Serial Casting for Neuromuscular Flatfoot and Vertical Talus in an Adolescent With Hereditary Spastic Paraplegia

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Purpose: The purpose of this report is to explore assessment and serial casting intervention for painful rigid flatfoot deformities with vertical talus in an adolescent girl with hereditary spastic paraplegia who was nonambulatory. Summary of Key Points: The participant’s right foot underwent 2 phases of casting with correction first toward hindfoot inversion and then dorsiflexion. Because of a vertical talus, her left foot required an intermediate casting toward plantar flexion, inversion, and forefoot adduction prior to casting toward dorsiflexion. Statement of Conclusions: The patient improved despite the underlying progressive neuromuscular disorder. Pain ameliorated and she returned to supported standing and transfers. Spasticity decreased bilaterally and the flexibility of her foot deformities improved to allow orthotic fabrication in subtalar neutral. Results were maintained at 12 and 16 months. Recommendations for Clinical Practice: Individualized multiphase serial casting requires further investigation with patients such as those with hereditary spastic paraplegia. (Pediatr Phys Ther 2014;26:253–264) Key words: adolescent, female, flatfoot, hereditary spastic paraparesis, orthoses, pain, physical therapy methods, plastic casts, vertical talus

INTRODUCTION

Hereditary spastic paraplegia (HSP) encompasses a rare group of neurodegenerative disorders causing lower extremity spasticity and weakness that worsens over years and decades. Hereditary spastic paraplegia is classified clinically as either pure or complex. “Pure” HSP refers to localized lower extremity symptoms associated with slow and continuous degeneration in the corticospinal motor tracts. “Complex” HSP involves degeneration in additional areas with further symptoms such as, but not limited to, upper limb involvement, dysarthria, peripheral neuropathy, and hearing impairment. There are nearly 50 different subtypes of HSP, with each relating to an inherited or sporadic gene mutation in 1 of at least 25 HSP genes. Spastin/SPAST (formerly SPG4) gene mutations are the most common cause of HSP. The spectrum of clinical presentation differs widely from mild symptoms such as brisk reflexes to quadriplegia with wheelchair dependence. Symptom onset may occur between birth and nearly 80 years of age. Childhood-onset HSP often leads to a misdiagnosis of cerebral palsy with differentiation by the progressive nature of HSP and genetic testing. Currently, HSP treatment is symptomatic, as the disease process cannot be prevented, halted, or reversed.

Foot and ankle involvement is common in both pure and complex forms of HSP, with findings such as foot deformities, muscle wasting below the knees, peripheral neuropathy, ankle clonus, pes equinus, distal limb pain, and marked limitations in ankle range of motion.

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Dr Sweet was a student at the University of St. Augustine during the time this Case Report was conducted.

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motion (ROM). Pes cavus foot deformities are most common, although Li et al identified pes planus as a novel HSP-related foot phenotype in 2007.

The term pes planus or flatfoot generically describes a spectrum of foot conditions with potential for misalignment across multiple joints. The Clinical Practice Guideline Pediatric Foot Panel of the American College of Foot and Ankle Surgeons developed a Clinical Practice Guideline to aid in the evaluation and treatment of such deformities. We review here pathways 3, 5, and 8 of those guidelines with associated serial casting protocols relevant to the present report.

“Other causes of pediatric flatfoot” (pathway 5) encompasses a spectrum of rigid and flexible neuromuscular foot deformities that are secondary to underlying disorders such as HSP or CP. The clinician considers baseline function, weight-bearing demands, the flexible or rigid nature of deformities, and symptoms associated with the specific disorder. The few existing HSP reports with reference to foot structures involve spasticity management, surgical correction of foot deformities, and nonspecific physical therapy for strengthening and contracture management. Serial casting is unexplored as a means to conservatively improve foot deformities in the HSP population, necessitating comparison with other neuromuscular disorders. Both HSP and CP are often associated with plantarflexion contractures and spasticity (rigid and spastic pes equinus.) Casting toward dorsiflexion improves ROM and spasticity in children with CP, both with and without concomitant use of botulinum toxin (Botox) injections. Glanzman et al found a more dramatic ROM improvement with casting than with Botox alone.

