Surgical Management and Treatment Algorithm for the Subtle Cavovarus Foot

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ABSTRACT

Background: Subtle cavovarus foot is a condition that can lead to significant foot pain and disability. We review the results of our treatment algorithm at medium-term followup. Materials and Methods: Thirty-five consecutive patients with lateral based symptoms due to an underlying congenital subtle cavovarus foot type were surgically corrected. Various procedures were utilized, including some combination of the following: lateral displacement calcaneus osteotomy, peroneus longus to brevis transfer, dorsiflexion first metatarsal osteotomy, and Achilles tendon lengthening. Twenty-three patients, with 29 feet, returned for followup examination. The mean patient age at the time of surgery was 43.4 years, and the mean followup to date was 4.4 years. Results: The mean AOFAS ankle hindfoot score preoperatively was 45, and postoperatively was 90. Radiographically, the medial cuneiform to floor height changed from 3.5 cm preoperatively to 3.0 cm postoperatively. The talo-first metatarsal angle improved 7.5 degrees postoperatively. There were no nonunions. No patients to date have gone on to fusions or revisions. Ten feet (34%) required hardware removal. All patients had resolution of their symptoms following hardware removal. Conclusion: The surgical management for the subtle cavovarus foot based on the proposed treatment algorithm provided symptomatic relief, longstanding correction, and high patient satisfaction.

Level of Evidence: III, Case Control Study

Key Words: Cavovarus; Subtle Caves Foot; Ankle Instability; Peroneal Tendon Disorders

INTRODUCTION

In the past few years there has been increased interest in the diagnosis and treatment of the subtle cavovarus foot (SCF). Pes planovalgus deformities have been discussed and understood, but the SCF deformity and its resultant pathological conditions have not been given equal emphasis. The cavovarus foot has traditionally been associated with neuro-muscular conditions and severe deformity. Lately, a less severe form has been identified in the general population.

The subtle cavovarus foot typically presents with lateral symptoms commonly seen in patients with ankle/hindfoot instability, peroneal tendon injury, lateral column pain (pain along the anterior process of the calcaneus, cuboid, fourth, and fifth metatarsal), and even stress fractures of the fourth and fifth rays. Authors have thus placed increased emphasis on this deformity as a probable underlying cause for these symptoms. The importance of identification and correction of this deformity along with its associated pathology has been shown.

The incidence of the SCF is probably higher than reported as it often goes undiagnosed. Most often the presenting symptoms are attended to, but the SCF deformity goes without correction potentially leading to a higher risk of recurrence of symptoms. An algorithm for surgical correction of the SCF has not been formulated to date. Procedures that have been typically utilized in the past have been Dwyer calcaneus osteotomies for hindfoot varus, peroneus longus to brevis tendon transfers, and dorsiflexion first metatarsal and lesser metatarsal osteotomies to correct the residual forefoot bony deformity. The purpose of this study was to evaluate clinical and radiographic outcomes of the surgical management of the SCF and present a surgical treatment algorithm.

MATERIALS AND METHODS

Between May 1997 and November 2008, thirty-five consecutive patients with a symptomatic subtle cavovarus deformity were treated with a combination of procedures. Twenty-three patients (29 feet) were available for followup. Six patients had bilateral deformities that were treated. The average time to followup was 4.4 (range, 1 to 10.1) years. There were 15 females and eight males with a mean age at time of operation of 43.4 (range 13, to 72) years.
All patients presented with lateral sided pain. Fourteen of the 29 feet (13 patients) had lateral sided pain secondary to a traumatic inversion ankle injury. Five of the 14 feet (36%) developed ankle instability, and nine of 14 (64%) sustained peroneal tendon tears. Fifteen of the 29 feet presented with persistent lateral column pain. This was characterized as pain along the calcaneocuboid joint, fourth and fifth tarsometatarsal joints, and/or fourth and fifth metatarsals.

The decision for operative intervention followed being treated conservatively for a minimum of 6 months with custom-molded orthotics, various physical therapy modalities, bracing, and immobilization, if necessary. All patients in the study failed conservative management and had persistent pain upon performing activities of daily living. The goal of operative intervention was to correct the underlying subtle cavovarus deformity using a combination of procedures. The procedures performed included a lateral displacement calcaneus osteotomy (LCO), peroneus longus to brevis tendon transfer, dorsiflexion first metatarsal osteotomy, and an Achilles tendon lengthening (Table 1). All operations were performed by the senior author (G.C.P.).

