13 Cavovarus foot

13.1 Introduction

The term *cavus* is a descriptor of the shape of the foot that includes a higher-than-average arch. It is part of a continuum of foot shape that includes a low arch and a neutral arch in which the transitions are incompletely defined. The cavus foot is most often defined by Meary’s talo-first-metatarsal angle, as measured on a lateral weight-bearing radiograph. It may also include hindfoot varus and forefoot adduction and complex torsional changes. Neuromuscular problems such as poliomyelitis, stroke, head injury, spinal cord injury, and Charcot Marie-Tooth disease may cause the cavus foot, but it may be idiopathic.

13.2 Anatomy

Anatomy is highly variable in cavus foot. Clinically, it is an abnormal elevation of the medial arch in weight bearing. Biomechanically, cavus may include a varus hindfoot, high calcaneal pitch, high-pitched midfoot (defined by the navicular height), and plantar-flexed and adducted forefoot.

The deformity can be a result of the position of the hindfoot, the midfoot or the forefoot; often it involves all three. The high arch and varus alignment can be from rigid hindfoot anatomy, in the form of abnormal shape and relationship of the talus and calcaneus. It may also be from a flexible hindfoot that is a secondary deformity resulting from a plantar-flexed midfoot and forefoot.

The most distinguishing characteristic of cavus foot is the plantar flexion of the first metatarsal relative to the axis of the talus, a relationship described as Meary’s angle. When cavus foot is defined by this angle, it is present in up to 24% of the population. Something affecting that much of the population is, by definition, not abnormal. In addition, something that common is likely to have variations in its anatomy.
There is a division within cavus that is determined by whether the cavus is driven by forefoot deformity (flexible or secondary cavus) or by a (fixed) hindfoot deformity.

- Forefoot-driven cavus is caused by a relatively fixed plantar location of the first metatarsal head relative to the other metatarsal heads. When the forefoot is on the ground, a plantar-flexed first ray forces the medial border of the midfoot up and into varus, which then drives the hindfoot into varus secondarily. Coleman tested for cavus foot with flexible hindfoot by placing a block beneath the foot but not beneath the first ray. The block allows the first ray to plantar flex without driving the rest of the foot. If the hindfoot corrects in the absence of first ray torque, the foot is considered to be correctable by reducing the plantar flexion of the first ray and/or balancing the dynamic cause (peroneus longus overdrive).

- Conversely, the structure of the hindfoot bones can be the direct cause of the varus and high arch. In some cases, it has only increased pitch angle, is directly attributable to the calcaneus, and has no functional effect on mechanics. Abnormal anatomy of the talus and calcaneus is common in cavus. Talar neck alignment may be in varus or adduction. Unlike pathologic flatfoot, in which there is subluxation of the subtalar joint, the subtalar joint is not subluxated but may have altered shape or axis of rotation (Figures 1a-b).

Figure 1a.
Figure 1b.

Figures 1a-b. Figure 1a shows the talocalcaneal relationship in a neutral right foot, as viewed from the position of the toes. The talar head is superior and medial to the anterior calcaneus. In the cavus foot (Figure 1b), there is less of an angle between the talar and calcaneal axes. The talar head and its articulation with the navicular are nearly directly above the calcaneal articulation with the cuboid. This imposes a varus, or inverted, position on the midfoot.

The balance of muscle tendon strength and timing also plays a role in pes cavus. In adults with post-stroke deformity, excessive tension in the tibialis anterior and tibialis posterior is common. The posterior tibial tendon pulls the foot — by way of the tarso metatarsal joints — into adduction and plantar flexion, while the tibialis anterior pulls the medial border of the foot cephalad.

13.3 Biomechanics

The structure and dynamics of cavus cause clinical problems in several areas:

- Varus of the hindfoot, either static or dynamic, leads to recurrent sprains and abnormal loading of the ankle.
- Varus and altered pitch of the midfoot leads to overloading of the lateral rays, with stress fracture of the navicular and metatarsals.
- Uneven forefoot loads due to variable metatarsal alignment have varied effects on metatarsals and stability during heel rise.
- Hyperplantar flexion of the medial foot causes lateral overload and pain under the first metatarsal and dynamic hindfoot varus, with adduction thrust in heel rise.

