Tarsal Coalitions

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KEYWORDS

• Tarsal coalition • Cause • Diagnosis • Management

A tarsal coalition is an aberrant union between 2 or more tarsal bones and can be classified as osseous (synostosis) or nonosseous (cartilaginous [synchondrosis] or fibrous [syndesmosis]). This union may be complete or partial and the joints in the hindfoot and midfoot are most commonly affected. The resulting abnormal articulation presents as a noncorrectable flat foot, usually during adolescence, leading to accelerated degeneration within adjacent joints. An understanding of the condition and presenting symptoms enable the clinician to correctly diagnose and initiate appropriate treatment. This review discusses the evidence-based literature on the cause, diagnosis, and current management of tarsal coalition.

HISTORICAL REVIEW

Tarsal coalition is a phenomenon that has been known for many years. Archeological specimens dating from 900 to 1000 AD have confirmed their presence in the ruins of a Mayan temple in Guatemala[1] and a pre-Columbian Indian skeleton in Ohio.[2] More recently in 2005, Silva[3] presented 2 cases of nonosseous calcaneonavicular coalition in older specimens recovered from Portuguese burial sites dating from between the late Neolithic and early Bronze Age, circa 3600 to 2000 BC.

The first description of a tarsal coalition is attributed to Buffon[4] in 1769. This French naturalist attempted the monumental task of encapsulating the sum of human knowledge about the natural world in a single book, *Histoire naturelle, générale et particulière.* However, Cruveilhier[5] is credited with performing the first anatomic description of a calcaneonavicular coalition in 1829. This was later followed by descriptions of talocalcaneal and talonavicular coalitions by Zuckerlandl[6] and Anderson.[7] In 1880, Holl[8] tentatively suggested a relationship between tarsal coalition and peroneal spasm. This association was later supported by work from Slomann,[9] Badgley,[10] and Harris and Beath.[11]

The first radiologic depiction of a tarsal coalition took place in 1898 by Kirmisson,[12] only 3 years after Roentgen discovered x-rays. In 1921, Slomann[9] demonstrated the

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usefulness of a 45° lateral oblique radiograph in identifying calcaneonavicular coalitions. This enabled him to explain the association between hindfoot rigidity, marked flat foot, and tarsal coalition. Badgley[10] demonstrated this in 1927 by successfully resecting 2 osseous calcaneonavicular coalitions. In 1934, Korvin[13] first described the 45° axial or ski-jump view of the heel to visualize talocalcaneal coalitions. This technique was later popularized by Harris and Beath[11] in their classic paper from 1948, in which they published a series of peroneal spastic flatfoot in association with talocalcaneal coalition. The term peroneal spastic flatfoot is no longer used, as it describes only one of several clinical presentations of tarsal coalition and the condition may exist in the absence of a coalition.[14,15]

Other tarsal coalitions have been described but are less common. Calcaneocuboid coalition was first recognized by Holland[16] in 1918. Waugh[17] and Lusby[18] first reported cubonavicular and naviculocuneiform coalitions, respectively. Multiple coalitions involving several tarsal bones have also been reported.[19,20]

INCIDENCE

The documented overall incidence of tarsal coalition is 1% or less.[21–23] However, it is commonly agreed that the true incidence is much higher as coalitions go undiagnosed in the asymptomatic and nonosseous subtypes.[24–26] Solomon and colleagues[27] studied 100 cadaveric feet using computed tomography (CT) scanning and subsequent dissection, and concluded that the incidence of talocalcaneal coalition was as high as 12.7%. The joints most commonly affected are talocalcaneal and calcaneonavicular, which account for approximately 90% of cases. Stormont and Peterson[21] performed a review of 314 cases of tarsal coalition from 11 studies, revealing the proportion of talocalcaneal coalition to be 48.1%, calcaneonavicular was 43.6%, both talonavicular and calcaneocuboid were 1.3% each, and an unspecified group made up the remaining 5.7%. Of the 2 most common types, calcaneonavicular coalitions tend to be overwhelmingly nonosseous, whereas talonavicular coalitions have a more even distribution of the 3 histologic subtypes.[25]

