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Original article

Is non-operative management of childhood neurologic cavovarus foot effective?

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ABSTRACT

Introduction: Neurologic pes cavus is a progressive deformity that is difficult to treat during growth. The present study reports results of non-operative management, based on the pathophysiology of the deformity, by untwisting nocturnal splint, preceded in some cases by untwisting walking cast. The objective was to assess efficacy and impact on indications for surgery.
Method: Twenty-three children (35 feet) were included. All had neurologic cavovarus foot, which was progressive in 24 feet (69%) (Charcot-Marie-Tooth disease). Mean age at initiation of treatment was 8.8 years. In 13 feet (38%), treatment began with a untwisting walking cast and in 22 (62%) began directly with the splint.
Results: Mean follow-up was 4.5 years. Fifteen feet showed very good and 8 good clinical results (65%); 9 children (12 feet) had moderate or poor results, requiring renewed treatment in 11 feet at a mean 4.5 years after initiation of non-operative treatment. Thirteen patients (56.5%, 21 feet) had reached end of growth by last follow-up; 10 of these feet (48%) had good or very good results without surgery. No triple arthrodeses were required. Factors weighing against good outcome comprised young age at treatment initiation and poor compliance with the splint. Primary deformity severity did not affect outcome.
Conclusion: The present study demonstrated efficacy for non-operative treatment of childhood neurologic cavovarus foot. Surgery was either avoided (in half of the cases followed up to end of growth) or delayed by a mean 4.5 years, allowing a single procedure before end of growth. We recommend initiating non-operative treatment of childhood cavovarus foot, associating untwisting walking cast and untwisting nocturnal splint, as soon as clinical progression is detected and/or Méary angle on lateral X-ray with block reaches 15°.
Level of evidence: IV.

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1. Introduction

Management of cavovarus foot is controversial [1]. Natural progression is negative, due both to the underlying neurologic pathology, which is often progressive [2–4], and to growth [5]. The deformity induces functional signs: ankle or plantar pain, and calluses under the base of the 5th and head of the 1st metatarsals. Deformity is 3-fold, associating hindfoot supination and forefoot pronation [6,7], thereby inducing torsion of the calcaneopedal unit. The classic theory is of anterior tibial muscle dysfunction [1–4,8]. However, onset of cavovarus foot is secondary to palsy in the interosseous muscles of the foot, often in a context of Charcot-Marie-Tooth disease [5,7,9]. The interosseous muscles fail to stabilize the metatarsophalangeal joints, and the antagonist action of extensor digitorum longus and extensor hallucis longus [5,9,10] causes dynamic joint hyperextension; this in turn tenses the plantar aponeurosis inserting on the extremities of the first phalanges, pulling the anterior and posterior anchorages of the foot together and increasing the height of the plantar arch [11–13]. Sagittally, given the anatomy of the plantar arch [12], this hollow flattens out from medial to lateral, resulting in medial cavus. Frontally, medial metatarsal verticalization results in forefoot pronation. To recover a stable calcaneal support, the hindfoot develops supination, resulting in torsion between forefoot and hindfoot. Coronally, hindfoot supination combines with calcaneopedal unit adduction under the tibiotalofibular unit [4–6,14–18]. The hindfoot deformity can be reduced in early stages but hardens with growth; reducibility can be assessed on Coleman and Chesnut's

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Table 1
Untwisting walking cast technique.

Deformity	Action by surgeon	Action by assistant
Cavus and equinus	Ankle at 90°	Pressure on knee
Adduction of calcaneopedal unit	Lateral rotation (abduction) of foot	Medial rotation of leg
Talar varus	Mediolateral pressure on heel	Lateromedial pressure on leg
Forefoot pronation	Forefoot supination, maintaining mediolateral pressure on heel	No specific action

block test [14], which, by eliminating the forefoot effect, corrects talar varus if the subtalar joint is still supple. In short, cavovarus foot is a primarily forefoot deformity with hindfoot adaptation.

We therefore developed a non-operative treatment in children, using an untwisting nocturnal splint, preceded in some cases by untwisting walking cast, in line with the above pathophysiology. The main hypothesis of the present study was that this treatment, applied during childhood, provides satisfactory correction, avoiding surgery. The secondary hypothesis was that using the untwisting walking cast ahead of the splint further improves results.

