Posterior tibial tendon transfer in the spastic brain-damaged adult does not lead to valgus flatfoot

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Conflict of interest statement

None of the authors has conflict of interest.

ABSTRACT

Background: We studied the possible development of valgus flat foot after transfer of the posterior tibial tendon to the lateral cuneiform, used for surgical restoration of dorsiflexion in brain-damaged adult patients with spastic equinovarus foot.

Methods: Twenty hemiplegic patients were reviewed with a mean postoperative follow-up of 57.9 months. Weightbearing radiographs, static baropodometry analysis and functional evaluation were used to assess postoperatively outcomes.

Results: On the operated side, weightbearing radiographs showed an absence of medial arch collapse and a symmetrical and physiological hindfoot valgus; static baropodometric analysis showed a reduced plantar contact surface with a pes cavus appearance. The surgical procedure yielded good functional results. Nineteen patients were satisfied with the outcome of their surgery.

Conclusions: Our findings support that transfer of the posterior tibial tendon does not lead to valgus flat foot in the spastic brain-damaged adult, and is still a current surgical alternative for management of spastic equinovarus foot.

1. Introduction

Spastic equinovarus foot (SEF) combines deficient ankle dorsiflexion with inversion of the forefoot. The incidence of SEF in adults following stroke is estimated at 10% to 20% [1–4], with a percentage of true retraction (not correctable on slow passive stretching) estimated at between 5% and 30% [2]. A spastic equinovarus foot alters balance, quality of gait and the patient's ability to take part in the activities of daily living [3,5–7]. An orthosis or orthopaedic footware are often needed [2–4,7,8]. When there is no contracture, treatments such as intramuscular injection of botulinum toxin or selective neurotomy may be considered and be effective [6,7]. If the SEF cannot be corrected, surgery is the only alternative to use of an orthosis [8]. A surgical procedure is indicated in about 2 to 3% of patients [9], and improves the gait pattern and functional capacity [9–14].

Transfer of the posterior tibial tendon to the dorsum of the foot, in combination with lengthening of the calcaneal tendon, is one of the surgical options for SEF correction [15]. Some authors refuse this technique in the spastic brain-damaged adult as they consider that it leads in the long term to valgus deformity of the hindfoot and collapse of the medial arch (i.e. valgus flat foot) [12,16,17]. Posterior tibial tendon transfer to the dorsum of the foot is used in foot drop due to peripheral involvement of the common fibular nerve, where most authors do not report later development of painful valgus flatfoot [18–20]. In the patient with cerebral palsy, transfer of the posterior tibial tendon to the dorsum of the foot is also used for the treatment of SEF, but the results are debated [10,21–25].

Our principal aim was to evaluate the possible development of valgus flatfoot in spastic brain-damaged adult patients after posterior tibial tendon transfer for treatment of equinovarus deformity. The secondary aim was to evaluate the functional improvement gained from this surgical procedure.

2. Methods

2.1. Study population

We retrospectively studied 20 spastic brain-damaged adult patients (6 women, 14 men) who had undergone surgical transfer of the posterior tibial tendon to the dorsum of the foot between 2003 and 2008. All patients had hemiplegia, 16 after stroke and four after head injury. Mean duration of the disorder at the time of surgery was 101.8 months (20 to 271). Pre-operatively, all patients presented SEF calcaneal tendon contracture. Activity of tibial anterior muscle was considered insufficient to provide a split anterior tibial tendon transfer because the active voluntary contraction was deficient, and the visible activation during gait seemed insufficient and not entirely responsible for the hindfoot varus. In all cases, the fibular muscles were deficient in analytical testing, and showed no sign of overactivity during walking. Surgery was considered indicated after failure of medical treatment and validation by multidisciplinary medical and surgical consultation. Mean age at surgery was 51.7 years (22 to 66), mean weight 75 kg (48 to 112) and mean height 172.5 cm (157 to 182). Mean postoperative follow-up was 57.9 months (26 to 89). Detailed characteristics of patients are shown in Table 1.

Table 1

2.2. Operative technique

All patients underwent anterior transfer of the distal tendon of the posterior tibial muscle using a modified Watkins' technique [15]. The tendon was disinserted from the navicular bone and its plantar extensions were spared. It was secured on the lateral cuneiform by three fixations: a plantar pledget, a periosteal suture and a metallic staple. In addition, in all patients the calcaneal tendon was lengthened by a direct approach, for 2 to 4 cm (obtaining an intraoperative passive dorsiflexion of about 10°); 60% of patients underwent long and short toe flexor tenotomies, and 25% had lengthening of the great toe flexor. No arthrodesis was carried out. All patients were immobilised in plaster casts in neutral dorsiflexion without weightbearing for 4 weeks.

