Overview of foot deformity management in children with cerebral palsy

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Received: 19 February 2013 / Accepted: 17 June 2013 / Published online: 14 September 2013
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Abstract Foot deformities in children with cerebral palsy are common. The natural history of the deformities of the feet is very variable and very unpredictable in young children less than 5 years old. Treatment for the young children should be primarily with orthotics and manual therapy. Equinus is the most common deformity, with orthotics augmented with botulinum toxin being the primary management in young children. When fixed deformity develops lengthening only the muscle which is contracted is preferred. Varus deformity of the feet is often associated with equinus, and can almost always be managed with orthotics until 8 or 10 years of age. Planovalgus is the most common deformity in children with bilateral lower extremity spasticity. The primary management is orthotics until the child no longer tolerates the orthotic; then surgical management needs to consider all the deformities and all should be corrected. This requires correcting the subtalar subluxation with calcaneal lengthening or fusion, medial midfoot correction with osteotomy or fusion.

Keywords Cerebral palsy · Planovalgus feet · Equinovarus · Equinus

Introduction

Deformities of the feet are the most common musculoskeletal problem in children with cerebral palsy. Many of these are simple deformities, such as mild toe walking, that

resolve with simple treatments using a combination of orthotics and stretching exercises. There are, however, a substantial number of significant deformities for which the treatments continued to be debated, especially the management of planovalgus deformities in children with functional ambulation. The goal of this review is to give a brief overview of the management concepts generally in use for foot deformities in children with cerebral palsy.

Natural history

It is very important to have an understanding of the natural history of the deformity in the child who presents with a foot deformity. Much of this natural history is not well defined in the scientific literature and therefore is mainly experience-based.

Equinus deformity

The most common deformity is equinus, which is present in the large majority of children with CP at the beginning of standing and walking. This equinus is easily managed with daytime plantar flexion controlling orthotics. Along with the orthotics, the physical therapist should be instructing the caregivers to stretch the plantar flexors several times a day. When the orthotics are no longer being tolerated, a course of botulinum toxin injections are typically used. No stretching cast or splints should ever be used without also having the knee splinted in full extension, or there will only be progressive stretching of the soleus and further contracture of the gastrocnemius. The vast majority of children will be able to tolerate this conservative routine until 6–8 years of age, by which time they either have

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resolved the tendency for toe walking or are developing significant contractures of the gastrocnemius and in hemiplegia in the soleus as well. This is the typical time when surgical lengthening of the plantar flexors is first considered. If the foot is developing a severe midfoot break or the child can no longer tolerate the plantigrade orthotics, surgical lengthening is indicated. Children with spastic CP and equinus gait have longer than normal Achilles tendons and shorter than normal muscle bellies; moreover, surgical procedures aim to restore dorsiflexion but not normal muscle–tendon architecture [1]. The surgical lengthening should specifically focus only on the contracted muscle, in diplegia typically only the gastrocnemius, with a mid-calf myofascial release. Long-term results suggest that gastrocnemius–soleus intramuscular aponeurotic recession in cases of spastic diplegic CP sufficiently corrects equinus deformity while avoiding overlengthening, which can be detrimental to gait [2]. In hemiplegia, for unknown reasons, the soleus also develops contractures; in this case, a combined slightly more distal myofascial release of the conjoined tendon is preferred. Selective fractional lengthening does not impair the muscle architecture while significantly improving kinematic and maximum power generation at the ankle [3].