The incidence of bilateral tarsal coalition varies in the literature but is generally believed to be 50% or more.[28–30] Stormont and Peterson[21] found 68% of calcaneonavicular coalitions were bilateral. Leonard[31] reported a bilateral rate of 80% in 31 cases of tarsal coalition, most of which were also calcaneonavicular. He also found equal sex distribution but subsequent studies indicate a slight male preponderance.[21,30] Although no racial or geographic variation in incidence of calcaneonavicular or talocalcaneal coalitions have been demonstrated, a relatively large number of naviculocuneiform coalitions have been reported from Japan.[32–34] Furthermore, Burnett and Case[35] analyzed skeletal remains from African and European ancestry. They found naviculocuneiform coalitions were statistically more prevalent in the South African Bantu population than in European ancestry. This suggests the possibility of population variation with certain types of tarsal coalition.

ETIOLOGY

Tarsal coalitions can be congenital or acquired. Acquired coalitions may result from trauma, surgery, arthritis, infection and neoplasia.[15,36] They are rare and more prevalent in the adult population. Congenital tarsal coalitions are far more common and usually seen in the adolescent group. They originate from the failure of differentiation and segmentation of embryonic mesenchyme, inherited in an autosomal dominant pattern.[31,37–40]

In 1896, Pfitzner[41] proposed that tarsal coalitions were caused by the incorporation of accessory ossicles into the major adjacent tarsal bones. His primary evidence was that the accessory ossicles appear at the sites where many tarsal coalitions occur, such as the os sustentaculum proprium in the middle facet and the os calcaneus secundarius in the calcaneonavicular space. This idea received support from the work of Slomann,[9] Badgely,[10] and Chambers and colleagues.[42]

Harris[37] demonstrated the presence of a talocalcaneal coalition in the fetus in 1955 and confirmed their embryologic origin. This effectively eliminated Pfitzner's theory, as accessory ossicles could not have yet developed in the fetus. Earlier in 1890, Leboucq[38] suggested that tarsal coalitions resulted from the failure of differentiation and segmentation of primitive embryonic mesenchyme. The findings by Harris corroborated this and subsequent work by other investigators also support a mesenchymal defect as the cause.[22,28,39] Furthermore, there is strong evidence in the literature to suggest that an inherited defect in genetic coding is responsible for the development of tarsal coalition.[29–31,40] The inheritance pattern is believed to be autosomal dominant with high penetrance. Wray and Herndon[40] demonstrated a calcaneonavicular coalition in 3 successive generations of males with unaffected mother and sister. Based on Mendelian patterns of inheritance, they concluded that a specific gene mutation, behaving in an autosomal dominant manner, was responsible for calcaneonavicular coalitions. Leonard[31] reviewed 98 first-degree relatives of 31 index patients with confirmed tarsal coalitions. He found 33% of the parents and 46% of the siblings had radiographic evidence of tarsal coalition, all of which were asymptomatic. He concluded that tarsal coalition was a unifactorial disorder of autosomal dominant inheritance. He also suggested the condition had near full penetrance as he demonstrated a high rate of bilateral coalitions in parents (83%) and siblings (85%), similar to that found in the index group (80%).

Plotkin[43] presented a case of calcaneonavicular coalition in monozygotic twins and suggested that the inheritance of tarsal coalition is more complicated than a simple Mendelian pattern. He proposed that it is likely to be a defect in a general joint development gene as part of a complex polygenic system responsible for overall limb development. This would account for the findings in Leonard's study, which showed different sites of coalition in the relatives than those found in the index group. Syndromes that may present with tarsal coalition include carpal coalition, symphalangism, arthrogryposis, fibula hemimelia, Apert syndrome, and Nievergelt-Pearlman syndrome.[15,30,31,36] The relative contribution of an environmental congenital defect, an error in mesenchymal differentiation, or an inherited genetic defect that leads to the formation of tarsal coalition is still uncertain. The fact that a genetic component exists should alert the clinician to asymptomatic siblings and close relatives with the condition.

PATHOPHYSIOLOGY

The normal subtalar joint undergoes rotational and gliding movements during stance and walking. The axis of the joint is 42° from the horizontal plane and 16° medial to a line extending from the center of the calcaneus to the midpoint between the first and second metatarsals.[44] During the stance phase, the subtalar joint rotates from 4° of external to 6° of internal rotation, which accommodates the external rotation of the tibia.[45] The lack of internal rotation in the subtalar joint from a coalition causes the calcaneocuboid and talonavicular joints to compensate. This causes a planovalgus deformity with flattening of the longitudinal arch and forefoot abduction. Adaptive shortening and spasm of the peroneal tendons produces the so-called peroneal spastic flatfoot. Prolonged restriction of subtalar motion eventually leads to arthrosis of the posterior facet, as well as the midtarsal and ankle joints.

