CHAPTER 29

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The Foot

SURGICAL PROCEDURE INDEX

PRINCIPLES OF ASSESSMENT AND MANAGEMENT

The assessment and management of foot deformities and malformations in children and adolescents are based on principles, not techniques, due to the complexity and variety of the pathologic conditions and the complexity of the foot itself. An orthopaedist managing these conditions must have

1. An appreciation of the age-related physiologic variations in the shape of the foot
2. An understanding of the natural history of each variation and deformity
3. An appreciation of the effect of a chosen intervention on growth and development of the foot as well as the effect of growth and development on a chosen intervention
4. A thorough and working knowledge of the most unique "joint" in the human body, the subtalar joint complex, which is a combination of the talocalcaneal (subtalar) joint, plus the talonavicular and calcaneocuboid joints (transtarsal or Chopart joints)
5. The ability to obtain, and the commitment to evaluate, only weight-bearing or simulated weight-bearing radiographs
6. A dedication to preserving joint motion by utilizing soft-tissue releases and osteotomies instead of arthrodeses
7. A complete understanding of the phrase: "The foot is not a joint" (1)

The first principle to embrace is that "the foot is not a joint" (1), although it is often discussed as if it were another joint in the body, such as the hip, knee, shoulder, or elbow. It is a unique part of the musculoskeletal system comprised of 26 bones with countless articulations. It is extremely unusual for only one portion of the foot or only one joint of the foot or ankle to be congenitally or developmentally deformed. Its many joints are usually deformed or malaligned in rotationally opposite directions, "as if the foot was wrung out like a towel" (1). As examples, note that there is inversion of the subtalar joint and pronation of the forefoot on the hindfoot in a cavus foot and eversion of the subtalar joint and supination of the forefoot on the hindfoot in a flatfoot. And one cannot ignore the adjacent ankle joint as a potential site of additional deformity. The orthopaedist must identify all deformities preoperatively, if possible, and have a treatment plan that addresses each one individually and, usually, concurrently. There is no justification for creating a compensating deformity or incompletely correcting a deformity in order to avoid an additional procedure, particularly one that can usually be carried out during the same operative session.

The child's foot often looks different than that of an adult. In fact, there is so much variation in shape that the foot of one child can look quite different than that of another child. Age-related physiologic variations of the child's foot, such as flexible metatarsus adductus, positional calcaneovalgus, and flexible flatfoot, must be identified as normal, but not average, shapes in order to avoid inappropriate and potentially harmful interventions. This feature of physiologic variation is also seen in the long bones of the child's lower extremities in conditions such as genu varum, genu valgum, femoral anteversion, and tibial torsion (2, 3). There are age-related average shapes and normal ranges of shapes. The natural history is for spontaneous change

from the normal shapes of the child to those of the adult through normal growth and development. Externally applied forces cannot modify these physiologic shape variations of the long bones. And the long-term health consequences of persistent physiologic variations of the long bones have yet to be proven.

An understanding of the natural history of each foot shape variation and deformity is of paramount importance. Eighty-five to ninety-five percent of feet with metatarsus adductus correct spontaneously with little if any long-term disability even with mild to moderate residual deformity (4–6). Essentially all calcaneovalgus "deformities" correct spontaneously (7). Flexible flatfoot is almost ubiquitous at birth and is present in approximately 23% of adults, most of whom are asymptomatic (8). The height of the longitudinal arch increases spontaneously during the first decade of life in most children (9, 10). There is a wide range of normal arch heights at all ages (particularly in young children) (9, 10). Most feet with accessory naviculars (11, 12) and approximately 75% of feet with tarsal coalitions (13) are asymptomatic and do not need treatment, whereas one can expect the onset of symptoms from the rest to develop in late childhood or early adolescence. Conversely, all congenital clubfoot and congenital vertical talus deformities persist and cause disability unless treated.

The natural history of an intervention must also be fully appreciated and considered in relation to the natural history of the deformity or condition. Unfortunately, although there are few good natural history studies on deformities and variations of the child's foot, there are fewer good long-term follow-up studies on operative intervention for these conditions. It seems most reasonable that the default should logically go to the natural history of the condition.