Clinical evaluation included a motor and sensory exam to rule out a neurological etiology as the cause of the SCF. All patients with a neurological etiology were excluded from the study.

Evaluating the SCF without a neurological cause was done using a systematic approach. The Silfverskiold test was first performed to evaluate for the presence and type of equinus. This test distinguished between an isolated gastrocnemius contracture and a combined gastrocnemius and soleus contracture.

Next, the hindfoot position was examined. All patients in the study were noted to have a positive “peek-a-boo” heel sign. The hindfoot varus was then evaluated with the Coleman block test. The Coleman block test was performed by having the patient stand full weightbearing with the foot and heel on a block, allowing the first ray to drop off medially. It was used to isolate the hindfoot by eliminating the forefoot influence. If the hindfoot corrected completely, the hindfoot varus deformity was thought to be forefoot driven. If the hindfoot remained in a varus position and did not correct completely, the hindfoot was then noted to be a component of the deformity. All patients in the study were noted to have a residual varus deformity.

After the above examination, the forefoot was then evaluated intraoperatively. After the equinus and residual hindfoot varus deformities were corrected, the forefoot could properly be evaluated. If the first ray was hypermobile and manually reducible to the level of the lesser metatarsal heads, then no persistent forefoot deformity was present. If there was noted resistance to dorsiflexion of the first ray upon range of motion, plantarflexion of the first ray was present thus indicating a portion of the deformity was forefoot-driven. Twenty-five feet (86% of patients) had a forefoot deformity.

Radiographic evaluation was performed to assess the amount of structural correction obtained. Several radiographic parameters were measured, comparing preoperative and postoperative weightbearing radiographs (Figures 1 to 4). The lateral talo-first metatarsal angle, calcaneal inclination angle (CIA), the antero-posterior talo-calcaneal angle (TCA), and the medial cuneiform height (MCH) were all used to assess the degree of radiographic correction. The talo-first metatarsal angle evaluated the amount of correction obtained with a dorsiflexion first metatarsal osteotomy (Figure 1). The CIA and the antero-posterior TCA were measured to assess the overall cavus foot correction. The MCH was utilized to best show the radiographic change in arch height. The AOFAS ankle hindfoot score (AHS) was utilized preoperatively and postoperatively to assess clinical and functional outcome.

Operative technique

The patients were placed supine on the operative table with a bolster under their ipsilateral hip to allow for exposure to the lateral aspect of the foot and ankle. It was imperative that an Achilles contracture was addressed prior to any other procedure because it allows the surgeon to more accurately assess the residual varus deformity.

Intraoperatively, the Silfverskiold test was repeated. Anecdotally, with anesthesia the patient was more relaxed, thus the examination was more reliable. If the patient had a global gastrocnemius-soleus contracture, a tendo-Achilles lengthening was performed percutaneously using the triple hemisection technique. If an isolated gastrocnemius contracture was present, then an isolated gastrocnemius recession was done using a postero-medial approach.

Table 1: Procedures Performed

<table>
<thead>
<tr>
<th>Procedure</th>
<th># of Feet</th>
<th>% Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral displacement calcaneus osteotomy</td>
<td>29</td>
<td>100%</td>
</tr>
<tr>
<td>Peroneus longus to brevis tendon transfer</td>
<td>25</td>
<td>86%</td>
</tr>
<tr>
<td>Dorsiflexion first metatarsal osteotomy</td>
<td>25</td>
<td>86%</td>
</tr>
<tr>
<td>Percutaneous tendon-achilles lengthening</td>
<td>8</td>
<td>28%</td>
</tr>
<tr>
<td>Gastrocnemius recession</td>
<td>5</td>
<td>17%</td>
</tr>
<tr>
<td>*Peroneal tendon repair</td>
<td>9</td>
<td>31%</td>
</tr>
<tr>
<td>*Ankle ligament reconstruction</td>
<td>5</td>
<td>17%</td>
</tr>
</tbody>
</table>

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Fig. 1: Preoperative lateral view showing the elevated medial cuneiform height, increased calcaneal inclination angle, and an increased talo-first metatarsal angle.