During foot dorsiflexion, the gliding motion of the subtalar joint is recruited.[46] The calcaneus glides forward on the talus until it is restricted by capsular ligaments. At the end of dorsiflexion the talonavicular and calcaneocuboid joints glide superiorly. A reduction in subtalar glide as a result of the presence of a coalition leads to compensatory hingelike movement at the talonavicular joint. The navicular overrides the talar head at maximum dorsiflexion, repeatedly elevating the dorsal capsule and creating a traction spur.[15,47] This is believed to be the mechanism behind talar beaking seen on lateral radiographs (**Fig. 1**).

PRESENTATION

Patients with tarsal coalition usually present with symptoms during the second decade of life. Those younger than 8 years may present with foot fatigue while the coalition remains fibrocartilaginous. Symptoms are more likely to manifest as the coalition progressively ossifies, altering the kinematics of the joint.[15,23,48] The onset of symptoms can be variable as different types of coalition ossify at different stages. The relatively uncommon talonavicular coalition ossifies earliest around 3 to 5 years of age, calcaneonavicular coalitions ossify between 8 and 12 years, and talocalcaneal coalitions usually between 12 and 16 years.[49,50]

Pain is the most common presenting symptom, followed by valgus deformity and subtalar stiffness. The primary source of pain may be attributed to ligament strain, peroneal spasm, sinus tarsi syndrome, or subtalar arthrosis. Microfractures and histologic signs of normal bone remodeling have been identified at the coalition-bone interface and are likely to be the pain generators via periosteal nerve fibers.[51] The absence of nerve tissue in histologic analysis of resected nonosseus coalitions argues against the abnormal coalition tissue acting as the primary pain generator.[51] Pain can be localized to the sinus tarsi in a calcaneonavicular coalition or the medial subtalar joint in a talocalcaneal coalition. However, it is often diffuse and insidious, exacerbated by strenuous activity or following an ankle sprain that is slow to resolve. An episode of trauma may act as the trigger to a previously dormant coalition and may be the case in patients presenting in adulthood. A history of recurrent sprains should alert the clinician to the possible diagnosis of tarsal coalition. Variability in the level of pain, stiffness, and deformity on presentation reflects the degree of restriction in

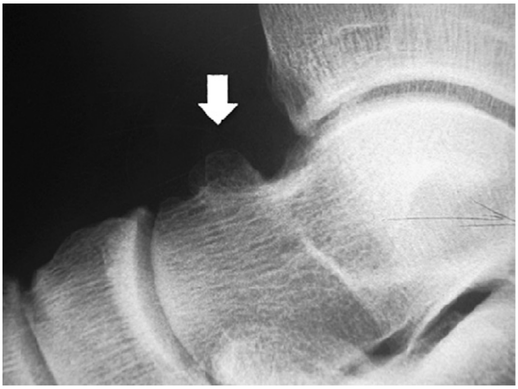

Fig. 1. Talar beaking on lateral radiograph.

subtalar motion from different types of coalition. Talocalcaneal coalitions within the middle facet create the greatest loss of subtalar motion and the most obvious valgus deformity.[15,30,52]

Physical examination can reveal a rigid valgus hindfoot with forefoot abduction, although a neutral or varus hindfoot does not exclude the diagnosis.[53] Loss of subtalar motion may be determined by a reverse Coleman block test: the patient's foot is supinated by raising the medial border of the forefoot using a block and keeping the heel and lateral border in contact with the floor. If the heel valgus remains uncorrected, the hindfoot is no longer mobile. In addition, a decrease in the normal external rotation of the tibia is observed, reflected by absent outward rotation of the patella. A simpler way to assess restricted subtalar motion is to ask the patient to walk on the outer borders of their feet, which may be difficult or uncomfortable to perform. A single-heel raise test will reveal the absence of normal heel varus. Tenderness may be elicited over the sinus tarsi or the middle facet, just distal to the medial malleolus. A reduction in passive eversion and inversion are commonly seen in all types of tarsal coalition. Although it is vital to compare the findings with the contralateral foot, there should be a high index of suspicion for the presence of bilateral coalitions. Associated peroneal muscle spasm on forced inversion is suggestive but not diagnostic of a coalition.[14,15]