2. Material and method

2.1. Patients

A single-center retrospective study included all patients managed for cavovarus foot by two of the present authors (RS and PW) between 2002 and 2010, systematically using an untwisting nocturnal splint, preceded in some cases by 6 weeks' untwisting walking cast. Twenty-three children (15 girls, 8 boys; 35 feet) were included. Etiology was in all cases neurologic: Charcot-Marie-Tooth disease (15 patients, 22 feet), encephalopathy (3 patients, 5 feet), cerebral palsy (2 patients, 3 feet), spinal dysraphia (1 patient, 1 foot), chromosomal abnormality (1 patient, 2 feet) or medullary trauma (1 patient, 2 feet). Mean age at treatment initiation was 8.8 years (range: 5–15 years). Parents confirmed the progressive nature of the deformity. The hindfoot was systematically in varus. All patients complained of calluses under the 5th metatarsal base or 1st metatarsal head, with iterative ankle sprain. Lateral weight-bearing X-ray [5,7], with the hindfoot on a block [14], allowed precise measurement of the Méary angle (between the talar and 1st metatarsal axes), which was a mean 16° (range: 12–30°) at treatment initiation.

2.2. Non-operative treatment

Treatment began with 2 successive walking casts, for 3 weeks each, to achieve progressive correction, followed by custom-made nocturnal splints, molded when the first cast was replaced by the second (13 feet, 37%). In the other 22 cases (63%), treatment began with the splint, as the family refused the plaster cast.

2.2.1. Untwisting walking cast production (Fig. 1)

A plaster of Paris walking cast was produced, with the lower limb on a knee bar, leaving the proximal two-thirds free so that the assistant could maintain correction. Table 1 presents the respective actions of the operator and the assistant and the correction achieved. Once the distal part of the cast had dried, the proximal part was added.

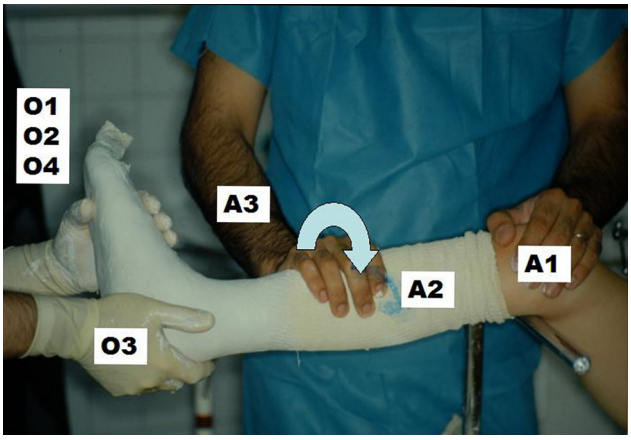


Fig. 1. Untwisting walking cast technique. Action by assistant to correct: cavus and equinus = axial pressure on leg = A1; calcaneopedal unit adduction = medial rotation of leg = A2; talar varus = lateromedial pressure on leg = A3. Action by surgeon to correct: cavus and equinus = O1; calcaneopedal unit adduction = O2; talar varus = O3; forefoot pronation = O4.



Fig. 2. Untwisting nocturnal splint: ankle held at 90°, lack of ankle dorsiflexion enabling counter-pressure and helping correction of cavus; forefoot supination: correction of forefoot pronation; hindfoot valgus: correction of hindfoot varus; oblique dorsal strap, providing lateromedial pressure (correction of cavus, dorsal hump and calcaneal varus).

Table 2
Untwisting nocturnal splint technique.

Effect of splint	Deformity component corrected
Ankle at 90°	Cavus and equinus
Forefoot supination	Forefoot pronation
Hindfoot valgus	Hindfoot varus
Dorsolateral strap	Cavus, dorsal hump and hindfoot varus

2.2.2. The untwisting nocturnal splint

The untwisting nocturnal splint (Fig. 2) was intended to counter the natural position of the foot during the night, which aggravates deformity by combining hindfoot varus, cavus, forefoot pronation, ankle equinus and claw-toe. The splint was in leather, for optimal skin tolerance, as sensitivity is often affected in these patients, and was reinforced by resin. Table 2 presents the effects of the splint and its impact on deformity. The splint was maintained until end of growth.