Fig. 2: Preoperative talocalcaneal angle.

Fig. 3: Postoperative radiograph shows a restored talo-first metarsal angle (A), lowered calcaneal inclination angle (B) and medial cuneiform height (C).

Fig. 4: Postoperative talocalcaneal angle.
Residual hindfoot deformity, clinically noted with a positive Coleman block test, was addressed utilizing a lateral displacement calcaneus osteotomy. The lateral displacement calcaneus osteotomy was made in an oblique fashion from lateral to medial and the posterior tuber was then shifted laterally 5 to 10 mm until the hindfoot was in neutral to mild valgus. The osteotomy was fixated with two parallel 6.5 partially threaded cancellous screws. The lateral border of the displaced tuber was smoothed down using a power rasp to avoid a painful prominence and/or sural neuritis.

Following correction of the equinus and residual hindfoot varus deformities, the forefoot examination was performed. If there was no residual forefoot deformity (the first ray reduced to the level of the lesser metatarsal heads), then no further procedures were required. If there was residual deformity of the first ray (the first metatarsal head was plantarflexed to that of the lesser metatarsal heads), a PL to PB was performed.

A curvilinear incision was made beginning 1 cm proximal and posterior to the lateral malleolus. The incision was carried distally to the interval between the peroneal tendons and the lateral aspect of the posterior tuber of the calcaneus. Care was taken to protect the sural nerve during the dissection. Dissection was first carried anteriorly where the PL and PB tendons were identified distal to the superior peroneal retinaculum (SPR). Their sheaths were incised, and the PL tendon was then transferred to the PB tendon in a side to side manner. Care was taken not to disrupt the SPR.

If residual plantarflexion of the first ray was noted following the PL to PB, then a dorsiflexion first metatarsal osteotomy was performed. This was done through a 4 cm dorsal incision beginning just proximal to the first tarsometatarsal joint (TMT) extending distally over the first metatarsal shaft. The extensor hallucis longus (EHL) tendon was protected, and the first TMT joint was identified. Measuring 1cm distal to the first TMT joint, a dorsal wedge osteotomy was performed in the first metatarsal. The first metatarsal was dorsiflexed to the level of the lesser metatarsal heads. A 3.5-mm cortical screw was placed from dorsal-distal to plantar-proximal. Care was taken not to encroach on the first TMT joint.

Lastly, in the presence of ankle instability, an anterolateral curvilinear incision was made for the modified Brostrum procedure. This incision was utilized in addition to the other adjunct incisions. Most importantly, the ligament repair was performed last to avoid disruption of the repair during the other procedures.

Postoperatively, the foot was placed in a bulky Jones compression dressing with a posterior splint in neutral position for 2 weeks. The foot was then placed in a nonweightbearing fiberglass cast for the remaining 6 weeks. Ambulation was permitted 8 weeks following surgery with progression of activities and return to regular shoewear at that point.

RESULTS

Assessment of patient outcome was performed using the AOFAS ankle-hindfoot rating system. Twenty-nine feet, 23 patients, were evaluated and had an average improvement from 45 to 90 points with an average followup of 4.4 years (Figure 5). The Wilcoxon Signed Rank Test was used which was expressed as the median and the range with a p value of 0.00004. Of the 13 patients (14 feet) that presented with a traumatic etiology, the postoperative score was 92. The remaining patients with non-traumatic etiologies had a mean postoperative score of 89. Twenty of the 23 patients were extremely satisfied with their surgery and functional outcome, with near to complete resolution of their preoperative symptoms. All of these patients were able to return to activities of daily living and recreational activities without restrictions. Three patients had continued pain postoperatively and were not completely satisfied with their surgical result, though all stated it was improved subjectively when compared to their preoperative symptoms. However, all patients felt as though their symptoms improved following surgery and no patient felt that their symptoms were worse after operative treatment.