IMAGING

Conventional Radiography

Initial evaluation of a patient with possible tarsal coalition begins with the acquisition of 3 images: anteroposterior, lateral, and 45° oblique weight-bearing views of the feet. It is well recognized that tarsal coalitions can be difficult to diagnose using conventional radiography, especially talocalcaneal coalitions,[30,36] because of bone overlap, obliquity of the coalition, and coalitions of fibrocartilaginous origin.[15] Instead, assessment is limited to the recognition of secondary signs suggestive of an occult coalition. An elongated anterior calcaneal process on the lateral view, known as the anteater nose sign, may suggest the presence of a calcaneonavicular coalition (**Fig. 2**). This radiographic sign may not be apparent in young children before the age of 8 years as the coalition has yet to ossify. The 45° oblique view of the foot demonstrates a calcaneonavicular coalition in 90% to 100% of cases (**Fig. 3**).[9,22,28,50] Of these, only 10% demonstrate a frank osseous bridge; the remainder demonstrate secondary signs. These include a decrease in the calcaneonavicular gap, irregular sclerotic cortices, an elongated lateral navicular as it approaches the anterior calcaneus (reverse

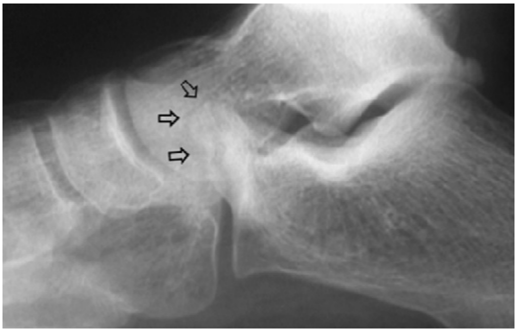

Fig. 2. Anteater nose sign suggestive of a calcaneonavicular coalition.

Fig. 3. Calcaneonavicular coalition visualized on 45° oblique radiograph.

anteater sign), and hypoplasia of the lateral talar head (**Fig. 4**).[36,54,55] Lysack and Fenton[26] used these secondary signs on plain radiographs to demonstrate a high prevalence of nonosseous calcaneonavicular coalitions (5.6%) in 460 patients presenting to the emergency department with acute foot pain. They suggested that many of the coalitions found did not require further evaluation with CT or magnetic resonance imaging (MRI) because most were asymptomatic.

Talocalcaneal coalitions are best seen with an additional axial or ski-jump view popularized by Harris and Beath.[11] This is taken with the patient standing on the cassette and dorsiflexing 10° at the ankle. Harris and Beath originally recommended a 45° beam from behind the heel. They later expanded the views to include beam angles of 30°, 35°, and 45° to visualize the subtalar joint clearly. An osseous coalition in the middle facet obliterates that part of the joint, whereas a nonosseous coalition produces irregular cortices and a dysplastic sustentaculum tali.

Lateur[56] described the C sign seen in talocalcaneal coalitions on the lateral radiograph, a circular density composed of the talar dome and inferior margin of the sustentaculum tali (**Fig. 5**). In 2000, Sakellariou and colleagues[57] concluded a 98% sensitivity and specificity using the C sign to diagnose talocalcaneal coalitions. They compared lateral radiographs of 20 patients with suspected talocalcaneal coalitions on clinical assessment and conventional radiography with 22 asymptomatic volunteers. The diagnosis was confirmed on subsequent CT scanning. However, a retrospective review by Brown and colleagues[58] of 48 patients with lateral foot radiographs and CT scans for atraumatic indications, found the C sign to be neither sensitive nor specific for talocalcaneal coalition, and only specific for a flatfoot deformity.