2.3. Evaluation of foot stance

Foot stance was comparatively evaluated in both feet by weightbearing radiographs and computerised pedobarographic analysis of contact areas. The non-operated foot was used as reference for each patient [26,27]. Collapse of the medial arch was assessed by measurement of two angles on a lateral weightbearing radiograph. Firstly, the medial arch angle (MAA) which is open inferiorly and whose apex is the lower part of the talonavicular joint. It is defined by the lines passing through the lowest point of the calcaneum posteriorly and by the lowest point of the sesamoid of the hallux anteriorly (Fig. 1a). The normal range is between 118° and 130°: cavus foot is defined by an angle of less than 118°, and flat foot by an angle of over 130° [27,28]. Secondly, the talometatarsal angle (TMA) is the angle formed by the axis of the talus and the axis of the first metatarsal. Normally, the two axes are aligned with a range of ± 4° (Fig. 1a), and the TMA is between 176 and 184°. In flat foot, TMA is open superiorly, with a value of 176° or less, whereas in cavus foot TMA value is greater than 184° [27,29–31]. The rearfoot valgus angle (RFVA) was measured on a weightbearing anterior radiograph with the heel circled. The RFVA is open inferiorly, the apex corresponding to the point lying between the superolateral and superomedial angles of the talus. The RFVA is defined between the vertical line drawn through this point and the centre of the contact area of the heel (shown by the circle) (Fig. 1b). An RFVA $< 0°$ corresponds to hindfoot varus, between 0 and 10° is moderate physiological varus, and RFVA $> 10°$ corresponds to increased valgus [28]. The angles were measured by two experienced operators.

Fig 1

The footprint was studied by electronic static baropodometry, with the subject standing immobile in bipodal stance for 10 seconds (Fusyo©, Medicapteurs©, Balma, France, measuring 530 x 600 mm, and with 2304 pressure gauges). The software measured the area of contact between the sole of the foot and the floor (footprint area or plantar area, expressed in cm^2) [20,27,32–34].

2.4. Functional evaluation

Patient satisfaction was evaluated using a visual analogue scale (range 0-100) and four ratings: very disappointed, disappointed, satisfied, very satisfied. With regard to function, we recorded pre- and postoperatively the ability to walk barefoot at home (which was preoperatively impossible for all patients), and the use of a cane or an orthosis (foot lifter or orthopaedic footwear) outdoors. Functional ambulation was assessed using the modified Functional Ambulation Classification (FAC) [35]. Clinical evaluation was only carried out postoperatively. Passive ankle plantarflexion as well as passive and active ankle dorsiflexion were examined with the knee extended in the operated foot. The foot lateral rotation was examined in both feet, and defined by the angle formed between the axis of progression of the patient and the axis of the second metatarsal. This measurement was performed in early stance phase with a manual goniometer, and included both distal rotation around the foot and ankle, and proximal rotation at hip and pelvis levels.

2.5. Statistics

Quantitative data before and after surgery were compared using the Wilcoxon test for non-matched series (non-parametric test) because the number of observations was less than 30. Percentages (binary variables) were compared with Fisher's exact test. An alpha coefficient (p value) < 0.05 was considered significant. Statistical analysis was carried out with SPSS version 14.0.1. software.

3. Results

3.1. Evaluation of foot stance

Table 2 shows the angle values measured from radiographs (MAA, TMA and RFVA) and the plantar contact area obtained by static baropodometry, on the operated and on the control side. On the operated side, mean MAA was 117.2°, mean TMA (open inferiorly) was 187.6°, and mean RFVA was 7.5°, with no significant difference between the two feet. Individual analysis of radiographic angles showed that 6 patients had hindfoot valgus > 10°. In one patient the valgus flat foot was bilateral and symmetric (RFVA operated/control 16°/18°, MAA operated/control 129°/133° and TAA 175° for both feet). Hindfoot valgus was > 10° in 3 patients on the operated side and in 2 patients on the control side, and was not accompanied by medial arch collapse. Only one foot (operated foot) had hindfoot varus of 5°. The mean plantar contact area of the operated foot was significantly less than that of the control foot, with decrease or disappearance of the isthmus suggesting cavus foot (Fig. 2a). No subject had a footprint suggestive of flat foot. Analysis of individual footprints showed that 5 patients (including the patient with hindfoot varus of 5°, or RFVA = -5°) had lateral edge contact of the operated foot (Fig. 2b). In 3 patients the footprint of the operated foot showed complete effacement of the isthmus with contact on the medial part of the forefoot, which was not accompanied by hindfoot valgus (RFVA < 10°) (Fig. 2c).