Peroneal spastic flatfoot (pathway 5), also known as spastic rigid pes planovalgus, encompasses peroneal spasticity, peroneal contracture, calcaneal valgus, and pain. Concurrent contracture and spasm is possible in the triceps surae, tibialis anterior, extensor hallucis longus, and tibialis posterior. Serial casting and/or common peroneal nerve blocks provide benefit in severe cases of peroneal spastic flatfoot. Blockey et al explored serial casting for 3 months in maximum available hindfoot inversion (varus) using plaster walking casts, followed by physical therapy and orthotics. Blockey’s group with rigid valgus deformities and less than neutral inversion at baseline (7 feet including 2 with vertical talus) achieved pain relief but did not attain normal ROM with casting. Kinoshita et al serially casted toward both maximum inversion and plantarflexion in the non–weight-bearing condition, yielding reduced pain and improved ROM in 2 teenaged boys with peroneal spastic flatfoot.

The symptoms of congenital vertical talus (CVT), or convex pes valgus (pathway 3), include hindfoot equinus and valgus, forefoot abduction, and dorsiflexion at the midtarsal joint. Contractures occur in the anterior tibialis, triceps surae, extensor hallucis brevis, and all peronei. In CVT, there is a lateral and dorsal dislocation of the navicular on the talus that does not reduce with plantarflexion of the foot. A rigid rocker-bottom (convex) deformity of the midfoot arises in the weight-bearing position. Dobbs and colleagues pioneered a conservative method of correcting CVT with serial casting on the basis of the reverse of the Ponseti method for clubfoot. Serial casting with simultaneous stretching toward plantarflexion, inversion, and forefoot adduction with counter pressure to the medial aspect of the talar head leads to correction of CVT in infants. Equinus deformity correction occurs last after serial casting to correct the other deformity components. A minimally invasive surgery of talonavicular pinning and heel cord release, as well as a specific orthotic protocol often follows casting. Vertical talus of genetic or neuromuscular origin is usually more rigid and less responsive to cast correction than CVT in infants. Pain, awkward gait, and decreased balance arise without treatment. Vertical talus is sometimes misdiagnosed as calcaneovalgus when Achilles contracture is not correctly appreciated. Oblique talus resembles vertical talus with differentiation by reduction of the talonavicular joint in plantarflexion and response to conservative care for oblique talus.

The purpose of this report is to describe the assessment findings, multiphase serial casting protocol, and outcomes related to complex painful foot deformities in an adolescent girl with HSP who was nonambulatory. Her bilateral rigid flatfoot deformities involved spastic pes equinus contractures and symptoms similar to peroneal spastic flatfoot as well as vertical talus on the left and symptoms of oblique talus on the right. To our knowledge, research on flatfoot deformity or serial casting is nonexistent in pediatric HSP, and large pediatric participant groups are difficult to locate. This report is unique with the application of Dobb’s method of serial casting, also known as the reverse Ponseti method, for an older child with vertical talus of neuromuscular origin.

**DESCRIPTION OF THE CASE**

**History**

The participant’s HSP symptoms began in infancy, at which time she received a diagnosis of CP. Progressive symptoms evolved with worsening spasticity and weakness, loss of upper extremity function including hand skills, loss of speech, regression in head control, decline in sitting and transfers, and loss of the ability to ambulate short distances using a reverse walker. Ultimately, at 11 years of age, she received a revised diagnosis of complex HSP with a SPAST mutation near a splice site confirmed with genetic testing. This case appears sporadic as family members are symptom-free and neither parent carries the sequence variant. Her history included bilateral percutaneous hamstring lengthenings (age, 11 years), mild left hearing loss, left hip subluxation, and mild scoliosis. Baclofen was her only oral medication at 55 mg/d and she previously received Botox injections to her hip adductors on multiple occasions. However, the patient did not receive
any Botox injections within 1 year before, during, or within 16 months after the intervention associated with this case report. There was no history of foot pain with standing or ankle-foot orthoses (AFOs) wear.

Until symptom presentation, the patient engaged in daily upright positioning in a standing frame for 2+ h/d for the purpose of weight-bearing, head control, and socialization at the same level as peers. She also participated in assisted stand pivot transfers using knee extensor spasticity, with the majority of weight translated through the right lower extremity because of a left hip subluxation with functional leg length discrepancy. Complete motor paralysis existed below the knees. Cognitive skills were intact and higher-level communication occurred via eye gaze technology with a Dynavox communication device. Alternatively, she responded to inquiries such as “look at your mom if your foot hurts and look at your dad if it does not.”

