Approach to bone procedure in fixed equinovarus deformity in cerebral palsy

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ABSTRACT

Fixed equinovarus deformity in cerebral palsy requires bone procedures for surgical correction. We reported the outcome of surgical procedure establishing the approach to multiple osteotomy and fusion to this problem. Retrospectively, 55 feet were reviewed. Step of surgical evaluation were applied to all patients by addressing each component of equinovarus deformity. 31 feet achieved correction by multiple osteotomy. Overall 78% had good outcome and maintained plantigrade foot. This study had outlined a simple surgical step-approached procedure to address fixed equinovarus deformity in cerebral palsy with high success rates. We recommended multiple bone osteotomy to preserve joint motion.

1. Introduction

Equinovarus deformity in patients with cerebral palsy is one of the most common problem which resulted from imbalance function of muscle around the foot.^{1,2} Spastic flexible deformity in younger age will gradually progressed to fixed deformity in older age. This process might be accelerated in cases with severe spasticity or in untreated patients. Long standing spasticity or over-activity of anterior and posterior tibial tendons in addition to peroneal muscles weakness had gradually caused some adaptive changes to the shape of bone and joint. Orthosis, physical therapy and botulinum toxin injection would temporarily control the spasticity of foot. When true equinus developed, lengthening of tendo-Achilles alone was preferred especially in younger children.^{3,4} However, when component of foot varus, cavus and adduction were obvious, tendon balancing procedure would be advocated either posterior tibialis tendon or anterior tibialis tendon transfer. Split posterior tibialis tendon transfer to peroneus brevis would correct the hindfoot varus effectively except in cases with concomitant overactivity of anterior tibialis tendon and in older patients who have some component of fixed heel varus deformity.^{5,6} Split anterior tibialis or total anterior tibialis tendon transfer also would have corrected flexible equinovarus foot.^{7,8} Failure of tendon balancing procedure may come from either failure of identifying fixed deformity component, severity of muscle spasticity, tendon procedure which was done in the older age children, as well as experience of attending surgeon.

Combination of bone and soft tissue surgery which aimed to achieve

plantigrade, painless and functional foot should be performed as it addresses both fixed component of deformity and spastic dynamic deformity.⁹ Joint arthrodesis would be the best procedure in correcting the fixed deformity and stabilises the joint. Thus, triple fusion was suggested for the most severe fixed equinovarus foot and majority of the patients had good outcome with plantigrade foot. Nonetheless, there is a risk of tibiotalar joint arthritis in long term.¹⁰

There was limited published data on outcome of single-staged combined bone and soft tissue surgery in fixed equinovarus foot. Radiological outcome had shown improvement of calcaneal pitch and talo-1st metatarsal angle after closed wedge osteotomy of calcaneus and first metatarsal bone in fixed equinovarus deformity of foot in cerebral palsy.¹¹ However, there were lack of reported clinical outcome and surgical method for correction of midfoot supination deformity component. The concept of early detection of fixed component of equinovarus deformity and combination of soft tissue and bone surgery need to be advocated. The objective was to prevent severe fixed deformity which required triple fusion for treatment.

Therefore, we would like to report on the outcome of surgical procedure establishing the approach to multiple osteotomy and fusion for fixed equinovarus deformity of foot in cerebral palsy.

2. Material and method

Charts were reviewed retrospectively for all patients with cerebral palsy who had a problem of fixed equinovarus deformity and

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Fig. 1. Illustration depict the step surgical approach to fixed equinovarus deformity in cerebral palsy.

underwent bone surgery at Queen Sirikit National Institute of Child Health between 2007 and 2014. We had excluded the non-ambulatory patients who had GMFCS level V and those whom had no potential to stand. All patients had a minimum period of two years follow-up. All feet were evaluated and operated by a senior orthopaedic surgeon.

Step of surgical approach was performed when the patients was in operative room under anaesthesia as shown in Fig. 1. Firstly, the equinus component was evaluated and corrected by lengthening or recession of tendo-Achilles by Z-plasty or intramuscular recession. Equinus component would limit physiological motion of subtalar joint complex and after releasing the tendo-Achilles we could easily evaluate the motion of the subtalar joint. Secondly, we evaluated component of hindfoot varus by applying valgus force while stabilising the ankle in neutral position. If the hindfoot was in fixed varus, we considered correction by Dwyer calcaneal osteotomy.¹² Thirdly, midfoot supination and convex lateral border component were evaluated by holding the ankle and hindfoot in neutral position. If the midfoot supination and lateral border curvature were not severe, cuboid wedge osteotomy was performed.¹³ Calcaneocuboid joint fusion would be considered in cases with severe deformity. Lastly, forefoot cavus and adduction component were assessed. The forefoot cavus deformity corrected by first metatarsal dorsal wedge osteotomy.