The mechanical disorder, in its most simple form, is derived from misalignment of the talocalcaneal relationship. As the talocalcaneal angle narrows, the position of the talar head becomes more cephalad to the anterior process of the calcaneus, rather than medial to it. The navicular is then cephalad to the cuboid, limiting the motion of the transverse tarsal joint.
13.4 Clinical Presentation

The clinical examination should begin with an evaluation of the standing position of the foot. The patient’s knees, leg, and foot need to be visible to assess rotation and weight-bearing axis. Tibia vara requires a compensatory hindfoot eversion if the foot is to meet the ground evenly. Conversely, patients with genu valgum (or patients with large circumference thighs) need the hindfoot to be inverted to meet the ground.

Any of these can artificially alter the alignment and radiographs of the foot. View the foot from the front and the side and from behind. Then examine the patient walking, watching him/her walking away from and towards you. Observe the part of the foot that strikes the ground, and note when heel rise and toe off occur.

If hindfoot varus is present, a Coleman block test is appropriate, as mentioned above. To do this, the patient should face away from the examiner so that he/she can be viewed from behind. A block is placed under the foot, but not under the first ray. If the hindfoot varus corrects on the block, it is a flexible varus or a forefoot-driven varus.

Figure 2. A Coleman block test. A foot rests fully on the block with the hindfoot in mild varus (left). The foot is on the block to test for flexible cavus, with the first metatarsal off the block to allow it to plantar-flex (middle). The foot from behind, after the deforming force of the first ray is eliminated by the block; the hindfoot is now in valgus (right).

With the patient seated, examine the motor strength of the extrinsic muscles, the axis of rotation, and the plantar callous pattern. The plantar flexors, the dorsi-flexors, the invertors, and the everters should be graded for strength. A distinction between the peroneus brevis (primary evertor) and the peroneus longus (primary plantarflexion of first metatarsal and evertor) is important. The peroneus longus is likely to be stronger in Charcot-Marie-Tooth and sometimes in idiopathic deformity. Compare the axis of the hindfoot with regard to inversion and eversion to distinguish static from dynamic varus. Patients with subtle cavus may appear to be neutrally aligned when standing. But that position may represent maximum eversion. The axis will show significant inversion with no eversion beyond the neutral standing position.

Cavus foot may present in a variety of ways. Recurrent ankle sprain is chief among the complaints for subtle and mild forms of the deformity. With moderate and severe forms, patients may complain of recurrent stress fractures of the lateral border, instability in gait, difficulty in shoe wear, or pain and callous formation along the lateral border of the foot.

13.5 Pathogenesis
The majority of cavus foot is idiopathic. Charcot-Marie-Tooth disease is a common familial cause of a specific type of cavus, characterized by a progressive muscle weakness involving the extrinsic dorsi-flexors and peroneus brevis, but not the peroneus longus and tibialis posterior. As a result of this imbalance, the foot is adducted and the first metatarsal is excessively plantar-flexed. When the motor imbalance occurs during childhood, there may be fixed bony deformity.

13.6 Imaging

All imaging of the foot should be done with the foot in a functional position, ie, weight-bearing. A non-weight-bearing radiograph of the foot has very limited utility. Even basic relationships cannot be identified if the foot is dependant.

Basic imaging includes a weight-bearing AP, lateral, oblique, and Harris axial views. Computed tomography (CT) scan can be useful in a complex deformity, especially in pre-operative planning. In particular, coronal plane reconstructions are useful to assess the axis of the subtalar joint. Sagittal reconstruction is ideally suited to define the angle of the first metatarsal relative to the talus and to the weight-bearing surface. As in radiographs, CT should be done with the foot in a functional position.

