TREATMENT OF IDIOPATHIC CLUBFOOT: AN HISTORICAL REVIEW

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ABSTRACT

Idiopathic clubfoot, one of the most common problems in pediatric orthopaedics, is characterized by a complex three-dimensional deformity of the foot. The treatment of clubfoot is controversial and continues to be one of the biggest challenges in pediatric orthopaedics. This controversy is due in part to the difficulty in measuring and evaluating the effectiveness of different treatment methods. We believe the heart of the debate is a lack of understanding of the functional anatomy of the deformity, the biological response of young connective tissue to injury and repair, and their combined effect on the long-term treatment outcomes. The aim of this review is not only to assess the different methods of clubfoot treatment used over the years in light of an evolving understanding of the pathoanatomy of the deformity, but to also clarify factors that allow a safe, logical approach to clubfoot management. Further research will be needed to fully understand the pathogenesis of clubfoot, as well as the long-term results and quality of life for the treated foot.

Initial Period of Serial Manipulations and Immobilization

Idiopathic clubfoot is one of the most commonly referred problems in pediatric orthopaedics and is characterized by a complex three-dimensional deformity. When clubfoot is analyzed from an historical perspective, it is difficult to ascertain if other types of foot deformity, for example equinovarus or metatarsus adductus, were included in the definition. However, we believe most experienced authors were able to differentiate it from the other foot deformities when they referred to a clubfoot, given the natural history of no improvement without treatment.

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Clubfoot was first depicted in ancient Egyptian tomb paintings, and treatment was described in India as early as 1000 B.C. The first written description of clubfoot was given to us by Hippocrates (circa 400 B.C.), who believed the causative factor to be mechanical pressure. He described methods for manipulative correction remarkably similar to current non-operative methods. Hippocrates understood two important principles in the treatment of clubfoot which succeeding generations have time and time again claimed as their own. He explained that the vast majority of cases can be successfully treated with serial manipulations, and that treatment should begin as early as possible before the deformity of the bones is well established. He also understood the inadequacy of restoring the foot to its normal position, but that it must be overcorrected and then held in this position afterwards to prevent recurrence.

Hippocrates treated clubfoot as soon after birth as possible. His technique involved repeated manipulations of the involved foot with his hands, followed by the application of strong bandages to maintain correction. There is no written account of the specifics of the actual manipulations, but there is mention of the importance of gentleness in correcting the deformity. When correction had been obtained by this method, special shoes were worn to maintain the correction and prevent recurrent deformity.

These techniques were apparently forgotten by subsequent generations. In the Middle Ages, the management of clubfoot and other deformities was the province of barber-surgeons, charlatans, and bonesetters, and minimal information is available concerning their practice. The next description of repeated stretching comes from Arcaeus, who in 1658 wrote a chapter on the treatment of clubfoot where he describes his stretching technique as well as two mechanical devices for maintaining the correction. The latter of these devices is similar to Scarpa's shoe, which will be discussed later.

In the mid 18th century, Cheselden, at St. Thomas' Hospital, treated clubfeet by repeated stretching using tape to maintain the improved position. From this time until 1803, when Scarpa published his historical *Memoir on Congenital Club-foot of Children,* the subject was apparently neglected.[17] The *Memoir* provides us with a

description of his concept of the deformity. He considered the talus to be normal both in position and shape, and that the deformity was due to a dislocation of the forefoot inward upon the head of the talus. His treatment involved forceful manipulation, not gentle stretching, and application of a complicated mechanical device, later known as Scarpa's shoe. His treatment method was never successful in other hands and for that reason was not widely accepted.

In the year 1806, Timothy Sheldrake published an essay entitled *Distortions of the Legs and Feet of Children*.[18] Sheldrake used bandages like Hippocrates, and claimed that most of his patients could be cured in two to three months. He also recognized that although an infant's foot might be cured, it should not be left free until the child was able to walk. He believed that half the disability was due to the ligaments and the other half to the muscles. In expressing an opinion as to the possibility of a cure, he said "that children taken at or within two months of birth a cure will be in every sense complete by the time they begin to walk. But the older the child is when treatment is begun so much longer will it be before a cure can be effected."[18]

Introduction of Percutaneous Achilles Tenotomy

In 1823, Delpech performed subcutaneous tenotomy of the Achilles tendon in two patients with acquired talipes equinovarus. Sepsis occurred in both patients and he did not repeat the operation. The high incidence of infection discouraged most surgeons from performing tenotomies. However, Stromeyer continued to practice the operation. In 1831, he subcutaneously divided the tendo-Achillis in several patients with no fever or other signs of infection. W.J. Little was a young British surgeon who acquired an equinovarus deformity due to poliomyelitis. He visited Stromeyer in Hanover, who successfully operated on him. In addition, Stromeyer taught Little how to perform the procedure and allowed Little to operate on several of the patients who came to his clinic. Little then returned to England where he introduced this procedure with great success. In his treatise, Little argues strongly against the mechanical theory of this deformity.[13] His view was that the deformity was due to abnormal muscular contractions during intra-uterine development. This was in contrast to Stromeyer, who believed the deformity was due to a deficiency of the internal malleolus.