**Chief Complaints**

This North American female patient of mixed descent presented at the age of 12 years and 5 months with progressive foot pain (left more so than right), preventing positioning in her standing frame for the previous 2 months. She was intolerant of her AFOs with skin irritation, swelling, and a flushed appearance in her feet. Her orthopedic physician ordered radiographs of her left foot only, leading to the diagnoses of pes planus, osteopenia, and neuromuscular flatfoot, with recommendations for replacement AFOs. The orthotist found that AFO fabrication was not possible due to the rigidity of her deformities. The physical therapists (PTs) and orthotist recommended serial casting and obtained a prescription from her orthopedist. The goals of both child and parents were to decrease foot pain and return to standing in a standing frame without the use of Botox injections or surgery.

**Outcome Measures**

The Clinical Practice Guideline developed by the American College of Foot and Ankle Surgeons provided a framework for assessment with the following outcome measures chosen after consideration of her diagnosis, history, and presenting symptoms.

**Tardieu Scale.** This 5-point rating scale (scores 0-4) differentiates velocity-dependent spasticity from hypertonus and contractures, with scores of 3 and 4 indicating severe spasticity. The assessor compares the angle of pertonus and contractures, with scores of 3 and 4 indicating severe spasticity. Gracies and colleagues report good to excellent intra- and interrater reliability for the ankle in children with CP. Spasticity grading was used for the peronei, anterior tibialis, and gastrocnemii.

**Parent and Patient Interviews.** The child and her parents reported the presence or absence of pain and brace tolerance and standing time in hours per day.

**Visual Inspection.** The clinicians visually inspected the skin for signs of irritation and measured capillary refill by blanching the skin near the toes to record seconds for return to baseline color. Circumferential swelling was measured around the landmarks of the first and fifth metatarsal heads.

**Tibiotalar and Subtalar Passive Range of Motion (PROM).** Foot posture measures such as the Foot Posture Index and pediatric flat foot proforma were inappropriate due to requirements for standing. Therefore, passive mobility of dorsiflexion and inversion were the outcome measures of choice to represent the potential to passively correct the equinovarus deformities and allow fabrication of AFOs in a neutral foot position.

The PTs measured degrees of dorsiflexion at the tibiotalar joint with the knee extended, using a standard goniometer and protocol described later. The patient was positioned in prone with the subtalar joint positioned as close to neutral as possible, given her rigid valgus deformities, with firm support provided at the midfoot. Reliability is high when following a strict protocol for children with spastic CP. The normative value for dorsiflexion in 7- to 14-year-old children is 26° (range: 16°-52°).

The PTs measured inversion PROM by manually moving the calcaneus from the position of valgus deformity toward inversion and recorded their findings using the grading scale outlined in Table 1. One therapist maintained the end range position while the other determined joint range via visual estimation. Allington et al used a protocol for children with CP and found visual estimation for inversion PROM to be reliable and reproducible (r > 0.75; mean measurement error 6/SD, 5°), with no statistically significant difference between visual estimation and goniometry. To account for measurement error, the first author devised the scale presented in Table 1 to classify change on the basis of 10° ROM increments.

| TABLE 1 |
| Calcaneal Valgus Deformity Grading Scale |  |
| Grade 1 | Available inversion PROM at least ≥11° |
| Grade 2 | Available inversion PROM limited to between 0° and 10°, with the 0° position achieved with ease |
| Grade 3 | Available inversion PROM limited to between −10° and 0°, with the 0° position achieved only with overpressure toward inversion |
| Grade 4 | Available inversion PROM limited to −11° or less |

*Abbreviation: PROM, passive range of motion.

*aThis ordinal scale represents the PROM of the subtalar joint from a calcaneal valgus deformity toward inversion as measured in the prone position with the knee extended. The joint angle is measured or visually estimated using a line through the bisected calcaneus in relation to a line through the bisected lower leg. The tibiotalar joint is positioned as near 0° of dorsiflexion as possible, although this may not be possible with equinus contractures. Excessive eversion PROM may be present. Appropriate subtalar PROM for orthotic intervention is suggested with a grade 1 or 2, provided sufficient dorsiflexion PROM is present when measured with knee extension.*
similar to those used by Blockey and Larsen et al. This Calcaneal Valgus Deformity Grading Scale categorizes inversion PROM measurements into deformity grades 1 to 4 on the basis of normative values for inversion (32°; range: 18°-47°) and eversion (10°-12°; range: 2°-27°) for 7- to 14-year-old children.