Unique challenges facing those who manage foot deformities in children are the consideration of the effect of a chosen intervention on growth and development of the foot as well as the effect of growth and development on a chosen intervention. Early reconstruction of foot deformities in children normalizes the stresses on the bones and joints to allow more normal development. Delay results in the development or persistence of abnormalities in the shapes of the bones and joints that makes reconstruction more difficult. Furthermore, procedures that affect or potentially affect growth in a positive or in an adverse way must be used judiciously. Conversely, one must consider how the early positive result of an intervention may change as the child grows. Cavus foot deformity is most commonly a manifestation of muscle imbalance from an underlying neuromuscular disorder. In some cases, the disorder is static (cerebral palsy) or can be stabilized but may recur (tethered cord in myelomeningocele). In others, the disorder is progressive and the rate and extent of neuromuscular deterioration may not be predictable (Charcot-Marie-Tooth [CMT]). It is difficult to establish precise muscle balance in any cavus foot, and it is well known that growth as well as progressive neurologic deterioration can undo an excellent early result of intervention. The child and family must be made aware that there are no panaceas and more surgery may be needed in the future. The surgeon must also remember this admonition, avoid burning bridges, and keep reasonable options available for future surgeries.

Although most congenital clubfeet and many congenital vertical talus deformities respond to nonsurgical or minimally invasive management, some undergo operative releases in the first year of life when the foot is 8 to 9 cm in length. The hope is that the correction of these deformities, located at the foundation of the human body, will be maintained through 14 to 16 years of growth and a doubling to tripling in the length of the foot. Problems, including recurrence, overcorrection, pain, and stiffness, as well as plans for their management, should be anticipated.

There is no other "joint" in the human body with the unique anatomy and three-dimensional motion of the subtalar joint complex. This complex consists of two components, the talocalcaneal or subtalar joint, plus the talonavicular and calcaneocuboid or transtarsal joints. These four bones, several important ligaments, and multiple joint capsules function together as a unit. Terms that apply to sagittal and coronal plane alignment and motions, such as varus, valgus, abduction, adduction, flexion, extension, supination, and pronation, do not necessarily apply to the subtalar complex because its axis of motion is in neither the sagittal nor coronal plane. Inversion and eversion are terms that, in my opinion, define the motions of this complex, but they need to be better defined and understood by all that use them.

Almost 200 years ago, Scarpa (14) saw similarities between the subtalar joint complex and the hip joint. He compared the femoral head to the talar head and the pelvic acetabulum to his so-called acetabulum pedis (AP). The latter is a cup-like structure made up of the navicular, the spring ligament, and the anterior end of the calcaneus and its facets. Although it is not a perfect comparison, I believe that the two anatomic areas share certain features that make the comparison both valid and worthwhile. The hip, a pure ball-and-socket joint with a central rotation point, is comprised of two bones, one intra-articular ligament, and a joint capsule. The subtalar joint is not an independent ball-and-socket joint, though the combined motions of the subtalar joint and the immediately adjacent ankle joint give the impression of a ball-and-socket joint. In fact, the subtalar joint has an axis of motion that is in an oblique plane that is not frontal, sagittal, or coronal, thus creating motions that are best described with the unique terms inversion and eversion. The stable structure in the hip joint is the acetabulum (the socket), while the stable structure in the subtalar joint complex is the talus (the ball). Inversion is comprised of plantar flexion, supination, and internal rotation of the AP around the head of the talus (15). Eversion is a combination of dorsiflexion, pronation, and external rotation of the AP around the talar head. The static position of inversion of the subtalar joint is called hindfoot varus and is found in cavovarus feet and clubfeet. Hindfoot valgus is the static position of the everted subtalar joint and is seen in flatfeet and skewfeet. It is essential that all who manage foot deformities have a thorough and working knowledge of this most unique joint complex.

It is important to evaluate deformity both clinically and radiographically with the foot in the weight-bearing position. That is the baseline against which the corrected foot will be judged. A flexible flatfoot appears to have an arch, and a normal foot may appear to have a cavus or clubfoot deformity when dangling in the air.

Deformities of the child's foot should be corrected by means of soft-tissue releases to align the joints and osteotomies to correct residual deformities. Arthrodesis should be reserved for the older child, adolescent, or adult with established degenerative arthrosis of a joint or with such severe deformity that correction cannot be achieved with soft-tissue releases and osteotomies. Long-term follow-up studies have demonstrated that arthrodesis of even the small joints of the child's foot should be avoided because of the risk of developing degenerative arthrosis at the adjacent unfused joints (16–18). Arthrodesis of the subtalar joint, particularly triple arthrodesis, leads to stress transfer to the ankle (19–27). The development of degenerative arthrosis at that important joint is a potentially disastrous outcome.

Correction of foot deformities must be combined with balancing of muscle forces in order to help prevent recurrence. Balancing muscle forces in a mobile foot is much more challenging than in one that has undergone arthrodesis. This challenge must be accepted.

There is a great need for more natural history studies on deformities and variations in the shape of the child's foot, as well as long-term follow-up studies on the interventions used to treat these conditions. The message must be to exhibit caution with interventions until it is clear that the treatment is not potentially worse than the condition.

All of these principles apply to the congenital and developmental deformities and other conditions that will now be presented individually and alphabetically, not in order of importance, incidence, or complexity.