Little also pointed out that although the medial ligaments cannot directly produce the deformity, stretching them can result in improvement. He believed that associated with the distortion of the foot there was a rotation of the thigh outwards, consequently affecting the entire extremity. From this line of thought arose the use of irons extending from the foot to the pelvis in the treatment of clubfoot.

For thirteen years after Little recorded his success with subcutaneous tenotomy, no work of note appeared in the literature. Subcutaneous tenotomy enabled many feet considered beyond correction to be remarkably improved. Rogers in 1834 and Dickson in 1835[6] were the first to perform subcutaneous tenotomy for clubfoot in the United States. In 1866, Adams was the first surgeon to draw attention to the error of dividing the Achilles tendon as the first stage in the correction of the deformity.

In order to further understand clubfoot deformity, Adams performed dissections on several stillborn infants with clubfoot and reported the results.[1] This report is especially interesting because it is the first to describe microscopic examination of the muscles in a patient with clubfeet. He found that they did not exhibit any abnormal structural conditions either to the naked eye or microscopically. He also examined the bones of several specimens and discovered the only one that exhibited any marked change was the talus, which tilted medially. He believed the alteration in the contour of the talus resulted from the altered position of the calcaneus and navicular. His observations of the articular surfaces of the tarsal bones in these specimens further supported this notion.

After discussing the evidence for and against the various theories of the causation of clubfoot, Adams stated he believed the muscles were the deforming force, and that anatomically, clubfoot is a dislocation of the talocalcaneonavicular joint. He emphasized that the talus can only assume its normal shape and position after the dislocation between it and the navicular and calcaneus has been reduced. He recommended early surgery to obtain anatomical reduction of the dislocation.

Adams condemned the use of Scarpa's shoe or other existing mechanical devices. He believed Scarpa's shoe was not constructed in accordance with the deformity it was supposed to correct. He did agree with Scarpa on the importance of correcting the varus element of the deformity before the equinus. However, after condemning the use of mechanical devices, he devised his own straight splint of turned sheet metal applied along the outer side of the leg.

In 1838, M. Guerin described the use of plaster-of-Paris in the treatment of congenital clubfoot, and was apparently the first to use it for this purpose. We will later discuss in further detail the current use of plaster cast techniques for the correction of clubfoot.

Introduction of Aseptic Surgical Techniques, Anesthesia, and Radiographs

With the exception of tenotomies, the operative treatment of clubfoot began with the introduction of aseptic technique and anesthesia. In 1867, Lister introduced antiseptic principles of surgery. Esmarch in 1873 described a flat-rubber bandage for expressing blood from a limb. The introduction of the pneumatic tourniquet to limb surgery by Cushing in 1904 was invaluable.[5] The introduction of radiography made possible the precise evaluation of deformities. The advent of anesthesia completed the surgical renaissance, and these advances set the stage for orthopaedic surgery to evolve from a specialty with much empirical craftsmanship into an important scientific discipline. However, in the case of clubfoot treatment, this evolution also allowed the development of more radical operations aimed to obtain a "perfect" foot.

In 1891, Phelps not only divided the Achilles tendon, but carried out a medial release of all soft tissues, elongation of the tibialis posterior and division of the medial ligament of the ankle joint and plantar fascia, abductor hallucis, flexor hallucis longus, all the short flexors and finally performed osteotomy of the neck of the talus and wedge resection of the calcaneus.[15] Duval (1890), Ogston (1902) and Lane (1893) all carried out similar radical procedures.

Elmslie (1920), however, considered these procedures too radical in their approach to the condition. He understood the resistance to correction to be largely due to the talonavicular capsule, the plantar fascia, the Achilles tendon, and less importantly the posterior tibial tendon.[8] Ober (1920) also agreed with Elmslie's approach.

Brockman (1930), in addition to releasing the medial ligaments and plantar fascia, divided the abductor hallucis, tibialis posterior and subsequently carried out elongation of the Achilles tendon to correct the equinus.[3] He noticed that the operated feet were left stiff and immobile and he eventually abandoned this procedure. He argued that widespread soft tissue release lead to the formation of extensive fibrous tissue. Steindler reported good results with this technique in only 45% of 91 operations.[19]

Elmslie, Ober, and Brockman all emphasized the importance of immobilization in a plaster-of-Paris cast until correction was established. These authors' operations all pursue the same end, namely correction of the adduction and inversion due to the soft tissue contracture. The Brockman operation is the most complete. These corrective procedures are all based on the notion that all elements of clubfoot must be corrected before correction of equinus is undertaken.