Photographs and video provided additional documentation. The protocol involved the following: the first and second authors simultaneously conducted all assessments and interventions; the testing environment was quiet and calm; and ROM movements were performed slowly to minimize spasticity and in consistent test positions.

**Evaluation Summary**

The patient presented with severely rigid calcaneal valgus and equinus deformities that were worse on the left than on the right. Forefoot abduction deformities appeared moderate on the left and mild on the right. Spasticity was symmetrical between the left and right lower extremities, with severe peroneal spasticity (25-30 beats of clonus) and lesser gastrocnemius and anterior tibialis spasticity. Medial protrusions appeared when viewing the soles of the feet with the talus heads palpable. The left foot posture in standing was not observable as most of her weight translated through the right leg because of left hip subluxation and functional shortening of the limb (Figure 1). The right medial longitudinal arch in standing appeared completely collapsed with midfoot dorsiflexion and a rocker-bottom form (Figure 1). The left foot posture appeared similar to the right in seated weight-bearing (collapsed/rockered-bottomed.) Capillary refill time was 3 to 4 seconds bilaterally. The skin of the distal lower extremities appeared generally flushed with a localized and superficial 1/2-in diameter heel sore on the left. The girl reported pain with weight-bearing and poor tolerance for AFOs. Mild forefoot swelling was evident with a 19-cm girth bilaterally.

**Impression.** Calcaneal valgus and peroneal spasticity paralleled symptoms of “peroneal spastic flatfoot” (pathway 5). Concomitant fixed spastic equinus presented in association with HSP (pathway 8). The rocker-bottom appearance evidenced possible bilateral oblique talus; however, the impression for the left foot changed during weeks 5 to 8 with eventual diagnosis of vertical talus (pathway 3).

**DESCRIPTION OF INTERVENTION**

Serial casting was the intervention of choice for low-load stretching across multiple joints and deformities. The PTs implemented the casting plan on the basis of the child’s intact pain sensation and reliable communication as well as high parental diligence to monitor pain, swelling, and capillary refill. Two PTs applied a 24-hour “test cast” to assess risk associated with swelling and the lack of an immediate capillary refill. Capillary refill and girth measurements did not change with the application of a test cast.

The PTs prioritized and sequenced phases of casting for each deformity component on the basis of the work of several authors. Phase 1 involved casting toward inversion and plantarflexion to first address the calcaneal valgus and peroneal spasticity because of symptom severity and to achieve at least a neutral subtalar position prior to equinus correction (Table 2).

Both feet improved, without complications, across 4 weeks with 4 casts in phase 1 (Figure 2). The transition to phase 2, which involved casting toward dorsiflexion, was seamless on the right side across 4 weeks, with 4 casts plus an additional 2 weeks to maintain the position for AFO fabrication (Figure 3). However, phase 2 was not tolerated on the left with associated discomfort, early removal of a cast, and skin irritation surrounding the talus head. This necessitated continuation of phase 1 treatment of the left foot for 4 additional weeks, as the problem warranted further exploration. In comparing her feet, the right foot exhibited a normal firm end feel with dorsiflexion and smooth arch formation with plantarflexion. Conversely, the left foot evidenced a bony end feel with dorsiflexion and the absence of arch formation with plantarflexion. The PTs obtained radiographs of the left foot to relate symptoms to her deformities. Because of the patient’s response to serial casting and unusual radiographic presentation, the PTs sought a second opinion from another orthopedic physician (third author) specializing in uncommon pediatric foot deformities and specific serial casting techniques. This physician diagnosed vertical talus (Figures 4A, B) and provided critical intervention guidance at week 8. Revisions to the initial intervention plan were necessary (Table 2), involving...
TABLE 2
Summary of Phases of Intervention