CONGENITAL DEFORMITIES AND MALFORMATIONS OF THE FOOT

Accessory Navicular

Definition. Accessory navicular is a term applied to a plantar-medial enlargement of the tarsal navicular beyond its normal size. It may consist of a separate ossicle connected to the main body of the navicular by fibrous tissue or cartilage, or it may be a solid bony enlargement of the bone. Other terms that have been used to describe the separate ossicle are the os tibiale externum, the navicular secundum, or the prehallux (Fig. 29-1).

Epidemiology. The accessory tarsal navicular is the most common accessory bone in the foot, occurring in between 4% and 14% of the population (8, 11, 28). It is frequently bilateral and occurs more commonly in females. Geist (28) recognized a higher incidence of accessory naviculars in young patients evaluated radiologically than in cadaver studies.

Etiology. McKusick (29) believed that the accessory navicular was inherited as an autosomal dominant trait. Geist (28) reported that there are three types: (a) a sesamoid bone within the substance of the posterior tibial tendon, (b) a separate bone with a true articulation (synovial joint) with the navicular, and (c) an ossicle with a synchondrosis to the main navicular.

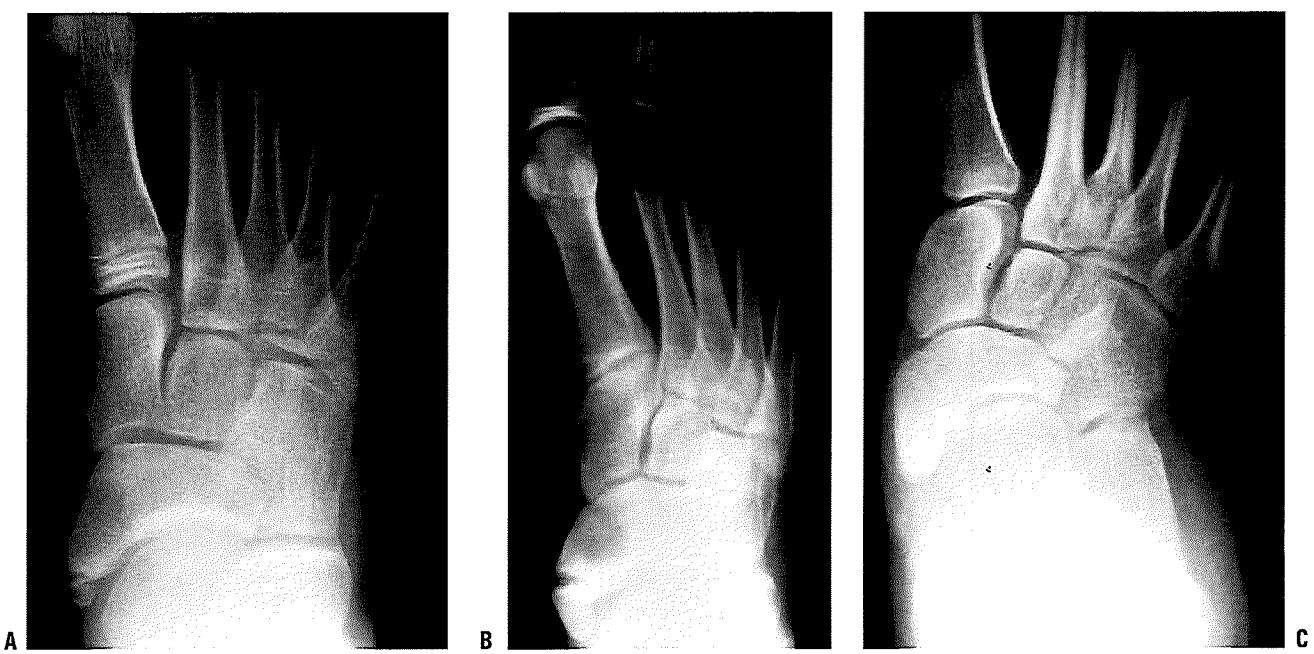

FIGURE 29-1. Accessory navicular. **A:** Type I. **B:** Type II. **C:** Type III. (From the private collection of Vincent S. Mosca, MD.)

Clinical Features. Pain, tenderness, and callus formation may develop over the firm prominence distal to the talar head on the plantar-medial aspect of the midfoot starting in adolescence. There may be a coexistent flexible flatfoot (30–33), but there is not conclusive evidence that there is a cause-and-effect relationship between the two conditions as was historically believed (12). The prominence of an accessory navicular is in close proximity to the head of the talus, which is prominent in a flexible flatfoot. Inverting and everting the subtalar joint with one's thumb on the prominence is helpful for differentiating the two. If the prominence moves, it is an accessory navicular. If it remains stationary, it is the head of the talus.