Fig 2

3.2. Patient satisfaction

Mean patient satisfaction was 75.9/100 (31 to 100). In 95% of cases patients were satisfied or very satisfied with the results of surgery (7 very satisfied and 12 satisfied). One patient was disappointed because of forefoot pain due to poor shoe fit, which resolved after use of an appropriate sole insert.

3.3. Functional and clinical data

When seen at follow-up, 4 patients required secondary removal of the staple causing pain of the dorsum of the foot, and 2 patients underwent distal tenotomy of the toe flexors because of the development of painful claw foot.

Table 3

The results of functional and clinical evaluation are presented in Table 3. Ninety per cent of patient (*n* = 18) were able to walk barefoot in the home postoperatively. Eleven of the 18 patients (61%) who used an orthosis before surgery (a foot lifter for 6 patients and orthopaedic footwear for 12 patients) no longer needed it. Of the 7 patients who were not able to discontinue their orthosis (1 for the foot lifter, 5 for orthopaedic footwear and one who discontinued orthopaedic footwear for a foot lifter), none experienced pain or discomfort from use of the orthosis. Only 2 of the 16 patients (12.5%) who used a cane preoperatively no longer needed it after surgery. The mean FAC score improved significantly by 0.5 points after surgery.

Observation of barefoot walking showed that only 3 patients (15%) had toe drag during the swing phase. Fifteen patients (75%) had initial heel or sole contact and 5 (25%) patients had initial forefoot contact. Five of the 6 patients who had not undergone initial or secondary tenotomy of the long toe flexor had non-symptomatic claw toe. One patient with head injury who presented permanent ankle dorsiflexion (calcaneus deformity) secondary to hyperactivity of the transposed posterior tibial tendon required regular injections of botulinum toxin in the muscle to enable him to obtain sole foot contact. Lateral rotation of the operated foot was more extensive than the control foot in 90% of the patients, with a mean differential lateral rotation of 22.3° (Fig. 3). The overall gait pattern remained unchanged and the majority of patients had decreased knee flexion (stiff knee) during the swing phase of the disabled limb. Passive examination of the range of joint movement showed mean ankle plantar flexion of 7.5°, with mean passive ankle dorsiflexion with the knee extended of 11.5° (positive or nil), indicating there was no recurrence of equinovarus. A low voluntary active contraction was observed in nine patients for the anterior tibial muscle, which did not allow full active ankle dorsiflexion. In two patients the transposed posterior tibial muscle showed a voluntary active contraction, but just one of them displayed a full and voluntary active ankle dorsiflexion.

Fig 3

4. Discussion

In our series, dual evaluation of foot stance, both radiographic and baropodometric, did not reveal systematic progression to valgus flat foot. Post-operative follow-up before evaluation was over 4 years, sufficient to adequately assess the development of secondary deformities of the foot [8,10,11,14,20,21,36,37]. Weightbearing radiographs showed there was no collapse of the medial arch. On the contrary, there was a bilateral tendency to cavus foot, characterised by an MAA less than 119° and a TMA greater than 184° [27–31]. Static baropodometry evaluation clearly showed a more cavus foot on the operated side, with a significantly decreased contact area. Generally, the isthmus was no longer apparent secondary to hollowing of the midfoot (Fig. 2a), unlike flat foot where the area of the isthmus increases [20,27,32–34]. We observed no systematic valgus deformity of the hindfoot, with an RFVA which remained symmetrical and within the normal range on both sides, nor any relation between lateral contact (Fig. 2b) or medial contact (Fig. 2c) on the footprint and the value of the RFVA. There was thus no strict agreement between the radiographic and the static baropodometric evaluations. This finding has already been underlined by some authors, showing a moderate correlation between these two types of evaluation, which however remain complementary for better definition of disorders of foot stance [27,32].