Tendon transfers first became popular in the 1920's. Dunn in 1922 described transfer of the tibialis anterior tendon in selected cases of clubfoot to prevent relapse.[7] However, he did not publish his results. In 1947, Garceau and Manning reported good results in a series of tibialis anterior transfer in 83% of 86 patients with recurrent deformity. Barr (1958) believed that the tibialis anterior tendon should not be transferred to a lateral insertion if peroneus longus is functioning, due to resultant muscle imbalance.[2]

During the same time period that many soft tissue surgeries were being performed, many surgical procedures on the skeleton of the foot were also being devised for treatment of clubfoot. Operations aimed at correction of the prominent talus were popular during the latter part of the nineteenth century. In 1872, Lund performed talectomy, not as a corrective procedure for the equinovarus deformity, but because it was prominent.[14] Unfortunately, this procedure resulted in a plantigrade foot. Agustoni in 1888 and Morestin in 1901 also attempted to improve the position of the foot through talectomy. Steindler reported good results in 1950 with removal of the ossific nucleus of all the tarsal bones.

Osteotomy and wedge resection of the tarsal bones was performed by Robert Jones in 1908.[11] He always obtained as much correction as possible by manipulation and plaster before considering any operation on bone, and when necessary, removed as little bone as possible. Denis Browne in 1937 disagreed and suggested that in all cases beyond the possibility of correction by casting, a "cresentic resection of the tarsus " below and in front of the ankle should be performed right away.[4] However, as Robert Jones wisely said in 1920, "There is not much to be said for the removal of large masses of bone. I have never seen a case of clubfoot when a good portion of bone has been removed where the foot has functioned well."[11] In fact there are very few indications for surgery on the bones of the foot to correct clubfoot deformity.

Interestingly, current trends contend that clubfoot is a surgical deformity where only mild cases can be corrected by manipulation and immobilization. This view is supported by the disappointing results obtained after prolonged manipulations and casting in the more severe cases. Interestingly, most publications on the surgical treatment of clubfoot emphasize that early alignment of the displaced skeletal elements results in normal anatomy of bones, joints, ligaments and muscles. However, there is still no unanimity about when surgery should be performed, how extensive it should be, or how to evaluate the results. Adding to the uncertainty is the lack of long-term follow-up of surgically treated cases.

We believe this lack of understanding has resulted in poor correction of the initial deformity accompanied by severe iatrogenic deformities. An immediate correction of the anatomic position of the displaced bones is, in fact, impossible. Any attempt to roughly realign the talonavicular, talocalcaneal, and calcaneocuboid joints requires wire fixation through the joint cartilage. Inevitably, the joint cartilage, as well as the joint capsules, are damaged and joint stiffness sets in. A few reports indicate that surgery is almost invariably followed by deep scarring, which appears to be particularly severe in infants. In addition, the average failure rate of clubfoot surgery is 25% (range 13% to 50%) and many complications can occur including wound problems, persistent forefoot supination, loss of reduction and recurrence, overcorrection of the hindfoot, dorsal subluxation of the navicular, and loss of normal motion of the ankle and subtalar joints.

Return to Serial Manipulations and Immobilization

It is striking when reviewing the history of clubfoot management to see how the same mistakes are made time and time again by the treating physicians. The mistakes are made because the treating physician consistently ignores what has already been learned by his predecessors and instead he is often misguided by new information or trends.

Hugh Owen Thomas (1834-1891) studied medicine at Edinburgh and University College, London. He developed the Thomas test for hip flexion contracture as well as the Thomas splint used in fracture treatment. In addition, he developed the Thomas wrench, a device used to forcibly correct clubfoot. The plane through which the correction occurred was never clear. Experts claimed that if properly applied, the Thomas wrench could easily detach the foot from a cadaver.

In 1894, Sir Robert Jones at the British Orthopaedic Society said that he had given up operative treatment in place of treatment by manipulation. He wrote that he had never met with a case in which treatment had been started in the first week where deformity could not be corrected by manipulation and bracing for two months. He also noted that the cure was only finally completed when the patient could walk. He accepted the view that the condition is due to pure mechanical causes. He expressed the view that tenotomy should only very rarely be necessary. Bone operations, he held, should never be performed without obtaining maximum correction by manipulation with the Thomas wrench. However, his claimed results could not be duplicated.

Denis Browne (1892-1967), a second generation Australian, became the father of pediatric surgery in the United Kingdom. He is best known in orthopaedics for his Denis Browne bar used to correct clubfoot; a similar abduction orthosis is still used today to maintain correction of the deformity.

Michael Hoke (1874-1944) was the first medical director of the Scottish Rite Hospital in Decatur, Georgia, and was instrumental in advocating manipulative treatment for clubfoot and holding the correction with plaster casts.