Individuals with an accessory navicular may present for evaluation because of the prominence, but more commonly they present because of pain at the site. The typical patient is an active adolescent girl with a history of minor trauma who presents with pain, callus formation, tenderness, redness, and, occasionally, swelling over the bony prominence. Maximum tenderness is elicited by upward pressure under the prominence. Because of the frequency of this anatomic variation in the general population, one must be careful not to assume that a radiographic finding of an accessory navicular is the cause of the foot pain without thorough evaluation (34).

Radiographic Features. An accessory navicular can usually be seen on standing AP and lateral radiographs, but a lateral oblique view (opposite to the standard medial oblique view that is generally obtained) may be necessary for identification. There are three types of accessory naviculars (35) (Fig. 29-1). Type I is a rarely symptomatic, small pea-sized sesamoid bone located in the center of the most distal portion of the tibialis posterior tendon. Type II, the most frequently symptomatic type, is a bullet-shaped ossicle joined to the tuberosity of the navicular by a syndesmosis or synchondrosis. Type III is a large, horn-shaped navicular that probably results from fusion of a type II with the body of the navicular over time.

Pathoanatomy. There is proliferating vascular mesenchymal tissue, cartilage proliferation, and osteoblastic and osteoclastic activity in the tissue between the ossicle and the main body of the navicular in painful type II accessory naviculars (35). These histologic findings are consistent with healing microfractures, substantiating the opinion that pain at this site is related to chronic, repetitive stress. There are at least two other possible sources of pain. One is pain from pressure on the skin overlying the bony prominence. The other is tendinitis in the tibialis posterior, the tendon in which the ossicle resides. Any or all of these sources may exist in the same painful foot.

Natural History. Accessory naviculars are for the most part asymptomatic. If symptoms do occur, a period of protection from stress and injury generally returns the patient to the asymptomatic state (32).

Treatment. Nonsurgical treatment of a painful accessory navicular often relieves symptoms. Pain is due to inflammation of skin, tendon, and/or cartilage. Strenuous, pain-exacerbating activities should be curtailed. Shoes should be examined to assess the site of contact with the bony prominence. Shoes can be stretched. Alternatively, shoes that provide softness or no contact in that area should be purchased. An over-the-counter orthosis can be used to elevate the arch and change the site of contact between the prominence and the shoe. Orthoses may also decrease the stress on the tibialis posterior tendon and relieve the tendinitis. If pain is acute and persistent, the foot can be immobilized in a below-knee cast for 4 to 6 weeks.

Surgery is indicated if prolonged attempts at conservative management fail to relieve symptoms. The Kidner procedure combines removal of the ossicle with advancement of the tibialis posterior tendon (30, 31). This was based on Kidner's belief that the height of the longitudinal arch was related to its muscular support, a theory that has since been disproved (36, 37). Several studies have shown good to excellent results in 90% or more of cases by simple excision of the ossicle and shaving of the medial enlargement of the main body of the navicular through a tendon splitting approach (12, 28, 37–41). The incision should be placed slightly dorsomedially to avoid creating a painful scar.

Cavus Foot Deformity

Definition. Cavus refers to a fixed equinus (plantar-flexion) deformity of the forefoot in relation to the hindfoot resulting in an abnormally high arch. The high arch may be along the medial border of the foot or across the entire midfoot. The heel may be in a neutral, varus, valgus, calcaneus (dorsiflexed), or equinus position. There may be an accompanying clawing of the toes. There are two common patterns of cavus deformity (42). Cavovarus, or anterior cavus, is the most common pattern. It consists of pronation of the forefoot on the hindfoot and inversion (or varus) deformity of the hindfoot, rotationally opposite direction deformities that give the impression that the foot has been "wrung out like a towel" (1). Calcaneocavus, or posterior cavus, occurs less frequently. It is also known as transtarsal cavus, because the entire arch is elevated from the ground from medial to lateral.

Etiology. Cavus is a manifestation of a neuromuscular disorder with muscle imbalance, until proven otherwise. At least two-thirds of patients who seek treatment for a painful high arch will have an underlying neurologic problem, and over half of these will have Charcot-Marie-Tooth (CMT) disease (43, 44). There are many other causes of cavus foot deformity. It is helpful to consider those that cause unilateral versus bilateral deformity when developing a differential diagnosis for your patient (Table 29-1). The number of cases termed "idiopathic" cavus foot continues to decrease as diagnostic methods improve.

Calcaneocavus deformity is seen almost exclusively in children with myelomeningocele and poliomyelitis due to a specific pattern of muscle imbalance seen in many of these children.

Epidemiology. The incidence of cavus is variable and is related to the prevalence of neuromuscular disorders at any point in time.