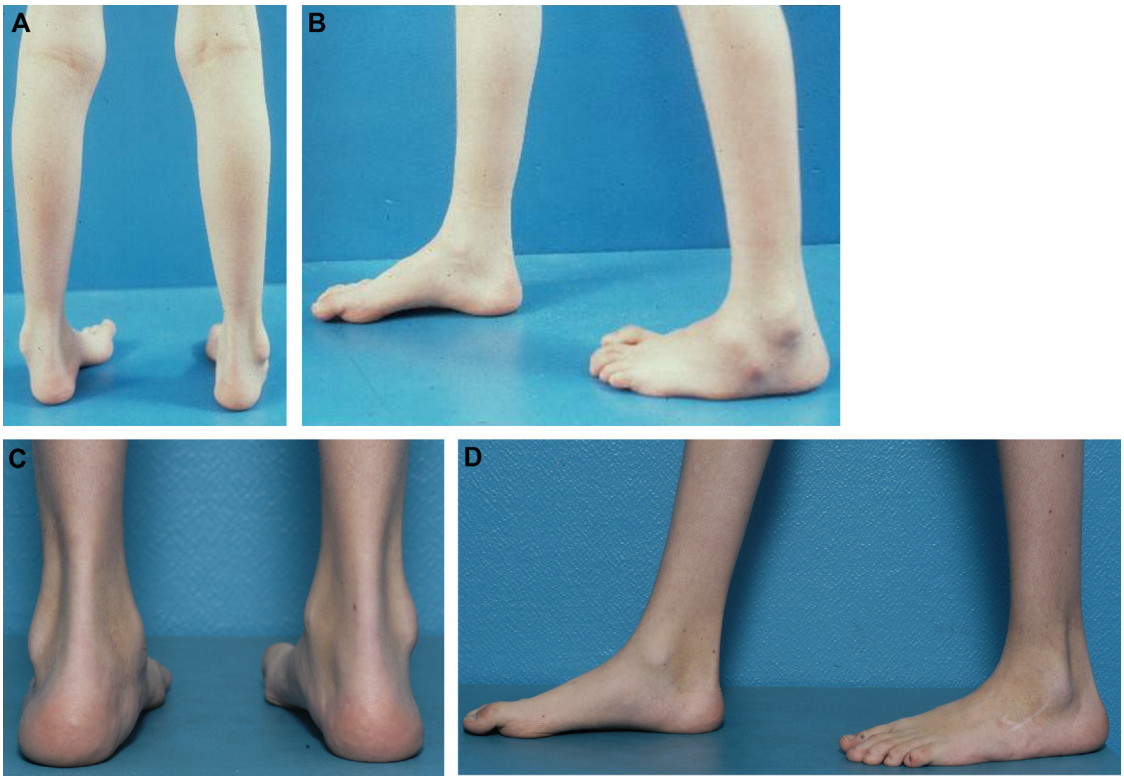


Fig. 3. Clinical result in a 10-year-old girl with Charcot-Marie-Tooth disease. A and B. Initial aspect of foot: indication for surgical correction (POWOC) in left foot (more severe) and cast + splint in right foot. C and D. Result at 16 years: very good.

Table 3
Wicart-Seringe grades [7,19].

Results	Functional signs	Clinical position of heel and Méary angle
Very good	None	VG, and $0^\circ \leq$ Méary angle $\leq 15^\circ$ Or N or VR, and $0^\circ \leq$ Méary angle $\leq 5^\circ$
Good	None	VG, and $15^\circ <$ Méary angle $\leq 20^\circ$ Or N, and $5^\circ <$ Méary angle $\leq 20^\circ$ Or VR, and $5^\circ <$ Méary angle $\leq 15^\circ$ Or $-15 \leq$ Méary angle < 0 (minor hypercorrection)
Moderate	None	VG or N, and Méary angle $> 20^\circ$ Or VR, and Méary angle $> 15^\circ$ Or Méary angle $< -15^\circ$ (major hypercorrection)
Poor	Pain and/or instability	VR, and Méary angle $> 20^\circ$ Or cavus surgery

VG: talar valgus; N: heel in neutral position; VR: talar varus.