In severe equinus contractures, an open z-lengthening of the tendon Achilles is the safest approach. In very severe neglected equinus, the foot develops a cavus deformity with a contracture of the plantar fascia, which often needs to be released. In these severe neglected cases, toe flexor lengthening is often also needed, but ankle joint capsule release is almost never required. In adolescent age children with severe equinus contractures, there is also too much length in the tibialis anterior tendon, and concurrent shortening of the tendon with Achilles lengthening will provide much better postoperative swing-phase ankle function. Surgical tendon shortening of the tibialis anterior tendon with distal insertion fixation in the medial cuneiform to rebalance muscle strength in conjunction with tendon Achilles lengthening has been shown to significantly improve the movement analysis profile for ankle dorsi- and plantarflexion, gait profile score, gait deviation index, and postoperative Gillette gait index. In addition, 93 % of patients may obtain active dorsiflexion, so this combination is recommended in order to achieve optimal postoperative function [4]. Significant improvements in passive ankle dorsiflexion range of motion and ankle dorsiflexion in the swing phase have also been demonstrated following ankle plantar flexor surgery [5]. Although the goal of treating equinus is to be conservative, and it is extremely important to avoid overlengthening the plantarflexors, the development of a severe contracture should not be neglected, as this also leads to significant long-term disability from progressive cavus, foot, and ankle pain.

However, it is much better to have many recurrent equinus contractures than to have one overcorrection. The mean age at surgery in one study of 186 patients (308 feet) was 6.8 years, and among children with hemiplegia and diplegia, the younger children (before age 8) showed a higher rate of recurrence compared with the older children. The overall recurrence rate is 43.8 %, and is highest among patients with hemiplegia (62.5 %) [6]. Therefore, in our clinic, children treated with surgical lengthening before 10 years old are made aware they may in fact need a second procedure by full skeletal maturity (Fig. 1).

Hyperdorsiflexion deformity

This deformity occurs mostly in children with a very severe quadriplegic pattern during adolescence. The same child may have equinus during the childhood years but then develops a severe hyperdorsiflexion valgus deformity during rapid adolescent growth. Since these children are almost always not functional ambulators, orthotic treatment is usually successful; however, if a fixed deformity develops, a tenotomy of the tibialis anterior is simple and usually adequate to resolve the footwear problem.

Varus feet

Varus deformity of the feet is very common in young children 3–7 years of age with equinus. The natural history of varus in the young child is for it to be stable or persist in children with hemiplegia; however, in children with diplegia, almost all will overcorrect into valgus. Since the principal deformity is equinus, the treatment practice at this age should follow the equinus protocol. If surgical lengthening of the plantar flexors is required, there is often a concern regarding the need to also address muscle balancing in order to treat the varus component of the deformity. In children under 8 years of age, this should almost never be done because there is a very high risk of overcorrection into planovalgus with both release of the plantarflexion contracture and the muscle causing the varus. In children above age 8, the varus should never be addressed unless it is a fixed deformity—meaning that the foot cannot be brought to neutral under anesthesia after plantar flexor lengthening—in a child with bilateral involvement (diplegia or quadriplegia) because there is a very high risk of the foot going into planovalgus during the adolescent and teenage years. In hemiplegia in children above the age 8, if the varus is mostly forefoot and present in swing and there is high or constant activity in the tibialis anterior EMG during swing, a split transfer to the lateral side of the foot or complete transfer to the midfoot is indicated. If the

Fig. 1 Example of a 16-year-old boy with asymmetric diplegia with an equinovalgus foot on the left. The weight-bearing photograph shows severe hindfoot valgus with medial forefoot weight-bearing (a), the pedobarograph shows a similar weight-bearing pattern (b), while the lateral radiograph shows a midfoot break (c), and the AP radiograph shows a bunion and uncovering of the head of the talus

(d). One year after surgery, the hindfoot is well corrected (e), as confirmed by the pedobarograph (f). The lateral radiograph shows excellent correction of the subtalar and medial cuneiform–navicular fusion (g), and good correction is seen in the AP plane with the addition of the Aiken bunion correction (h)

deformity is more stance phase, hindfoot, and the tibialis posterior is overactive or out of phase, a split transfer of the tibialis posterior to the peroneus brevis on the lateral side of the foot is indicated.