The absence of development of valgus flat foot in our series may probably be explained by several factors. Firstly, the patients operated were adults with spasticity of the intrinsic muscles of the feet in combination with probable contracture of plantar soft tissues. During the surgical procedure, the plantar expansions of the posterior tibial tendon were spared. The contracted, preserved plantar soft tissues thus helped to support the plantar arch. Secondly, the traction of the posterior tibial tendon transposed to the dorsum of the foot is also a factor that contributes to the rise of the plantar arch [10], especially as hyperactivity of this muscle may have persisted postoperatively [17]. The same secondary effect was observed with the long toe flexor [12]. Thirdly, the action of the fibular muscles, which contribute to the development of valgus flat foot if there is rupture of the posterior tibial tendon [24,36,38], was certainly minimal as they were almost constantly deficient in patients operated for SEF. Lastly, the site of fixation of the posterior tibial tendon may also contribute to the development of valgus flat foot if it is too lateral (i.e. on the cuboid bone) [21,24,25]. In our series, the tendon was inserted on the lateral cuneiform, thus more medially, and this probably contributed to the absence of development of secondary deformities [20,39]. The split posterior tibial tendon transfer to fibular brevis has shown similar good results in hemiplegic cerebral palsy, until skeletal maturation [13,36]. Transfer of the posterior tibial tendon to the lateral cuneiform is probably a safe alternative to this technique in spastic brain-damaged adults.

From a functional viewpoint, anterior transposition of the distal tendon of the posterior tibial muscle has demonstrated that it is well tolerated in the long term in spastic brain-damaged adults. In our series, patient satisfaction was good and functional improvement was high. In the literature [10–14], the criteria of good surgical results are: discontinuation of the orthosis and use of normal footwear, easier donning of the orthosis, obtention of foot sole contact, correction of foot deformities (equinus or talus deformity, exaggerated valgus and varus), and the elimination of painful pressure points with formation of callosities.

In our series, after the surgical procedure 90% of patients were able to walk barefoot for short distances in the home and 61% of patients were able to discontinue the orthosis and use normal footwear. Our results are in agreement with published data on management of SEF in spastic adults, either with transfer of the long toe flexor to the dorsum of the foot [8], with split anterior tibial tendon transfer [40], or with various operative techniques [41]. The percentage of patients who no longer need an orthosis is higher when surgery is carried out for peroneal nerve palsy (over 80%) [19,20], or in the patient with cerebral palsy (at least 90%) [25,36,42], probably because these are populations with fewer comorbid conditions and who are better able to adapt than the spastic brain-damaged adults. In our series, 2 of the 16 patients (12.5%) were able to discontinue use of a cane, which is quite similar to published data on adult series [8,40,41]. This difference between footwear and technical aid is explained by the fact that surgery corrects the static foot disorder, but has little impact on balance disturbances secondary to motor control and cognitive problems. The significant improvement in the mean FAC score reflected greater facility in using stairs.

Lastly, 7 of the 8 patients who did not undergo initial tenotomy of the toe flexors presented postoperative claw toe, of which two required surgical revision. These results support the opinion that toe flexor tenotomy should be almost systematic in surgical management of SEF [10]. One patient with head injury presented permanent ankle dorsiflexion ankle, which was improved by repeated injections of botulinum toxin in the transposed posterior tibial tendon. This complication, which has been described by some authors [10,13,23,24], is secondary to excessive tension of the transplant associated with lengthening of the calcaneal tendon. In our case, the patient probably had persistent hyperactivity of the posterior tibial tendon, which remained unchanged after surgery [17], and which contributed to this complication. We observed no recurrence of equinovarus, exceptionally reported with this procedure [11], probably because the transplant was placed under appropriate tension and the operated patients preserved their walking ability. A voluntary active contraction of anterior tibial muscle was observed in nine patients, but did not allow full active ankle dorsiflexion. The transposed posterior tibial muscle showed a voluntary active contraction in only two patients, but displayed a full and voluntary active ankle dorsiflexion only in one case. These findings confirm that the action of the posterior tibial muscle is probably in part based on a tenodesis effect, which has already been reported for other surgical procedures [8,11]. However, we did not perform electromyographic recordings during walking, and we cannot exclude an antiphasic activation of the posterior tibial muscle [17,43], undetected during analytical testing (due to a lack of voluntary motor control). In these cases, from a plantaflexor and invertor, the transferred posterior tibial muscle became a dorsiflexor and evertor, which should have contributed to active ankle dorsiflexion in swing phase.