In a case of severe midfoot deformity, sometimes correction was not achieved after calcaneocuboid joint fusion due to talonavicular joint stiffness. Talonavicular joint fusion would be added in the surgery to obtained full correction. Triple fusion would be considered in severe fixed hindfoot deformity.¹⁴

After steps of bone surgery were performed, tendon transfer procedure would be considered if the tendon still noted to be active. In pre-operative tendon assessment, if the anterior tibialis tendon was active upon stimulation and achieved nearly full dorsiflexion of ankle, we recommended to do split anterior tibialis tendon transfer to peroneal tertius tendon. However, if that tendon had fair function (slight dorsiflexion of ankle), we preferred total anterior tibialis tendon transfer. Lastly, if it had no function and shortened, tendon tenotomy would be considered. We tried to preserve posterior tibialis tendon because we were concern about midfoot break after posterior tibialis tendon transfer. If it showed marked spasticity upon stimulation, we would do tendon recession or split posterior tibialis tendon transfer.

All feet were fixed with K-wire for 6–8 weeks. Ankle foot orthosis was applied for nearly all patients and recommended to wear the orthosis for 6–8 h a day in the first year. Post-operative evaluation was

performed by foot examination and gait observation after K-wire removal during clinic follow-up. Surgical complication, under-correction, over-correction and recurrent of deformity were carefully documented in each follow-up.

The goal of treatment was a plantigrade and painless weight bearing foot. The plantigrade weight bearing foot was defined as the ability to fully placed the plantar side of a foot on a ground and bear the body weight, without pain or varus deformity.

Recurrent component of equinovarus deformity were evaluated and divided into four components, as mentioned below:

1. Hindfoot varus: hindfoot in fixed varus when valgus force applied.
2. Midfoot supination: midfoot in supination with lateral border curvature when the hindfoot in neutral.
3. Forefoot cavus: forefoot in cavus and plantarflexed position when the hindfoot and midfoot in neutral.
4. Ankle equinus: degree of ankle dorsiflexion less than 10-degree when the knee in 90-degree flexion.

Over-correction was defined as a midfoot break when the patient bear weight with hindfoot valgus more than 15-degree.

3. Results

51 feet (n = 40 patients) were included in the study. Mean age at surgery was 9.8 years (range 4–17 years) and mean of last follow up was 4.2 years (range 2.5–8.5 years). There were 18 males and 22 females. The distributions of GMFCS were 6, 22, 6 and 6 corresponded to GMFCS I, II, III, and IV respectively. Hemiplegic type was the most common which was 22 patients as compared to diplegic and triplegic which were 13 and 5 patients. The demographic data was shown in Table 1.

All patients that underwent the step-approached surgical procedures were analysed and categorised into three groups (Table 2).

1. Multiple osteotomy group: underwent any osteotomy procedure including calcaneus, cuboid and 1st metatarsal bone.
2. Combined group: underwent either calcaneus or 1st metatarsal osteotomy or both; and combined with calcaneocuboid joint fusion or midfoot fusion.
3. Fusion group: underwent triple fusion.

Table 1
Demographic data.

Demographic	
Patients (n)	40
Feet	51
Sex M/F	22/18
Mean age at surgery (year)	9.87
Mean year of follow-up	4.20
CP type (He/Di/Tr) ^a	22/13/5
GMFCS level (I/II/III/IV)	6/22/6/6

^a He mean Hemiplegia. Di mean Diplegia. Tr mean Triplegia.

There were 31 feet (22 patients) in the multiple osteotomy group and the mean age at surgery was 7.75 years. Closed wedge cuboid and 1st metatarsal dorsal wedge osteotomy was performed in more than 60% of feet. Almost all feet underwent tendo-Achilles lengthening and about 50% underwent tendon transfer. For the combined group, there were 13 feet (11 patients) underwent calcaneocuboid joint fusion or midfoot fusion for supination deformity correction and osteotomy for forefoot cavus and hindfoot varus correction. Almost all feet required tendo-Achilles lengthening but only 5 in 13 feet underwent tendon transfer procedure. In the fusion group, there were only 7 cases. The mean age of the fusion group and the combined group were higher than the multiple osteotomy group, which was statistically significant. The details were shown in Table 2.

We found that equinus, forefoot cavus and midfoot supination deformity were more common than hindfoot varus in our patients. All feet achieved full correction intra-operatively. Tendon transfer procedures additionally performed if indicated after the multiple osteotomy or joint fusion.

There were neither deep surgical wounds infections, nor non-union of osteotomy or fusion documented. All patients able to bear weight post operatively, however the timing of weight bearing without pain depend on the type of surgery that was performed. Mean period of full weight bearing after surgery was 4.2 months. The group of patients whom had multiple osteotomy procedure had shorter time to bear weight compared to the group of patients whom received joint fusion,

which was statistically significant.