13.7 Conservative Treatment

Conservative treatment is directed at the symptoms and deformity. Bracing comes in many forms. An ankle lacer is used for instability and recurrent sprains. An in-shoe orthosis can be used to mitigate the problem of a plantar flexed first metatarsal. The lateral border of the foot is raised and the medial border accommodated.

13.8 Operative Treatment

13.8.1 Flexible and Dynamic Cavovarus

No bone deformity exists in simple dynamic cavus deformity, such as in a stroke or head injury, only muscle imbalance and soft tissue contracture. This may be due to paralysis or spasticity.

The treatment goal is to re-establish the balance between plantar flexion and dorsi-flexion and between inversion and eversion. By correcting the motor imbalance, usually with a transfer of the posterior tibial tendon, the soft tissue contracture will correct itself after a few months of weight-bearing. Similarly, when the peroneus longus is pulling too strongly on the first ray, transferring it into the peroneus brevis may rectify the deformity without any bony work.

13.8.2 Mild or Subtle Cavovarus

In the mild cavovarus, the hindfoot is in inverted or varus position. At heel strike, the foot is forced inward and stresses the lateral ligaments and peroneal tendons. Moving the point of contact of the calcaneus away from the midline improves the mechanics.
This can be done with a lateral closing wedge, a lateral displacement, or a Z osteotomy, as described by Malerba. When the hindfoot varus is secondary, correcting the primary deformity — plantar flexion of the first metatarsal — is usually successful. This may be accomplished by a skillfully created orthosis that allows the metatarsal room to plantar flex. It may also be accomplished by surgical reduction of the position of the metatarsal. The reduction may be performed through the tarsometatarsal joint or by a closing wedge in the proximal metaphysis.

Figure 3a.

Figure 3b.

**Figures 3a-b.** Lateral radiograph of a patient with moderate cavovarus (Figure 3a, top). The forefoot cavus is caused by hyper-plantarflexion of the first metatarsal. The hindfoot is in varus, with both a fixed and flexible component. Figure 3b shows the same patient after transfer of the peroneus longus to the peroneus brevis and dorsi-flexion of the first metatarsal combined with a lateralizing osteotomy of the calcaneus.

### 13.8.3 Fixed Cavovarus

When the deformity is more severe, correction usually requires osteotomy and arthrodesis. The goal of treatment is to create a plantigrade foot — one that meets the ground evenly. A plantigrade foot is often not the same as a neutrally aligned foot measured by radiograph. Intrinsic bony deformity is often present. Even when there is clinical correction, traditional radiographic measures such as Meary’s angle might not be corrected because of the altered shape of the bones.
These are the before-and-after radiographs of a patient with severe deformity. The patient walks only on his 4th and 5th metatarsals and has had recurrent sprains and stress fractures and ulceration. Figure 4a shows an AP radiograph of a severe cavus foot. Note the twisting of the foot, the complete overlap of the talus on the calcaneus, and the hypertrophy of the 4th and 5th metatarsals. Figure 4b shows the preoperative lateral radiograph. Similarly, the traditional radiographic lines are distorted. The lateral border of the foot is on the ground, but the medial border is up in space. Figure 4c shows a transverse plane CT. The severity of the deformity is reflected in the different alignment of the metatarsal and the calcaneus. Figures 4d and 4e show the foot after correction. Surgical intervention included soft tissue balancing (tendo-Achilles lengthening, transfer of the peroneus longus to the peroneus brevis with release of the plantar fascia), a triple arthrodesis with de-rotation of the talocalcaneal relationship, shortening of the lateral column, and a supramalleolar osteotomy. Although the anatomy is not normal, the foot now meets the floor evenly.

13.9 Controversy

Too little is known about treatment to have real controversy. Most physicians recognize the uncertainty of treatment and classification. There is little Level I evidence in the literature regarding cavus foot. In most cases, cavus foot is idiopathic. The severity of the deformity and the type of deformity determine what is needed. Many people go through life with a cavus foot and do not require treatment. Athletes playing sports that require pivoting may get symptoms from subtle cavus due to its inability to resist inversion.
13.10 References


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