping with two previous studies [9,19], the study of foot function in the supine position showed active dorsiflexion at least to the neutral position in a similar proportion of patients. The mean dorsiflexor strength in our study of 2.9/5 is less than reported by Wagenaar and Louwerens [19], but their population was different from ours. Active dorsiflexion is not necessarily due entirely to the tendon transfer. Posterior plane release, which is often performed concomitantly, may unmask tibialis anterior activity that was undetectable before surgery. Dynamic electromyogram testing would have provided more accurate data. As a pre-operative test, dynamic electromyography may assist in planning the surgical procedure based on the pattern of tibialis posterior and tibialis anterior activation during the swing phase [17,18]. Since writing this article, we routinely obtain a dynamic electromyogram if the gait analysis suggests possible tibialis posterior contraction during the swing phase (notably seen as an increase in medial arch height).

Our study has several limitations. The evaluation bias inherent in the retrospective design limits the interpretation of the results, notably regarding foot alignment. To mitigate this source of bias, we compared the operated and non-operated sides. We assessed gait by observation of 2D videos. With this method, spatial distortion results in loss of accuracy compared to quantitative gait analysis [20,21]. Nevertheless, ours is the only study that includes a filmed gait analysis in adults with central neurological abnormalities. Filmed gait analysis is more accurate than simple observation of gait. Finally, the heterogeneity of our study population in terms of the underlying neurological diagnosis and surgical procedures performed in combination with TPT hinders the evaluation of the contribution of TPT to both post-operative improvements and adverse events. However, ours is among the few studies providing a multi-dimensional assessment of TPT efficacy together with a detailed evaluation of foot alignment.

5. Conclusion

None of our patients developed valgus flatfoot after TPT. On the contrary pes cavus occurred in a substantial proportion of patients. The functional outcomes were satisfactory, with a high level of weaning off anti-equinus devices, improvements in gait, and good patient satisfaction levels. However, these outcomes were obtained by combining TPT with other procedures to release the posterior structures. The findings reported here require additional investigation by a prospective study of changes in foot alignment over time depending on pre-operative morphology, with dynamic electromyography testing to better assess the contribution of TPT to the improvements in active dorsiflexion.

Disclosure of interest

Prof. Fontaine has ties with Ipsen and Dr. Sturbois-Nachef with Ipsen and Merz Pharma.

The other authors declare that they have no competing interest.

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None.

Contributions of each author

Nadine Sturbois-Nachef: study design, data collection and entry, manuscript preparation.

Etienne Allart: study design, manuscript preparation.

Michel-Yves Grauwin: manuscript preparation.

Marc Rousseaux: manuscript preparation.

André Thévenon: manuscript preparation.

Christian Fontaine: study design, manuscript preparation.

All authors have read and approved the final version of the manuscript.

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