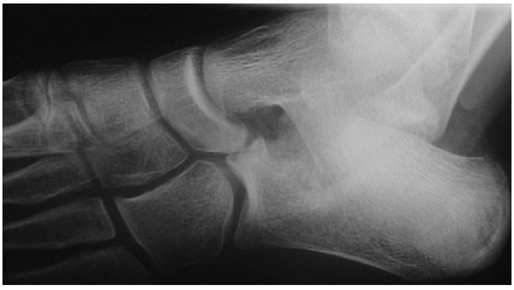

Fig. 4. Nonosseus calcaneonavicular coalition with reduced joint space, sclerotic cortices, elongated lateral navicular (reverse anteater sign) and hypoplasia of the lateral talar head.

Fig. 5. C sign on lateral radiograph suggestive of a talocalcaneal coalition.

Talar beaking is seen most commonly in talocalcaneal coalition but also occurs in calcaneonavicular coalition (see **Fig. 1**). It is believed to be the result of repeated elevation and traction of the dorsal capsule of the talonavicular joint, as the navicular overrides the talar head during foot dorsiflexion.[15,47] Other secondary signs suggestive of a talocalcaneal coalition include a short talar neck with a concave inferior surface, narrow posterior facet of the subtalar joint and failure to see the middle facet.[36,54] Conventional radiography in the initial consultation is also useful in identifying other causes of peroneal spasm, such as an inflammatory arthropathy, a subtle cavus deformity, or infection of the tarsus leading to ankylosis.[15] Despite the secondary signs on conventional radiographs, most patients nowadays undergo further imaging with CT or MRI for better characterization of the coalition and preoperative planning.

Computed Tomography

CT scanning remains the standard imaging technique to demonstrate and evaluate tarsal coalition. Herzenberg and colleagues[59] used coronal CT images to evaluate tarsal coalitions in cadaveric specimens. They showed that CT demonstrated osseous and nonosseous coalitions in 14 of 22 specimens; in the remaining 8 specimens, CT effectively ruled out the diagnosis of subtalar coalition. They concluded that CT was superior to other modalities in identifying all aspects of the subtalar joint and talocalcaneal coalitions. CT assessment requires axial and coronal views of the feet and ankles. Cross-sectional thickness of 3 mm or less is optimal. Findings that suggest a calcaneonavicular coalition are joint-space narrowing, reactive sclerosis, medial broadening of the anterior and dorsal calcaneus on axial views, and rounding of the lateral talus on coronal views. Coronal CT views are the most useful in assessing talocalcaneal coalitions. Findings may include an osseous bridge at the middle facet, irregular cortices, broadening of the sustentaculum tali, and the drunken waiter sign (**Fig. 6**). The dysplatic sustentaculum may be upturned or downturned (likened to the hand of a waiter having difficulty carrying his tray), thereby sloping the joint line so it is no longer parallel to the posterior facet.[28,56] The advent of high-speed spiral

Fig. 6. Coronal CT image showing a middle-facet talocalcaneal coalition. Note the dysmorphic sustentaculum tali and upturned joint line (named the drunken waiter sign where the sustentaculum represents the hand and tray).

CT scanners and subsequent image reconstruction software has allowed good demonstration of talocalcaneal coalitions on coronal reconstructions of noncoronal CT views. CT is useful not only to confirm the diagnosis of coalition but also to define the size and location, assessing for degenerative changes such as subchondral sclerosis and cysts, and for preoperative planning. The radiation exposure for a CT scan of the foot is variable depending on the type of scanner and sequencing used. The approximate exposure dose is 2 to 4 mSv, which is comparable with the natural background radiation dose for 1 year.[60]

Magnetic Resonance Imaging

MRI scanning is advocated by some investigators for evaluating nonosseous coalitions and confirming the presence of arthrosis in the surrounding joints.[23,36,61] However, no good study has demonstrated significant diagnostic advantage over CT scanning. The protocol should ideally have 3 views of the feet and ankles: axial, coronal, and sagittal. Fat-suppressed sequences such as short-tau inversion recovery (STIR) or fat-suppressed T2-weighted sequences are useful in evaluating coalition in the presence of bone or soft-tissue edema. Osseous and ligamentous structures are evaluated using T1-/T2-weighted and fast spin-echo proton density–weighted images. As with CT imaging, sagittal and axial views are most useful in assessing calcaneonavicular coalitions and coronal views are best for talocalcaneal coalitions. A continuous bone marrow bridge may be seen in osseous coalitions, whereas articular narrowing and irregular joint cortices with marrow edema suggest a nonosseous coalition (**Fig. 7**). Nalaboff and Schweitzer[25] suggested that more subtle signs such as the reverse anteater and drunken waiter signs are better visualized on MRI. The high sensitivity of MRI is favored when a fibrous tarsal coalition is suspected, whereas CT is the standard imaging modality for detecting an osseous coalition and is more cost-effective.[30]