Kite then became the leading advocate of the conservative treatment of clubfoot for many years in the early and mid 1900's. Kite completed his orthopaedic training at Johns Hopkins and succeeded Michael Hoke as medical director of the Scotish Rite Hospital in Decatur, Georgia. He continued the meticulous clubfoot cast application and molding that he had learned from Hoke. Kite corrected each component of the deformity separately instead of simultaneously. He was able to correct the cavus and to avoid foot pronation, but correcting the heel varus took many casts. He recomended "getting all the correction by abducting the foot at the midtarsal joint" with the thumb pressing "on the lateral side of the foot near the calcaneocuboid joint."[12] However, by abducting the forefoot against pressure at the calcaneocuboid joint the abduction of the calcaneus is blocked thereby interfering with the correction of the heel varus. Therefore, it took many months and cast changes to slowly correct the heel varus and obtain a plantigrade foot. Due to the inordinate amount of time it took to obtain correction of the deformity, he lost many followers who sought quicker corrections via surgery.

It was through his attempt to understand the pathophysiology of clubfoot, as well as his ability to learn from the mistakes of his predecessors, that Ponseti developed his current method of treatment for clubfoot. His understanding of the anatomy of the tarsus of the normal foot and of the clubfoot was greatly enhanced by the work of Farabeuf's *Precis de Manual Operatoire*, first published in 1872.[9] Farabeuf described how in the normal foot when the calcaneus rotates under the talus, it adducts, flexes, and inverts. More precisely, as the foot goes into varus, the calcaneus adducts and inverts under the talus while the cuboid and the navicular adduct and invert in front of the calcaneus and the talar head, respectively. Farabeuf also explained that in the clubfoot deformity the ossification center of the talus responds to the abnormal pressures placed on it by the displaced navicular. In addition, he observed that while bony deformities in the infant with clubfoot were reversible, recurrences are high due to soft tissue contractures. In his time, clubfoot patients were rarely treated at an early age, so surgery was usually necessary to correct the deformity.

Huson in 1961 wrote his Ph.D. thesis entitled "A functional and anatomical study of the tarsus."[10] This work supported and advanced the ideas of Farabeuf. Huson demonstrated that the tarsal joints do not move as single hinges but rotate about moving axes. Furthermore, motions of the tarsal joints occur simultaneously. If the motion of one of the joints is blocked, the others are functionally blocked as well. Based on these concepts, Ponseti developed his treatment guidelines:

1. All the components of the clubfoot deformity have to be corrected simultaneously with the exception of the equinus which should be corrected last.
2. The cavus results from a pronation of the forefoot in relation to the hindfoot, and is corrected as the foot is abducted by supinating the forefoot and thereby placing it in proper alignment with the midfoot.
3. While the whole foot is held in supination and in flexion, it can be gently and gradually abducted under the talus, and secured against rotation in the ankle mortise by applying counter-pressure with the thumb against the lateral aspect of the head of the talus.
4. The heel varus and foot supination will correct when the entire foot is fully abducted in maximum external rotation under the talus. The foot should never be everted.
5. After the above is accomplished, the equinus can be corrected by dorsiflexing the foot. The tendo-Achilles may need to be subcutaneously sectioned to facilitate this correction.

When proper treatment of clubfoot with manipulation and plaster casts has been started shortly after birth, a good clinical correction can be obtained in the vast majority of cases. A plaster cast is applied after each weekly session to retain the degree of correction and soften the ligaments. After two months of manipulation and casting the foot often appears slightly overcorrected. As mentioned, the percutaneous tenotomy of the Achilles tendon is an office procedure and is done in 85% of Ponseti's patients to correct the equinus deformity. Open lengthening of the tendo Achilles is indicated for children over one year of age. This is done under general anesthesia. Excessive lengthening of the tendon must be avoided since it may permanently weaken the gastrocsoleus. Transfer of the tibialis anterior tendon to the third cuneiform is done after the first or second relapse in children older than two-and-a-half years of age, when the tibialis anterior has a strong supinatory action. The relapsed clubfoot deformity must be well corrected with manipulations and two or three plaster casts left on for two weeks each before transfer of the tendon. With appropriate early manipulations and plaster casts, surgery of the ligaments and joints should only be rarely necessary.

To provide patients with a functional, pain-free, normal-looking foot, with good mobility, without calluses, and requiring no special shoes, and to obtain this in a cost-effective way, further research will be needed to fully understand the pathogenesis of clubfoot and the effects of treatment, not only in terms of foot correction, but also of long-term results and quality of life. One thing that is definitely missing in the literature is a long term follow up study on surgically treated clubfeet. The authors of this paper are currently involved in a multi-center retrospective study to look at this group of patients.

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