Split tibialis posterior tendon transfer is performed to balance the flexible spastic varus foot, and is preferable to tibialis posterior lengthening, as the muscle does not lose its power. Those feet with the poorest results in one study presented as a residual varus deformity due to intraoperative technical errors [7]. Split tendon transfers of the tibialis posterior performed to eliminate excessive hindfoot inversion have been described, with tendon transfer to either the proximal or distal peroneus brevis tendon routing behind the lateral malleolus, or tendon transfer routing through a

window in the interosseous membrane with attachment to the distal peroneus brevis tendon. Of these techniques, tendon transfer routed around the lateral malleolus shows no difference in mechanical effect whether inserted proximal or distal onto the peroneus brevis tendon, but routing through the interosseous membrane leads to reduced tibialis posterior plantarflexion function, and may lead to overcorrection into dorsiflexion [7]. The involvement pattern of CP, age at operation, and preoperative status of ambulation are significant factors in the outcome of surgery. Hemiplegic patients demonstrate the best results regardless of age, whereas diplegic and quadriplegic patients who are less than 8 years old or who are not capable of community ambulation had a high failure rate from operative intervention [8].

Planovalgus

This is the foot deformity that generates the most discussion among pediatric orthopedics because it is very common—there are many treatment alternatives, none of which have clear, documented benefits over the others. Another problem with planovalgus is the deformity, which varies from a mild flat foot to such a severely deformed foot that one cannot put a shoe on it. Obviously, one treatment option will not work over the whole spectrum of severity, but there is no clearly defined measure of severity like the Reimers migration percentage measure of hip subluxation. Several pathologies contribute to the deformity, beginning with the lateral displacement of the navicular, causing the talar head to become uncovered and prominent in the medial midfoot. The relationship between radiographic and foot pressure component measurements has been reviewed using simple linear regression [9]. In our experience, the pedobarograph or foot pressure measurement is the most objective method for assessing severity or change over time.

The natural history of planovalgus has to be considered in every child in whom treatment is being considered. In young children under the age of 5, the deformity is extremely unpredictable. In general, if the child has hemiplegic pattern involvement, the planovalgus has a very high chance of resolving and even going to varus later in childhood. However, in many cases, it is difficult to tell if the 3-year-old child has hemiplegia or diplegia until the child is 5 or 6 years old. For the child with bilateral involvement, the planovalgus often improves until age 5 or 6 and is then stable in middle childhood before again collapsing into more deformity and becoming painful during the adolescent growth period.

Considering the natural history, it is very rare for there to be an indication to perform any surgical treatment of planovalgus prior to 9 or 10 years old, and then only if the foot is painful or there is progressive mechanical collapse causing decreased walking ability. The primary treatment of planovalgus in childhood is orthotic control. The impact of orthotic use in planovalgus feet has no scientific documentation; specifically, we have no indication of whether the natural history is impacted positively or negatively. It seems reasonable to protect the planovalgus foot from high pressures in the cartilaginous joints during walking, which seems like it would cause further progressive deformity; on the other hand, if the foot is constantly controlled with orthotics, the muscle control and strength in the foot will completely atrophy and therefore lead to more collapse unless rigidly controlled with an external orthotic, dooming the child to lifelong orthotic use. For this reason, we recommend using orthotics for one-half to three-quarters of the awake time during the period of most active walking,

starting with full calf-height AFO but then reducing to ankle height if the equinus is controlled. Almost all pre-adolescent children tolerate these orthotics well if they are properly fitted and padded and the foot is not overcorrected. Most of the time, stance stability during gait is improved and the children have better gait function. Almost all children with planovalgus have contractures of the gastrocnemius, which can be noted by testing passively with the planovalgus corrected. The impact on the natural history of planovalgus deformity of treating this contracture is not known, and it is our experience that it is extremely unpredictable; therefore, if equinus is not a problem, we do not do isolated gastrocnemius lengthening to treat planovalgus. However, the vast majority of children who have surgical correction of the planovalgus will need gastrocnemius lengthening as part of that combined procedure. After hindfoot correction, every foot needs to be carefully checked to make sure the foot can come to plantigrade; if not, the appropriate muscle should be lengthened.