Lastly, 90% of operated feet showed more lateral rotation than control feet (Fig. 3). We could not distinguish between a distal or proximal lateral rotation, but we suggest two potential causes of this deformity. First, the gait pattern of our patients was abnormal (stiff knee, circumduction), so an increased lateral rotation was possibly already present before surgery, through abnormal proximal gait pattern. Second, part of the lateral rotation was probably located in the foot and ankle, related to loss of the action of medial rotation of the posterior tibial muscle.

Some limitations of the study must be emphasized. It is a retrospective study, without exhaustive preoperative evaluation. The choice to transfer the posterior tibial tendon was performed without preoperative dynamic electromyography, and based on considerations of analytical insufficiency of the anterior tibial muscle strength and characteristics of SEF when walking, especially hindfoot varus. In some patients, the posterior tibial tendon transfer probably only had a tenodesis effect of dorsiflexor and eversor. Therefore, the indication of any other surgical technique, including a split anterior tibial tendon transfer, is debatable [8,40,41,42]. The patients presented with low functional status and with largely affected distal motricity, which is not necessarily the case for all patients undergoing surgery. The assessment of lateral rotation lacked precision and did not allow distinguishing between proximal and distal rotation. This could be improved by performing a pre- and postoperative kinematic gait analysis.

In conclusion, our study demonstrated that valgus flat foot did not develop after posterior tibial tendon transfer in the adult spastic brain-damaged patient. Our functional results were entirely satisfactory. Posterior tibial tendon transfer remains a validated technique for management of spastic equinovarus. As far as possible, we reserve this surgical technique for patients whose preoperative gait pattern is already altered, in view of the lateral rotation induced by surgery. In other cases, we prefer alternative surgical techniques that have less effect on the gait pattern.

Conflict of interest statement

None of the authors has conflict of interest.

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Captions to illustrations

Fig. 1.

Lateral (left) and anterior with the heel circled (right) weightbearing radiographs showing the angles of the foot. MAA: medial arch angle, TMA: talometatarsal angle, RFVA: rearfoot valgus angle. Metallic staple is visible on the radiographs.

Fig. 2.

Postoperative footprints obtained by static baropodometry. For the operated foot, a) typical cavus foot (left foot), b) lateral edge contact (left foot), c) complete effacement of the isthmus with contact on the medial part of the forefoot (right foot).

Fig. 3.

Typical postoperative appearance of the operated foot (right side): lateral rotation and rise of the longitudinal arch.

Table1

Table 1. Detailed characteristics of patients.

Patient No	Age / Sex / Pathology	Time after surgery, month	Orthosis Pre / Post	FAC Pre / Post	MAA, degrees Op / Co	TMA, degrees Op / Co	RFVA, degrees Op / Co	Footprint area, cm² Op / Co
1	41 / M / S	66	FL / -	5 / 7	125 / 127	185 / 183	10 / 10	55 / 111
2	61 / M / S	54	OF / OF	6 / 6	129 / 133	175 / 175	16 / 18	82 / 125
3	57 / F / S	33	FL / -	5 / 5	125 / 129	181 / 179	2 / 4	62 / 99
4	61 / F / HT	74	OF / OF	5 / 5	115 / 111	189 / 183	10 / 12	61 / 100
5	53 / M / S	88	OF / -	6 / 6	127 / 127	175 / 175	18 / 8	78 / 114
6	49 / M / S	86	FL / -	6 / 6	127 / 119	183 / 185	8 / 10	121 / 128
7	62 / M / S	89	OF / OF	5 / 6	125 / 111	189 / 185	4 / 2	75 / 109
8	22 / M / HT	27	- / -	6 / 6	111 / 129	179 / 175	10 / 15	28 / 81
9	50 / M / S	65	- / -	5 / 6	119 / 125	193 / 187	4 / 4	92 / 123
10	50 / F / S	61	OF / OF	6 / 6	125 / 127	185 / 175	10 / 4	72 / 98
11	51 / M / S	33	FL / FL	6 / 6	107 / 115	200 / 190	6 / 6	72 / 117
12	52 / M / HT	78	OF / OF	6 / 6	117 / 115	185 / 197	15 / 4	27 / 88
13	61 / M / S	77	OF / FL	4 / 4	105 / 115	195 / 175	0 / 0	42 / 74
14	40 / M / S	83	OF / -	6 / 6	114 / 105	186 / 193	7 / 6	39 / 79
15	42 / F / HT	55	OF / -	4 / 6	115 / 107	189 / 187	1 / 2	33 / 54
16	62 / F / S	26	OF / -	6 / 6	107 / 113	195 / 195	15 / 1	19 / 67
17	62 / M / S	27	OF / -	6 / 6	104 / 113	197 / 191	-5 / 3	45 / 115
18	47 / M / S	82	FL / -	6 / 7	120 / 115	183 / 187	4 / 6	94 / 70
19	66 / M / S	26	OF / -	5 / 5	115 / 115	191 / 191	7 / 7	17 / 117
20	45 / F / S	28	FL / -	5 / 6	112 / 120	197 / 185	7 / 8	60 / 96