Radiographic parameters were examined as well. There was a significant improvement noted in the talo-first metatarsal angle as it improved from a mean of +9.9 degrees preoperatively to an average postoperative mean of +2.4 degrees. The Wilcoxon Signed Rank Test was used for this parameter and was expressed as the median and the range (Figure 6) (p < 0.00005). In a similar manner, the calcaneal

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**Fig. 5:** The distribution of preoperative and postoperative AOFAS scores among all patients in the study.

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inclination angle (CIA) was measured preoperatively and postoperatively and evaluated using the Wilcoxon Signed Rank Test expressed as the median and the range. The mean preoperative CIA was 26.1 degrees and postoperatively was 22.7 degrees. This resulted in a mean decrease in the CIA of 3.4 degrees ($p < 0.00001$) (Figure 6). The medial cuneiform to floor height was significantly improved as well. The mean medial cuneiform height (MCH) preoperatively was 3.5 cm and the mean postoperative MCH was 3.0 cm giving an average correction of 0.5 cm ($p < 0.00001$) (Figure 6).

Every patient had a lateral displacement calcaneal osteotomy in which the average amount of shift was 7.5 (range, 5 to 10) mm.

To date, using our proposed treatment algorithm, no patient has had recurrence of their subtle cavovarus deformity. There were no delayed unions, nonunions, or malunions noted of the lateral displacement calcaneal osteotomies or dorsiflexion first metatarsal osteotomies. There were three minor surgical complications. Three patients developed superficial wound infections. All of these patients received local wound care and oral antibiotics and went on to heal uneventfully.

Nine patients and ten of 29 feet (34%), experienced pain located over the os calcis screws plantarly after beginning to weightbear. These patients required hardware removal. The hardware was removed at a mean of 11 months postoperatively. The removal of the screws resulted in complete resolution of their symptoms. One patient had screws removed from bilateral heels.

The average time to return to work was 11 weeks. All 23 patients returned to their preoperative employment, or level of activity if retired or still in school. All patients working returned to work initially part-time, working 4 hours per day light duty beginning at 10 weeks, then returned to work full-time without restrictions at 12 weeks.

DISCUSSION

The treatment for the SCF has not been equally described or pursued in the literature when compared to the pes planovalgus deformity. Most likely it is due to the lack of awareness of the subtle deformity. The incidence has not been described in the literature, however it is not as uncommon as we once thought. It has been shown that a persistent cavovarus foot position leads to chronic lateral ankle instability with subsequent ankle arthritis, peroneal tendinopathy, and lateral column overload with recurrent stress fractures along the lateral column. Recognition of this foot type and position is very important in the conservative and surgical management of the SCF. Historically, the foot has been viewed as a tripod. Therefore, when the heel is in a varus position, it causes peroneus longus overuse and further plantarflexes the first ray. Subsequently, the metatarsal declination angle increases, causing increased stress on the forefoot, potentially leading to symptoms such as metatarsalgia of the first ray. In addition, the plantar fascia contracts due to the shortened distance.
between the first metatarsal head and calcaneus. It is unclear as to whether forefoot deformity causes hindfoot varus, or whether the hindfoot varus causes the forefoot deformity. Perhaps in each patient it is different. Either way, the tripod favors the lateral direction in the presence of varus. Therefore, the stress dramatically increases on the lateral side causing lateral sided pathology as previously mentioned. Remembering the tripod stance of the foot, biomechanically it is important to correct the varus deformity before correcting any lateral pathology. If left uncorrected, recurrence of the presenting complaint may be more frequent.24

Few associations have been made connecting lateral foot and ankle pathologies with the SCF.16 The incidence of other lateral foot pathology in the presence of a SCF deformity should be evaluated in future studies. In our study, 48% (14 of 29) patients underwent concomitant lateral sided surgery along with the SCF reconstruction. No failures have been noted to date. The only lateral ankle pathologies operated on were lateral ankle instability and peroneal tendon tears.