2.3. Analysis method

During the final consultation, functional complaints (ankle sprain, plantar pain) and clinical (hindfoot orientation) and radiological (Méary angle) criteria were recorded. A classification was applied, following Wicart and Seringe (2006) (Table 3) [19].

In surgery patients, results were considered poor if plantar opening-wedge osteotomy of the cuneiform bones (POWOC) [19] or tarsectomy to correct residual varus was necessary. In other types of surgery, patients were classified by global score. Quantitative variables were assessed on Mann-Whitney test, with the significance threshold set at 0.05.

3. Results

Mean follow-up was 4.5 years (range: 1–12 years); mean age at end of follow-up was 13.5 years (range: 11–20 years).

3.1. Overall results (Table 4)

Clinically, 65% of feet showed good or very good results. Function improved in 79% of cases. Hindfoot varus was corrected in 25 feet (69%). Méary angle diminished significantly ($P = 0.001$) from 16° (range: 12–30°) pre-treatment to 7.5° (range: 0–28°) at end of treatment or last examination. All patients with poor compliance ($n = 4$, 6 feet) had moderate ($n = 4$) or poor results ($n = 2$). Figs. 3 and 4 show examples of good clinical and radiological results.

3.2. Results according to etiology (Table 4)

In the Charcot-Marie-Tooth subgroup, 7 feet (32%) were operated: 5 POWOCs and 2 tarsectomies. In the subgroup of other etiologies, 5 feet (38%) were operated: 3 POWOCs and 2 tarsectomies. There was no significant difference in result or rate of surgery according to subgroup.

3.3. Results at end of growth

Thirteen children (56.5%) (21 feet: 60%) were followed up to end of growth (distal tibia shaft fusion). Ten of the 21 feet (48%) required no surgery, with 6 very good and 4 good results. Ten feet (48%) required surgery for global correction of the deformity: 6 POWOCs [19] and 4 tarsectomies associated to Dwyer calcaneal osteotomy and plantar aponeurotomy; 1 foot required Dwyer calcaneal osteotomy and osteotomy of the 1st metatarsal base to correct residual hindfoot varus and plantar protrusion of the 1st metatarsal head. The mean interval between primary



Fig. 4. Radiologic result in an 11-year-old girl with Charcot-Marie-Tooth disease. A. Pre-treatment weight-bearing radiograph: maximal cavus (Méary angle = 33°). B. Pre-treatment weight-bearing radiograph: above (without block): Méary angle underestimated (15°); below (with block): true Méary angle of 29°. Cavus lessened in weight-bearing. Transverse defects not completely reducible. C. Untwisting walking cast: incomplete correction of cavus (Méary angle = 17°) but complete correction of transverse defects. D. Result at 18 years: complete correction of cavus and transverse defects.

Table 4
Results according to Wicart-Seringe grade [7,19].

	Whole series ($n = 35$) (%)	CMT ($n = 22$) (%)	Other etiologies ($n = 13$) (%)	C + S ($n = 13$) (%)	S ($n = 22$) (%)
Very good result	15 (42)	11 (50)	5 (38)	7 (54)	8 (36)
Good result	8 (23)	5 (23)	2 (16)	4 (31)	1 (5)
Moderate result	1 (3)	1 (4)	1 (8)		3 (14)
Poor result	11 (32)	5 (23)	5 (38)	2 (15)	10 (45)

CMT: Charcot-Marie-Tooth disease; C + S: casts + splint; S: splint.

non-operative treatment and surgery was 4.5 years (range: 1–8 years); mean age at surgery was 12.7 years. Initial deformity was no more severe in operated than non-operated feet: initial Méary angle was 14° (range: 10–25°) in non-operated feet and 18° (range: 12–30°) in operated feet ($P = 0.32$). Three of the children undergoing surgery (4 feet: 40% of operated feet) had shown poor compliance with nocturnal splinting.

Overall, results in the feet seen at end of growth were significantly better when treatment was initiated after the age of 10 years ($P = 0.002$). No revision surgery or triple arthrodesis was needed. There were no complications, such as scarring under the cast.

3.4. Results according to non-operative treatment: cast + splint (C + S) versus primary splint (S) (Table 4)

All patients were offered the possibility of an untwisting walking cast ahead of splinting, and 9 accepted (13 feet); otherwise, treatment began with splinting (14 patients, 22 feet).