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Right: 10 Casts Total</th>
<th>Left: 16 Casts Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4</td>
<td>Phase 1: Cast toward INV and PF NWB</td>
<td>Phase 1: Cast toward INV and PF NWB</td>
</tr>
<tr>
<td>5-8</td>
<td>Phase 2: Cast toward DF at angle of 1st spastic catch for GASTROC with plaster footboard insert Inv. stretch applied simultaneous with DF stretch Limited PWB on R with cast, using heel lifts Knee immobilizer at night to stretch GASTROC</td>
<td>Phase 1: Continued to cast toward INV and PF after intolerable attempt to stretch toward DF NWB</td>
</tr>
<tr>
<td>9-12</td>
<td>Maintenance of range: Casted in maximum DF while awaiting AFO AFO delivered week 11 WBAT on R only with AFO in place</td>
<td>9-12 Maintenance of range: Casted in maximum DF while awaiting AFO AFO delivered week 11 WBAT on R only with AFO in place</td>
</tr>
</tbody>
</table>

Abbreviations: ADD, adduction; AFO, angle-foot orthosis; DF, dorsiflexion; GASTROC, gastrocnemius; INV, inversion; L, left; NWB, non-weight-bearing; PF, plantar flexion; PWB, partial weight-bearing; R, right; WBAT, weight-bearing as tolerated.

Fig. 2. Phase 1/week 4: Posterior view, serial casting in maximum inversion and slight plantar flexion with greater range of motion apparent on the right as compared to the left.

Fig. 3. Phase 2/week 9 on right: Serial casting toward dorsiflexion with use of a plaster footboard.

an intermediate phase of casting for the left foot that comprised serial casting toward plantar flexion, inversion, and adduction with manual reduction of the talonavicular joint (Figure 5).

Cast applications occurred during 90-minute sessions at a frequency of 1 every 7 days for a total of 10 weeks per 10 casts on the right and 16 weeks per 16 casts on the left. Gentle mobilizations in the direction of correction and generalized myofascial manipulation preceded the application of short leg casts. A parent supported the patient in bench sitting with her knees flexed, as 1 therapist applied corrective stretch and 1 applied casting tape. Both PTs worked together to maintain the position and mold the cast material as it cured. The PTs chose a lightweight semirigid casting tape for all phases of treatment, rather than plaster, to ease transfers and to allow quick removal by unraveling (no cast saw) in case of circulation compromise or increased swelling. See the Appendix (Supplemental Digital Content 1, available at http://links.lww.com/PPT/A59) for a list of all casting materials. The girl’s parents provided
retrograde massage, toe ROM, and elevation of her lower extremities to promote circulation while in the home environment and then removed casts on the 6th day of each week. Traditional physical therapy services continued once per week for trunk strengthening and head control.

Two weeks prior to the conclusion of casting for each foot, an orthotist obtained molds for new AFOs while a PT assisted in maintaining alignment. Custom-molded plaster footboards were used in the molds to maximize contact with the arches of her feet. The patient transitioned seamlessly from casting into new solid AFOs with the recommended wear schedule of 23 h/d to maintain correction (Figure 6). Table 3 provides details about the intervention protocols for casting, positioning, weight-bearing, and AFO fabrication for both feet.

**DESCRIPTION OF OUTCOMES**

The multiphase serial casting approach led to improvements in all outcome measures for return to her pain-free prior level of function despite the presence of a neurodegenerative disorder. Her family was highly committed to the plan of care and reported to be very satisfied with the outcomes of treatment.

**Spasticity**

Peroneal spasticity decreased from Tardieu scale scores of 4 (severe) pretreatment to 1 (mild) posttreatment...
(Figure 7). Spasticity reduced in the gastrocnemius and anterior tibialis from Tardieu scale scores of 2 pretreatment and 1 posttreatment. Spasticity did not increase at 12 and 16 months posttreatment. Attempts to capture the angles of spastic catch resulted in inconsistent values, as it was not possible to maintain optimal joint alignment with fast passive motion.

**Calcaneal Valgus Deformity/Inversion PROM**

The right hindfoot improved from a grade 3 valgus deformity with $-5^\circ$ to $-10^\circ$ of maximum inversion PROM precasting to a grade 2 with approximately $8^\circ$ of inversion postcasting (Figures 8 and 9A-C).

The left hindfoot improved from a grade 4 valgus deformity with $-20^\circ$ inversion PROM precasting to grade 3 after 9 weeks and grade 2 postcasting with $5^\circ$ of inversion PROM. Both feet remained at grade 2 at 12 and 16 months posttreatment. The soles of the feet exhibited reduction of the medial talar prominences as evidenced in photographs (Figures 10A-D).