Co: control foot, F: female, FAC: modified Functional Ambulation Classification (from 0 to 8), FL: foot lifter, HT: head trauma, M: male, MAA: medial arch angle, OF: orthopedic footwear, Op: operated foot, Post: post-operative, Pre: pre-operative, RFVA: rearfoot valgus angle, S: stroke, TMA: talometatarsal angle.

Table2

Table 2. Radiographic and baropodometric characteristics of the operated and control feet

	Operated feet	**Control feet**	**p**
Medial arch angle, mean (range), degrees	117.2 (104 to 129)	118.6 (105 to 133)	0.46
Talometatarsal angle, mean (range), degrees	187.6 (175 to 200)	184.7 (175 to 197)	0.08
Rearfoot valgus, mean (range), degrees	7.5 (-5 to 18)	6.5 (0 to 18)	0.93
Plantar area, mean (range), cm^2	58.7 (17 to 121)	98.3 (54 to 128)	0.00*

Comparisons with a Wilcoxon test (significant if $p < 0.05$; * if $p < 0.001$).

Table3

Table 3. Functional and clinical characteristics of our patient sample

	Preoperative	Postoperative	p
Ability to walk barefoot in the home, Yes / No	0 / 20	18 / 2	-
Use of orthopaedic footwear or orthosis, Yes / No	18 / 2	7 / 13	0.00*
Use of cane, Yes / No	16 / 4	14 / 6	0.72
Modified Functional Ambulation Classification, mean (range)	5.5 (4 to 6)	5.9 (4 to 7)	0.02
Toe drags during the swing phase, Yes / No	-	3 / 17	-
Taligrad or plantigrad initial contact, Yes / No	-	15 / 5	-
Lateral rotation of the operated vs. control foot, mean (range), degrees	-	22.3 (-10 to 45)	-
Passive ankle plantar flexion of operated foot, mean (range), degrees	-	7.5 (0 to 20)	-
Passive ankle dorsiflexion of operated foot, mean (range), degrees	-	11.5 (0 to 20)	-

Comparisons were done using Fisher's exact test for use of orthopaedic footwear or orthesis and cane, and the Wilcoxon test for the modified Functional Ambulation Classification (significant if $p < 0.05$; * if $p < 0.001$).