Nuclear Imaging

Bone scintigraphy has been proposed as a screening tool for tarsal coalition.[62] In 1982, Deutsch and colleagues[54] evaluated conventional radiography, bone scintigraphy, and CT scanning for the radiological assessment of 3 cases of talocalcaneal coalition. They found CT scanning provided the best visualization of the coalition site. In addition to the lack of anatomic detail, interpretation of scintigraphy is made more difficult by epiphyseal uptake present in children and adolescents, the population in which tarsal coalitions most commonly occur. With the decreasing expense of CT scans and increasing resolution of advanced multiplanar reconstruction, the use of bone scintigraphy in tarsal coalition has diminished. However, single-photon emission tomography (SPECT) may yield important localizing information in complex cases when used in conjunction with CT registration.[54,63]

TREATMENT

Treatment of symptomatic patients depends on the location and extent of the tarsal coalition, the severity of symptoms and the presence of degenerative changes. The

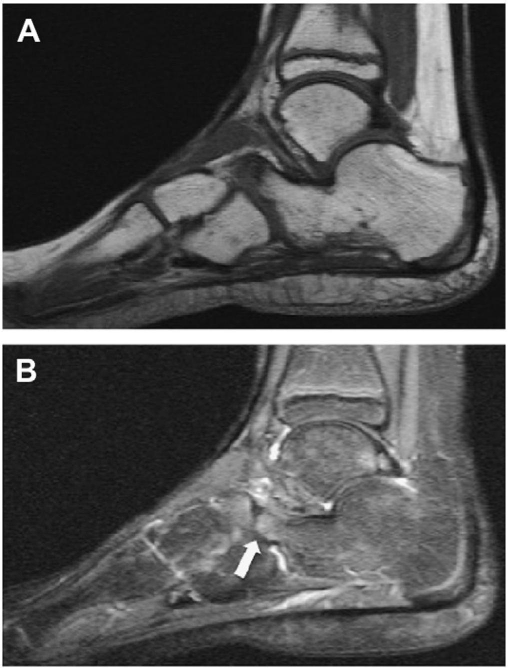

Fig. 7. (*A*) Sagittal MRI showing a calcaneonavicular coalition on T1-weighted image. (*B*) T2-weighted image of the same coalition with associated marrow edema (*arrow*).

patient's age, skeletal maturity and level of functional activity are important factors to take into account when considering operative treatment.

Nonoperative Treatment

Nonoperative therapy is usually the first line of treatment of symptomatic talocalcaneal and talonavicular coalitions.[11,23,49,64,65] This includes decreased activity, functional orthosis (ie, medial hindfoot wedge and arch support), antiinflammatory medication and University of California Berkeley Laboratory (UCBL) orthoses to prevent deterioration of the deformity in mildly symptomatic patients. If these simple measures fail to give pain relief, a limited period of immobilization in a cast or walker boot for 3 to 6 weeks may help. Cast immobilization decreases hindfoot and midfoot motion, reduces abnormal joint stresses and allows microfractures to heal. If symptoms settle after immobilization then physical therapy and a gradual return to full activities in a supportive shoe can be considered. These conservative measures can produce good results in cases of first presentation with no evidence of degenerative changes.[11,23,64,65]

Initial treatment of calcaneonavicular coalitions may include soft shoe inserts or a trial of walking-cast immobilization with the hindfoot in neutral if possible. It is reasonable to consider a second trial of cast immobilization if symptoms recur or persist, before conservative treatment is deemed unsuccessful. However, given the ease and relatively good results with surgical treatment, early resection of symptomatic calcaneonavicular coalitions in the younger patients have produced favorable results.[23,66,67]