**Dorsiflexion PROM**

Right dorsiflexion PROM with knee extended increased from $-19^\circ$ pretreatment to $3^\circ$ postcasting, with a total gain of $22^\circ$ (Figures 11 and 12A, B). Left dorsiflexion increased from $-23^\circ$ precasting to $9^\circ$ postcasting, with a total gain of $32^\circ$ (Figure 13A, B). The postcasting dorsiflexion range of the more involved left foot surpassed the right by $7^\circ$, and the overall change in range was $10^\circ$ greater. Arch formation occurred with plantarflexion in both feet posttreatment. Both right and left dorsiflexion regressed mildly to $0^\circ$ at 12 and 16 months posttreatment.

**Pain, AFO Tolerance, and Positioning in Stander**

Pain completely ameliorated and remained so throughout follow-up care for both feet. The gains in ROM (greater than neutral inversion and dorsiflexion PROM) allowed fabrication of solid AFOs in the neutral position,
Fig. 10. (A) Precasting: Medial rotation of the talar heads appreciated when viewing the soles of the feet, as the medial sides appear convex. (B). Week 9: Medial rotation is noticeably reduced. (C, D). Postcasting: Medial rotation of talus appears reducible in both feet.

Fig. 11. Dorsiflexion PROM with knee extended from pretest across intervention and follow-up period. DF indicates dorsiflexion; PROM, passive range of motion. This figure is available in color on the journal website, www.pedpt.com, and the iPad.

Fig. 12. Right ankle dorsiflexion in prone. (A) Precasting and (B) postcasting.

Fig. 13. Left ankle dorsiflexion in prone. (A) Precasting and (B) postcasting.

with the patient reporting comfort in wearing AFOs 23 h/d postcasting. Lower extremity weight-bearing appeared more symmetrical in supported standing and during stand-pivot transfers with supportive AFOs (Figure 14). The family initiated positioning in the stander at the conclusion of serial casting, increasing from 0 h/d at baseline to 0.75 h/d after the 16th week of treatment and to more than 2 h/d at 12 and 16 months posttreatment.

Skin

No complications occurred with regard to swelling or circulation during or after intervention. Swelling (girth) decreased to 17.5 cm on the right (1.5-cm decrease) and 18 cm on the left (1-cm decrease) postcasting and occurred only “rarely” per her parents’ report in follow-up sessions. Capillary refill improved to 1 to 2 seconds by the 10th week of serial casting in both feet, as flushing of the skin ceased.
postcasting. Skin remained intact without irritation or callous formation on the right while the left presented with skin irritation surrounding the talar head during weeks 5 and 6 that resolved with the protocol change.

DISCUSSION

To our knowledge, this is the first description of rigid flatfoot deformities with vertical talus, peroneal spastic flatfoot symptoms, and serial casting intervention in the HSP population. This adolescent’s foot deformities improved despite her progressive neuromuscular disorder and age. The positive outcomes provide support for the application of Dobb’s casting method to older children, as an upper age limit for this method is not yet established. This report is unique with the application of serial casting protocols from multiple sources in a phase-driven approach, highlighting the need for individualized serial casting plans.

Although the patient’s PROM at the conclusion of treatment was less than normal in comparison with peers, it was sufficient for return to positioning in the stander. Rather than surgical correction, the PTs used an

![Figure 14](https://example.com/figure14.png)

**Fig. 14.** Patient supported in standing at 1-week post–serial casting with new ankle-foot orthoses in place.

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**Table 3:**

<table>
<thead>
<tr>
<th>Initial Intervention Plan</th>
<th>Revised Intervention Plan for Left Foot</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase 1:</strong> Correction of peroneal spasticity and calcaneal-valgus</td>
<td>Casted in maximum available inversion with ankle slightly plantar flexed; no weight-bearing.</td>
<td>8 wk and 8 casts</td>
</tr>
<tr>
<td><strong>Phase 2:</strong> Correction of spastic and fixed equinus</td>
<td>Casted gradually toward dorsiflexion using a plaster footboard insert with contoured arch moldings to prevent midfoot collapse.</td>
<td>4 wk and 4 casts</td>
</tr>
<tr>
<td><strong>Intermediate phase:</strong> Correction of vertical talus</td>
<td>Casted in plantar flexion, inversion, and forefoot adduction with counter pressure applied to the head of talus.</td>
<td>4 wk and 4 casts</td>
</tr>
<tr>
<td><strong>Phase 3:</strong> Correction of spastic and fixed equinus</td>
<td>Casted gradually toward dorsiflexion using a plaster footboard insert with contoured arch moldings to prevent midfoot collapse.</td>
<td>4 wk and 4 casts</td>
</tr>
</tbody>
</table>