Post-operative outcome at last follow-up showed that 78% (40/51 feet) achieved plantigrade weight bearing (Fig. 2). However, 25% (13/51 feet) had some components of recurrent deformity. We noted that in our patients, the hindfoot varus and midfoot supination recurrent were more common. Almost all feet that had recurrent deformity came from multiple osteotomy group. However, only 11 feet were considered for second surgery, in which tendo-Achilles lengthening was done for 4 feet where as 7 feet underwent second step-approached evaluation.

Triple fusion group had better outcome in maintaining plantigrade weight bearing foot compared to multiple osteotomy and combined fusion group. Nevertheless, a fusion procedure was potent and stable in correcting the deformity but it made the joint motionless. Midfoot break was detected about 12% (6/51 feet) particularly in the multiple osteotomy group, which was 5 out of 31 feet (16%). The details of post-operative outcomes were shown in Table 3.

4. Discussion

Equinovarus deformity in patients with cerebral palsy developed gradually due to imbalance function of muscle around the foot. The deformity was not as stiff as that of congenital cause. Long standing spasticity of gastro-soleus, anterior and posterior tibialis tendons with concomitant peroneal muscles weakness gradually would cause some changes to the shape of bone and joint. Generally, each component of fixed equinovarus was not developed simultaneously but it progressed gradually with growth. When the fixed deformity was established, soft tissue balancing procedures were inadequate to correct the deformity.

In this study, each component of fixed equinovarus deformity was carefully distinguished and described. Accordingly, surgical step-approached were developed for correction of the deformity. Forefoot cavus component was quite common and effectively corrected by closed wedge osteotomy of 1st metatarsal bone. We found that this procedure has high successful rate as there were no recurrent of forefoot cavus found in our patients. Whereas, midfoot supination with lateral border curve, closed wedge osteotomy of cuboid would correct the deformity but in severe cases, calcaneocuboid joint fusion or midfoot fusion may be required. Fixed hindfoot varus component were addressed by closed

Table 2
Group of different type of surgical procedures.

	Group 1	Group 2	Group 3	Total	p value
	Osteotomy	Combined ^b	Triple fusion		G1:G2,G1:G3 ^a
Number of feet	31	13	7	51	
Number of patients	22	11	7	40	
Mean age at surgery (year)	7.75 (3.50–14.17)	12.0 (11.67–15.0)	13.05 (9.67–16.83)	9.67 (3.50–16.83)	< 0.001, < 0.001
Mean of last follow up (year)	4.50 (2.50–8.50)	3.58 (2.75–4.50)	3.58 (3.0–5.50)	4.17 (2.50–8.50)	0.02,0.09
Number of bone procedure					
1 st metatarsal osteotomy ^c	23	8	0	31	
Cuboid osteotomy ^d	28	0	0	28	
Calcaneus osteotomy ^e	11	9	0	20	
CC joint fusion ^f	0	8	0	8	
Midfoot fusion ^g	0	5	0	5	
Triple fusion	0	0	7	7	
Number of tendon procedure					
Anterior tendon transfer	9	4	0	13	
Posterior tendon transfer	7	1	0	8	
TA lengthening	30	12	6	48	

^a paired *t*-test between G1:G2 and G1:G3.

^b Combined group mean osteotomy and fusion procedure.

^c 1st metatarsal osteotomy mean dorsal closed wedge osteotomy.

^d Cuboid osteotomy mean closed wedge osteotomy of cuboid bone.

^e Calcaneus osteotomy mean closed wedge osteotomy of posterior process of calcaneus (Dwyer technique).

^f CC joint fusion mean fusion of calcaneocuboid joint.

^g Midfoot fusion mean fusion of talonavicular and calcaneocuboid joint.

Fig. 2. The above pictures showed a 7-year old girl with left hemiplegic cerebral palsy. **Fig. 2A:** Pre-operative pictures showed fixed left equinovarus deformity. **Fig. 2B:** 7 years after surgery. The left foot was plantigrade with no recurrent deformity. She received calcaneal closed wedge and 1st metatarsal closed wedge osteotomy, split anterior tibialis tendon transfer and tendo-Achilles recession. **Fig. 2C:** Anteroposterior and lateral radiograph films for calcaneal osteotomy and 1st metatarsal osteotomy with K-wire in-situ.

Table 3

Post-operative outcome at last follow up.