Surgical correction of the planovalgus is indicated if the foot is painful during gait or the mechanical stability of the foot is impacting the ability to achieve optimal gait. Since planovalgus is a multiplanar and variable deformity, it is important to consider all aspects of the deformity when planning surgical correction. The first consideration is the child's gait function: for children who are high-level ambulators (GMFCS I, II, and most III), attempts should be made to preserve mobile joints. Most of these feet also present when the deformity is not very severe because they become symptomatic earlier due to high force demands of the foot. Ambulatory children have had significantly better clinical and radiological outcomes (according to Mosca's criteria) than nonambulating children with calcaneal lengthening for correction of mild-to-moderate planovalgus deformity [10]. Calcaneal lengthening with concomitant peroneus brevis lengthening is an effective procedure for correcting a planovalgus foot deformity; however, it should be noted that, for patients with a 23° AP talus–first metatarsal angle, 36° lateral talus–first metatarsal angle, and 72 % naviculocuboid overlap, additional procedures should also be considered [11]. Our preferred treatment for this group is lateral calcaneal lengthening, which preserves the subtalar joint motion. After this lateral procedure, many children will have a prominent medial navicular tuberosity which should be excised with the tibialis posterior tendon advanced to provide medial arch support. If the forefoot is still in supination with elevation of the first ray, a medial plantar-based wedge resection of the naviculocuneiform joint is performed. Plantar flexor lengthening is then performed if needed, and a careful examination of the tibial torsion. If required, a tibial derotation is added. For children who are GMFCS IV or V and have painful feet or

severe deformity that limits their standing ability, a subtalar fusion is performed, followed by correction of the medial column with fusions as needed. For very severely deformed feet, a fusion from the first metatarsal to the talus is performed; for more mild feet, only the naviculocuneiform fusion; and for moderate feet, the talus to medial cuneiform may be included. Again, care has to be taken to ensure that plantarflexion contractures or tibial torsion are not left uncorrected. The major problem with the lateral calcaneal lengthening is recurrent deformity, which we usually treat with a subtalar fusion. The other major recurrent issues are related to not correcting associated deformities such as medial column collapse, tibial torsion, or plantar flexor contractures. Although the calcaneal lengthening may correct the planovalgus deformity, active muscle force is required to maintain this correction; therefore, in the feet of children with hypermobility or severe muscle weakness, or poor motor control such as dystonia, fusion is required, as there should be no consideration of calcaneal lengthening in these situations.

Toe problems

Hallux valgus and bunions are very commonly associated with planovalgus foot deformities. They are not typically a major cause of the pain, but they are the most common cause of unhappy patients, especially teenage girls. Correction of hallux valgus deformity may be indicated to address hygiene problems related to over- or underlapping of the great and second toes and/or to facilitate the use of orthotics or footwear.

Correcting these deformities at the same time as performing planovalgus feet correction adds substantially to improved patient satisfaction. Most often, hallux valgus deformity is simple to correct with a proximal phalangeal osteotomy and a mild resection of the bunion. Surgical techniques yielding satisfactory outcomes include first metatarsophalangeal joint arthrodesis, proximal first metatarsal osteotomy, distal soft tissue releases, and exostectomy of the bunion [12]. Ambulatory patients may be treated with great toe metatarsophalangeal joint arthrodesis, as it improves segmental foot malalignment and dynamic foot deviation [13]. We feel that there should be one attempt to correct the bunion without fusion in patients with good gait function (GMFCS I–III), since a mobile joint probably improves rollover function in the second and third rockers. However, of all the surgical options, first metatarsophalangeal joint fusion has demonstrated the highest percent correction [12], with significant improvement observed on the modified American Orthopaedic Foot and Ankle Society Hallux

Metatarsophalangeal–Interphalangeal Scale, as well as patient, parent, and caregiver satisfactions ranging from 81 to 100 % [14]. For those patients with previous surgical intervention and failed management, arthrodesis of the great toe MTP is clearly the most appropriate salvage option. It is very important in all procedures not to over-correct the deformity, as this leads to even more unhappiness.

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