Operative Treatment

Surgery is indicated in cases where conservative measures have failed to alleviate symptoms. The surgical options for tarsal coalition are resection or arthrodesis. Despite early studies recommending triple arthrodesis,[49,68] resection seems to be the appropriate treatment of calcaneonavicular coalitions, especially in the younger patients. The technique, as originally described by Badgley,[10] includes an anterolateral approach over the coalition, resection of at least 1 cm of the coalition, resecting a block rather than a wedge, interposition with the head of the extensor digitorum brevis (EDB) muscle, and avoid breaching the talonavicular capsule to prevent theoretical subluxation of the navicular over the talar head. Modifications of the original technique include use of bone wax after coalition resection and tying the interposition sutures over the plantar fascia, rather than securing them with a button over the plantar skin. Several long-term studies have shown 77% to 100% good or excellent results after calcaneonavicular coalition resection.[42,67,69] Cowell[14] suggested that the best outcome from resection of calcaneonavicular coalitions occurred when performed on patients less than 14 years old, before the coalitions had ossified. Routine use of an interpositional graft is necessary to reduce the recurrence of the coalition. Moyes and colleagues[70] performed a retrospective review of 17 calcaneonavicular coalition resections, of which 10 had EDB interposition and 7 had no soft-tissue interposition. Three in the second group had recurrence of the coalition along with their symptoms. Evidence for the ideal interposition graft remains controversial. The options include EDB muscle, bone wax, or fat. Cohen and colleagues[71] reported wound dehiscence in 3 out of 6 adult patients who underwent EDB transfer and bone wax application. Application of bone wax and gel foam produced similar results to those with EDB transfer, but with less wound complications. However, most studies in the pediatric population have reported good results using EDB interpositional grafts.

The optimal surgical management of symptomatic talocalcaneal coalitions has not been conclusively determined. Multiple factors have been described as important in predicting outcome including the patient's age, extent of the joint involved, degree of hindfoot valgus, and the presence of degenerative changes.[23] Before the advent of CT scanning, resection of the middle-facet talocalcaneal coalitions had unsatisfactory results because of poor preoperative visualization.[47] Hence, the surgical treatment of symptomatic talocalcaneal coalitions was traditionally a triple arthrodesis.[50,72] More recently, resections have become more popular and are indicated in cases in which conservative treatment has failed, CT/MRI visualization of the middle-facet coalition is good, and no degenerative changes are present in the posterior facet.[30] The surgical resection is approached medially, distal to the medial malleolus. The middle facet is exposed by retraction of the flexor hallucis longus (FHL) tendon inferiorly. The prominent joint is resected and interposition with either fat, split FHL tendon, or bone wax is performed.[73] To correct the residual valgus deformity, Luhmann and Schoenecker[52] recommended either a medializing calcaneal osteotomy if subtalar motion is restricted after coalition resection, otherwise, a lateral column lengthening. Giannini and colleagues[74] reported good or excellent hindfoot correction and pain relief in 11 out of 14 feet undergoing talocalcaneal coalition resection with correction of residual valgus using a bioabsorbable subtalar arthroereisis implant. Like Cowell,[14] they also recommended that patients younger than 14 years had better prognosis.

Comfort and Johnson[75] found a 77% success rate with resection when the coalition involved one-third or less of the total surface area of the subtalar joint on CT. Wilde and colleagues[76] found that a hindfoot valgus of greater than 16° and a coalition surface area greater than 50% of the posterior facet on CT were predictors of poor results after resection. Luhmann and Shoenecker[52] found that although an association existed between poor results and a heel valgus of more than 21° or a coalition greater than 50% of the posterior facet, some patients still had good postoperative results. They recommended that resection be tried initially, and the patient be counseled that they could still have a good result despite the presence of poor predictive factors. Long-term studies have shown variable good or excellent rates of 50% to 94% with resection of talocalcaneal coalition.[73,76,77] For cases in which a resection is not possible or desired, Mann and Baumgarten[78] proposed isolated fusion of the subtalar joint, instead of the traditional triple arthrodesis. Their reasoning was that any motion saved in the midtarsal joints would maintain force transfer during motion, decreasing any degenerative process in the adjacent joints. However, where degenerative changes in the midfoot are apparent, triple arthrodesis is indicated, as an isolated subtalar fusion would only accelerate the degenerative process. The presence of talar beaking seems to have no correlation to the outcome of coalition resection.[67,71,76] In 1983, Swiontkowski and colleagues[47] found no degenerative changes in the talonavicular joint on intraoperative inspection during resection of the talar beak. Therefore, isolated talar beaking is not a contraindication for resection surgery as it is not part of the degenerative change.