	Group 1	Group 2	Group 3	Total	p value
	Osteotomy	Combined ^b	Triple fusion		G1:G2,G1:G3 ^a
Number of feet	31	13	7	51	
Mean time of full weight bearing after surgery (months)	3.50	4.25	6.80	4.20	0.08, < 0.001
Plantigrade weight bearing ^c	24/31(77%)	10/13(77%)	6/7(86%)	40/51(78%)	
Recurrent deformity	8/31(26%)	4/13(31%)	1/7(14%)	13/51(25%)	
Heel Varus	6	2	1	9	
Midfoot Supination	6	2	0	8	
Equinus	2	2	0	4	
Midfoot break	5 (16%)	1	0	6(12%)	
Plan for second bone surgery	5	1	1	7(14%)	
Plan for second TAL	2	2	0	4	

^a paired *t*-test between G1:G2 and G1:G3.

^b Combined group mean osteotomy and fusion procedure.

^c Plantigrade weight bearing defined as patient ability to place the full plantar side of a foot on ground and bear the weight of the body in stable position, without varus deformity and pain-free.

wedge calcaneal osteotomy and small number of patients need fusion at posterior subtalar joint. This was different from congenital clubfoot in which subtalar joint usually more rigid and require intensive procedure on hindfoot.

In our surgical step-approached, we attempted deformity correction by multiple osteotomy before joint fusion to preserve joint motion. We found that multiple osteotomy procedures were commonly done in younger patients (60%) with mean age of 7.75 years and 13/51 feet (26%) required calcaneocuboid joint or midfoot fusion. Moreover, triple fusion procedure was done in only 7/51 feet (14%) with mean age of 13.05 years. Thus, early detection of fixed deformity in younger age patients would prevent joint-sacrificing surgery. Triple arthrodesis was reported to have adjacent joints osteoarthritis in long term.¹⁵

Tendon transfer procedures were considered in step-approached surgical algorithm after the bone procedures. The outcome of tendon balancing procedure depends on quality of the particular tendon. Therefore, pre-operative assessment of the strength of anterior and

posterior tibialis tendon should be done carefully. Anterior tibialis tendon was easier to assess clinically by active dorsiflexion and supination motion but in posterior tibialis tendon examination, the motion of hindfoot varus was obscured by the force exerted by anterior tibialis tendon. Line of pull of anterior tibial tendon would produce midfoot supination and adduction as well as hindfoot varus, whereas the line of pull of posterior tibial tendon would mainly produce hindfoot varus. Therefore, soft tissue balancing procedures were important to maintain plantigrade foot postoperatively.

We had monitored the overall outcome for mean follow-up of 4.2 years which depicted 78% (40/51 feet) had plantigrade weight bearing at the end of the follow-up. Those whom had achieved plantigrade feet, 77% (24/31 feet) were from multiple osteotomy group and 86% (6/7 feet) were from triple fusion group. The time for weight bearing was at mean post-operative time of 4.2 months. The patients in the osteotomy group bear weight earlier than the combined and the fusion group.

Recurrent deformity was found about 25% (13/51 feet) but only 7

feet were considered for second bone surgery. Hindfoot varus and midfoot supination were common recurrent component of deformity which were 9 feet and 8 feet, respectively, especially in the multiple osteotomy group. However, only 4/51 feet had recurrent equinus deformity and underwent second tendo-Achilles lengthening. Recurrent rate in cerebral palsy with fixed equinovarus were higher because of poor muscle control, gravitational force and growth. In order to reduce the risk of recurrent, the need of orthosis and patients' compliance were important post-operatively.

Midfoot break was found in 6/51 feet and 5 of them were from the multiple osteotomy group. We unable to delineate the exact cause of high incidence of midfoot break in multiple osteotomy group, however we postulated that the mobility of the joint and muscle weakness may had contribute to the deformity.

There were few limitations of this study. The overall outcome was solely based on clinical examination and no radiographic data were obtained even though all the patients had post-operative radiographs. This was due to inconstant foot position when the radiographs were taken thus made it difficult to measure the proper radiographic parameter. There was a report on radiographic improvement of the talo-first metatarsal angle and calcaneal pitch after closed wedge 1st metatarsal and calcaneal osteotomy, respectively.¹¹ These results were corresponded with the clinical outcome in our patients as both procedures were highly effective in correction of these deformities. Another limitation was no objective quantification of severity in each deformity component, as it was important in decision making of appropriate surgical procedure. However, the surgical step-approached procedure was a simple and effective methods to manage fixed equinovarus in cerebral palsy patient.

5. Conclusion

This study had outlined a simple surgical step-approached procedure to address fixed equinovarus deformity in cerebral palsy. The success rates to achieve plantigrade weight bearing were up to 78% and low recurrent rate. We recommended early detection and performed multiple bone osteotomy to preserve joint motion and avoid joint fusion.

Conflicts of interest

We declare that there was no conflicts of interest or funding sources to disclose.

Ethical approval

Not required.

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