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individualized serial casting plan to improve the equinovarus contractures as previously accomplished by Aydin et al.39 Recurrence is reported in young patients with CVT who did not undergo surgical pinning of the talonavicular joint.34 The authors hypothesize that AFOs may be sufficient to support the talonavicular joints for this particular girl, as exposure to weight-bearing is limited without ambulation. Also, the patient wore the AFOs day and night to maintain ROM. Long-term follow-up is needed to monitor ROM and any reoccurrence of deformity.

The present case involved a long duration of serial casting for 16 weeks (16 casts) on the left and 10 weeks (10 casts) on the right. Six was the maximum number of casts applied in many other studies for equinus contractures and CVT.27,30,34 However, Aydin et al39 applied 10 casts to an infant and achieved correction of CVT and equinus without surgery. More studies are needed to determine optimal duration of casting and number of casts specifically for adolescents with neuromuscular disorders regardless of ambulatory status.

Inversion was the corrective force used to some degree at every phase in both feet. This inversion stretch was applied during initial phases while the foot was in plantarflexion and during the later phase when stretching toward dorsiflexion. As a result, the peronei received an inversion stretch at varying angles from the plantar- to dorsiflexed positions. The significance of consistent and prolonged inversion correction and varied angle peroneal stretching is unknown and further exploration is warranted.

In the presence of multijoint involvement, it may be important to further explore the sequence of deformity correction. Dobbs et al and others recommend correcting equinus deformities after the correction of other deformity components.33-35,39 In this study, the PTs targeted subtalar motion (casting toward inversion), then talonavicular alignment (casting toward inversion/plantarflexion/adduction), and finally tibiotalar motion (casting toward dorsiflexion.) The question remains, is it beneficial to restore at least partial subtalar motion (inversion) prior to addressing the talonavicular joint or vertical talus? The PTs kept the girl non-weight-bearing until reaching at least 0° of inversion from the valgus position. While non-weight-bearing, cast correction was toward inversion and plantar flexion; the hindfoot remained in valgus for some of this time because of ROM limitations. This non-weight-bearing status possibly prevented the negative effects of ground reaction forces that might have forced the hindfoot further into valgus. In the study by Blockey,31 valgus deformities persisted in the most severely involved group when treated with walking casts molded toward maximum hindfoot inversion but in a position of hindfoot valgus. Conversely, Kinoshita et al32 observed decreased pain and resolved deformities by maintaining non-weight-bearing while casting toward inversion and plantar flexion. Further research is needed to explore the weight-bearing versus non-weight-bearing conditions for correction of severe valgus deformities.

Report Limitations
This case report involves only 1 child (2 feet) and results cannot be generalized, as larger studies are needed to determine the factors that definitively produce change. The authors devised a plan to develop a case report after the diagnosis of vertical talus, although the protocol began with the evaluation, which may improve the reliability of outcome measurement in this report. Nevertheless, measurement errors are possible as data collection occurred under clinical conditions with retrospective analysis of outcome measures. Furthermore, the Calcaneal Valgus Deformity Grading Scale is untested with unknown reliability or validity.

Another limitation is related to subjectivity regarding the talonavicular joint reduction. Both PTs agreed that reduction was palpable; although, it was impossible to determine full reduction without radiographs. Dobbs and colleagues34 standardly pursue radiographic evidence of talonavicular reduction. Radiographs of standing foot posture while wearing AFOs may have provided objective evidence of foot alignment and stability of the talonavicular joints.

SUMMARY
Pain and disability are foreseeable consequences of severe rigid foot deformities if untreated or insufficiently treated.34 Physicians continue to recommend major reconstructive surgical procedures for foot deformities despite multiple associated complications.34 Experts in the field suggest a paradigm shift toward more conservative care with casting and minimally invasive surgical procedures.35 Physical therapists and physicians require the skills to identify early signs of a developing rigid deformity for prompt collaborative intervention. Research regarding serial casting treatments and deformity prevention is needed across populations, including those with HSP as well as individuals who are ambulatory or nonambulatory and experience pain or other foot deformity-related limitations.

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