Lateral ankle instability is one example of lateral pathology associated with the SCF. Larson and Angermann found a higher frequency of cavus varus feet in patients who had chronic lateral ankle instability compared to patients with normal feet.14 Vienne et al. reported on four patients with idiopathic hindfoot varus that presented with ankle instability that underwent a lateral displacement calcaneus osteotomy.24 All of their patients on initial presentation had an underlying hindfoot varus deformity that was missed prior to their lateral ankle ligament reconstruction that subsequently failed. Colville stated that patients with chronic lateral ankle instability and hindfoot varus alignment require a calcaneus osteotomy in order to avoid a ligament reconstruction failure due to mechanical malalignment.9 Both groups of patients did very well and had complete resolution of their symptoms. If left untreated, ankle instability can lead to ankle deformity and subsequent arthritis.11 Our study included five patients that presented with lateral ankle instability. Of the five patients, all of them had a lateral displacement calcaneus osteotomy, and three had an additional PL to PB tendon transfer and a dorsiflexion first metatarsal osteotomy.

Of the lateral sided foot pathologies listed, generalized lateral column pain seems to be the most common presenting symptom associated with the SCF. The SCF can also be symptomatic in and of itself. Fifteen patients in our study had an isolated SCF foot that presented with generalized lateral column foot pain. The patients failed conservative management due to a residual varus hindfoot that was uncorrectable with orthotics. Surgical correction was their only option. The AOFAS scores in patients with isolated SCF deformity were evaluated and this subset of patients improved dramatically. Therefore, one cannot say that the correction of the lateral ankle pathology (ankle instability or peroneal tendon tears) was the reason for the improved postoperative AOFAS scores.

The SCF is often accompanied by an equinus contracture.2 If an equinus contracture is present, the forefoot cavus may be more pronounced. The peroneus longus tendon is a direct antagonist to the tibialis anterior tendon. As the foot becomes more plantarflexed secondary to the equinus contracture, the peroneus longus overpowers the tibialis anterior, which further plantarflexes the first ray.4,16 The Achilles tendon further enhances the varus stress secondary to the plantarflexed first ray and varus heel alignment which alters the transmission of axial forces through the ankle joint. In our study, 45% (13 of 29 feet) had an triceps surae lengthening. Of the 13 patients, eight had a percutaneous tendo-Achilles lengthening and five patients had a gastrocnemius recession. All but one of these patients had a peroneus longus to brevis tendon transfer and a dorsiflexion first metatarsal osteotomy. This supports the fact that an equinus contracture leads to increased forefoot deformity and the need for forefoot correction.

Whenever possible, osteotomies are preferred over fusions.17,18 An isolated dorsiflexion first metatarsal osteotomy is typically all that is needed to correct the forefoot deformity in the SCF. If the deformity is more significant, then occasionally lesser metatarsal osteotomies are needed as well.21,22 Fusions were not required in our study. All patients were treated with a dorsiflexion first metatarsal osteotomy and a peroneus longus to brevis tendon transfer.

After the combined operative treatment, the overall satisfaction rate was very high. All patients improved postoperatively and were pleased with their result. Pain and stability significantly improved postoperatively. The combined procedures did not impair the range of motion of the hindfoot or ankle. No patients in our series developed severe arthritic changes of the hindfoot or forefoot after an average of 53 months postoperatively.

The radiographic parameters were shown to improve significantly as well (Figure 6). Thus, the authors came to the conclusion that the improvement in deformity correlated with the improvement in patients’ symptoms. Due to the paucity of data on radiographic analysis, we chose these angles based on the pediatric literature for cavusvarus feet in comparison to the normal adult angles of the foot. These are the parameters that need to be evaluated when performing this correction.

One of the weaknesses of the study was the relatively small number of patients. Ideally, we would have liked to have more patients to increase the power of the study. Perhaps as we gain more knowledge of the deformity and more corrections are performed, future studies will have higher patient numbers. Also, the AOFAS scores were assigned preoperatively and used postoperatively. While not validated, they have been accepted in the literature. Half of our study was done with concomitant procedures making it difficult to differentiate the improvement in patient outcomes. However, we did show significance with both the lateral ankle procedures and the isolated SCF reconstructions. Not
only was this treatment effective, but it was a safe way to reconstruct the foot as there were very few complications encountered, and all were minor in nature.

Overall, the treatment algorithm presented to correct SCF foot was both safe and reproducible. The results of this study suggest that combining the proper operative procedures using the treatment algorithm provides good results and relief of symptoms of lateral ankle and foot pathologies associated with the SCF.

REFERENCES