The 2 treatment groups did not differ in age at treatment initiation (C + S, 8 years [range: 5.5–11 years]; S, 9.2 years [range: 5–15 years]; $P = 0.628$), or primary severity ($P = 0.41$). Foot function and talar varus were significantly improved in 70% of C + S feet and 69% of S feet. Méary angle was significantly improved ($P = 0.0002$), from 15° (range: 10–26°) before non-operative treatment to 6° (range: 0–12°) at end of treatment in the C + S group, and from 16° (range: 12–30°) to 10° (0–28°) in the S group ($P = 0.023$). These 2 parameters were significantly better in the C + S group ($P = 0.0042$). The need for surgery did not significantly differ according to treatment group ($P = 0.13$).

4. Discussion

The present treatment method was original. Non-operative treatment of cavovarus foot was previously reported in only 1 article, which concerned adult patients [20]. The main limitation of the present study was the small number of patients, and the inclusion of both progressive and non-progressive neurologic disease. Also, not all feet were followed up to end of growth. And finally, initial severity was not scored.

The single article on non-operative treatment of cavovarus foot [20] reported poor results; however, the splint was worn for only 6 weeks, and the age of the patients left no opportunity for bone remodeling. The non-operative protocol reported here proved effective, as half of the feet followed up to end of growth did not require surgical correction of the cavus, despite a progressive deformity liable to inevitable deterioration. The treatment thus reduced the risk of surgery in cavovarus foot. This is primordial, as surgery is associated with poor quality of life, at least in the

case of Charcot-Marie-Tooth disease [21]. Moreover, when surgery was necessary, it was able to be postponed by a mean 4.5 years, allowing definitive correction in a single step [19,22]. Finally, none of the patients required iterative surgery, unlike in the surgical series reported by Wicart and Seringe in 2006 [19], in which one-third of children, operated on at a younger age than in the present series, underwent iterative surgery. Later surgery thus seems to protect against recurrence of deformity under residual growth. A subsequent study will test the hypothesis that postoperative untwisting nocturnal splint treatment prevents recurrence.

The present study confirmed the contribution of untwisting cast treatment ahead of nocturnal splinting, at least in terms of Méary angle correction, even if it did not reduce the need for surgical correction of cavus, although the present small sample size may account for the failure to find a significant difference on this point. The effectiveness of the untwisting contention confirms the pathophysiological description given in the Introduction: forefoot pronation and midfoot cavus are the primary deformities in cavovarus foot, and are difficult to reduce even at early stages. Fig. 4C shows the moderate impact on cavus achieved by the untwisting cast. At end of growth (Fig. 4D), however, correction was satisfactory, thanks to the progressive remodeling induced by the nocturnal splint worn throughout growth. Frontal anomalies in hindfoot positioning, on the other hand, are reducible if treated early, in agreement with Coleman and Chesnut [5,14]. This reducibility can be seen with the untwisting walking cast (Fig. 4C).

Certain factors may impair the efficacy of non-operative treatment. One limitation, inherent to the deformity itself, is that it is maximal in the oscillating phase of gait: i.e., in upright stance, rather than at night, when the splint is worn. Young age (< 10 years) at treatment initiation was a factor for poor prognosis at end of growth, due to the progressive nature of the pathology underlying the deformity, resulting in recurrence before end of growth. Poor compliance with splinting was also a factor of poor prognosis; initial severity, on the other hand, was not. The present series showed no complications, but we nevertheless recommend that the greatest care be taken in producing the casts and splints, especially for patients with sensitivity disorder, as in Charcot-Marie-Tooth disease.

5. Conclusion

The present study demonstrated the efficacy of non-operative treatment of neurologic cavovarus foot in children. Surgery was either avoided (in 50% of cases at end of growth) or postponed by a mean 4.5 years, allowing treatment in a single step before end of growth. We recommend implementing non-operative treatment of childhood cavovarus foot, associating untwisting walking cast followed by untwisting nocturnal splints, as soon as clinical progression is detected or Méary angle on lateral X-ray with block reaches 15°.

Disclosure of interest

The authors declare that they have no competing interest.

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