Salvage Surgery

Patients with unsuccessful excision of calcaneonavicular or talocalcaneal coalition have persistent pain. This may be attributed to incomplete resection, recurrent bone formation, or an ongoing degenerative process in the surrounding joints. Although some success has been reported with isolated subtalar fusion in small case series,[47,71] triple arthrodesis is the most reliable salvage procedure for failed resection surgery.

POSTOPERATIVE MANAGEMENT

The postoperative rehabilitation for resection surgery includes immobilization for 3 weeks in a non–weight-bearing cast, followed by partial immobilization in a weight-bearing walker boot with range-of-motion exercises.[30] Postoperative rehabilitation for arthrodesis surgery involves immobilization for 3 weeks in a non–weight-bearing cast, followed by 3 weeks of partial immobilization with a non–weight-bearing walker boot with range-of-motion exercises out of the boot. This is followed by a gradual advance to full weight bearing and range-of-motion exercises with physical therapy. Bilateral procedures are staged to allow full recovery of the first foot before surgery on the second.

COMPLICATIONS

Infection and wound breakdown are possible complications with surgical treatment.[30,71] If symptoms fail to resolve after resection of the coalition, the subsequent arthrodesis may be significantly compromised by ongoing infection. During resection of a calcaneonavicular bar, violation of the talonavicular capsule may result in subluxation of the navicular on the talus, causing abnormal motion in the midfoot and risk of further pain and degenerative changes.

OUTCOME/PROGNOSIS

Nonoperative treatment of patients with symptomatic tarsal coalitions has not been uniformly successful and proper patient selection is a prerequisite for optimal results. Patients with extensive or multiple coalitions typically undergo fusion procedures, and those with less extensive or isolated coalitions undergo resection with soft-tissue interposition. Most calcaneonavicular coalitions can be excised with the expectation of successful long-term results. Resection of symptomatic talocalcaneal coalitions yields optimal results when the coalition involves approximately one-third to half of the posterior subtalar joint surface. The amount of postoperative subtalar movement correlates well with clinical outcome.[42] Although there is no consensus regarding patient's age as a predictor of success in coalition resection, it is reasonable to say that some degenerative change is inevitably present at the time of presentation,[49] especially in the older adolescents and adult cohort. Therefore, age may well be a significant factor in predicting successful outcome for coalition resection, with younger patients showing better prognosis.[49,66,74]

SUMMARY

Tarsal coalition is a relatively rare abnormality of the foot in which 2 or more of the tarsal bones are joined by bone, cartilage, or fibrous tissue. Tarsal coalition is believed to be a failure of mesenchymal differentiation and has an autosomal dominant inheritance with high penetrance. The incidence of symptomatic tarsal coalition is approximately 1%, but the true prevalence is unknown as most are asymptomatic. Calcaneonavicular and talocalcaneal coalitions are the most common types. More than half of tarsal coalitions are bilateral. Typically, the patient presents with a history of chronic pain with activity, following a traumatic injury, or with repetitive sprains. Pain from a tarsal coalition is believed to be generated by microfractures at the coalition-bone interface. The condition is poorly visualized with conventional radiography, but axial and 45° lateral oblique views offer better visualization. However, CT scanning with coronal cuts is the gold standard investigation, particularly in evaluating talocalcaneal coalitions.

Conservative treatment includes a medial heel wedge, arch support, and walking-cast immobilization for 3 to 6 weeks. Surgical treatments for coalitions unresponsive to conservative measures include resection or arthrodesis. Calcaneonavicular coalitions respond well to resection with interpositional graft, most commonly, EDB muscle belly. Currently, the true indications for resection of talocalcaneal coalitions have not been determined. Factors including heel valgus angle, patient age, and percentage of joint involvement do not produce consistent outcomes. Talar beaking does not indicate an arthritic joint and should not be a contraindication to resection. However, once global degenerative changes have begun, arthrodesis is the preferred surgical option. Routine use of CT and MRI is recommended to help make this decision. Subtalar arthrodesis is not sufficient in cases of talocalcaneal coalition where the midfoot joints are degenerate. It is also unproven as a salvage procedure for failed excision of a coalition. Triple arthrodesis is indicated in both circumstances.

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