Figure1
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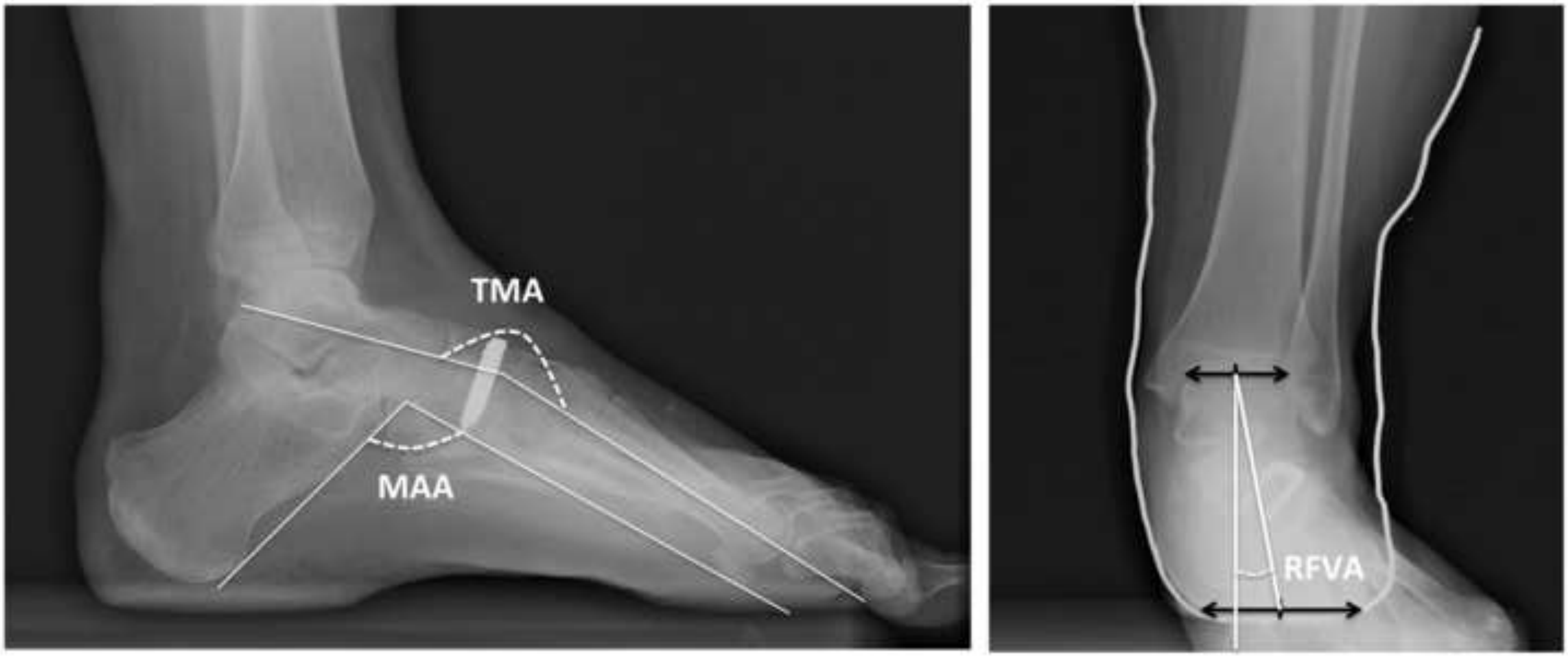

Figure2
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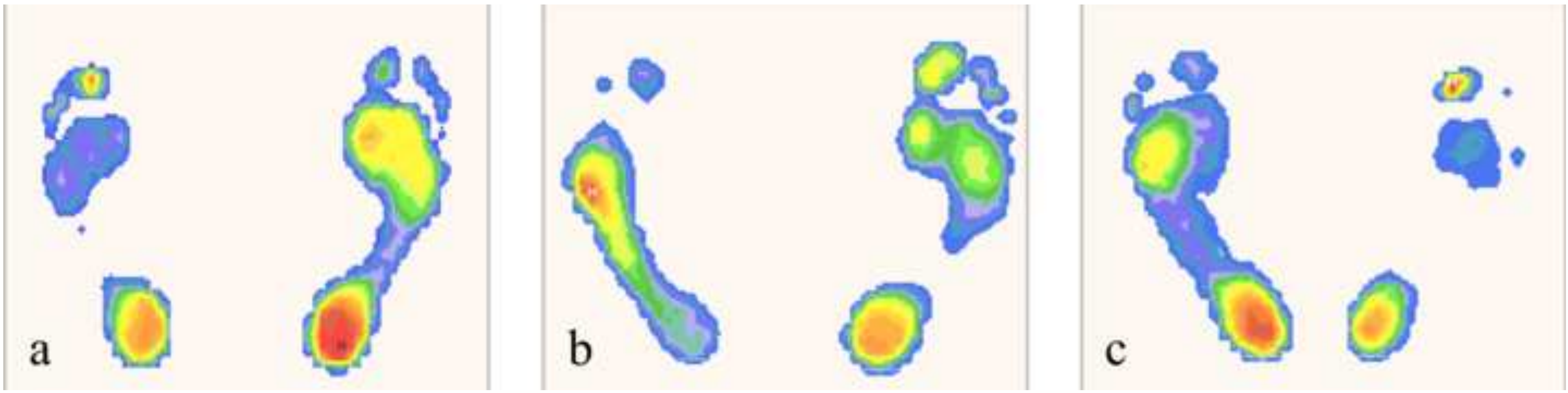

Figure3
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