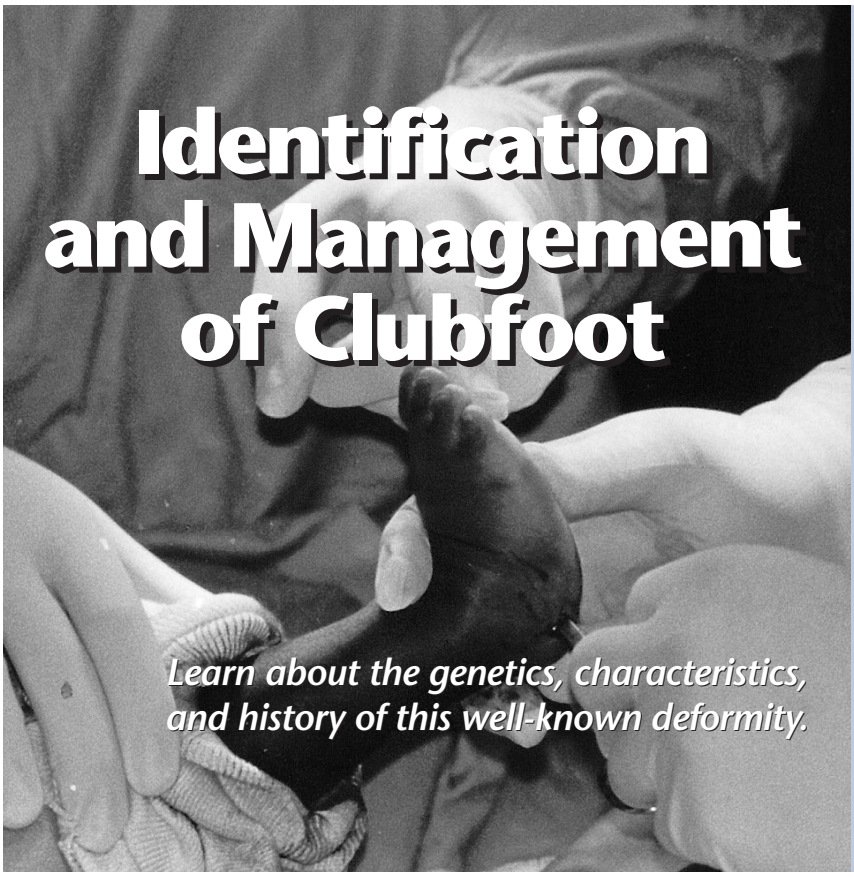
Continuing Medical Education

Identification and Management of Clubfoot



Learn about the genetics, characteristics, and history of this well-known deformity.

Objectives

1) To know the nature of clubfoot deformity, including the general incidence, genetics, and clinical characteristics.

2) To know and evaluate the basic theories for the origin of clubfoot.

3) To know the natural history of surgically corrected and non-surgically corrected clubfoot.

4) To know the clinical characteristics of clubfoot at all different stages, including infant, childhood, adult, and neglected clubfoot.

5) Specifically to know the general nature of the operations for clubfoot deformity, including the Turco procedure and the complete subtalar joint release.

6) To know the results of studies comparing the Turco procedure and the complete subtalar joint release and to know the advantages and disadvantages of each operation.

7) To be aware of the management of clubfoot at all different stages, including infant, childhood, adult, and neglected clubfoot.

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*Following this article, an answer sheet and full set of instructions are provided (p. 152).—**Editor***

By Ellen Sobel, DPM, Ph.D. and Renato Giorgini, DPM

Incidence and Genetics

Congenital talipes equinovarus (clubfoot) is one of the most instantly recognizable birth defects consisting of rigid hindfoot varus, forefoot adductus, forefoot varus, and ankle equinus (Figure 1). Approximately 1/1000 births is a clubfoot, with males affected two times as frequently as females, the right foot involved more commonly than the left and 50% bilateral.[1-3] After one child in a family is born with a clubfoot, the risk to a second child is increased to one in twenty or approximately five percent (Table 1).[4] Not only does the risk of clubfoot increase after a previous child is born with the deformity, but the deformity is more rigid as well.

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Clubfoot occurs in all races and ethnicities; however, Asians have the lowest incidence (about .57 per 1,000 live births) and Polynesians have the highest rate of clubfoot (Almost 7 per 1,000 live births).[5-8] There are four categories of clubfoot: postural (positional and corrects with casting), congenital (rigid clubfoot, isolated deformity), teratological (e.g., associated with spina bifida), and clubfoot occurring as part of a syndrome.[10] The most common form of congenital clubfoot, the idiopathic variety, is inherited by a polygenic multi-factorial inheritance with a sex-linked threshold effect.[7]

Treatment for the true clubfoot invariably requires surgery.

The clubfoot deformity cannot occur until the number of abnormal genes exceeds the threshold level. The threshold is sex-related, with a higher tolerance being found in females. Females need more genes to have a clubfoot, but when they do exceed the threshold number of genes the deformity is worse than in males. The deformity is less severe in males because males with clubfoot have fewer clubfoot genes. However, we have found that the female clubfoot patients correct more easily and need fewer surgeries, perhaps due to the inherently greater degree of ligamentous laxity in females.

Etiology

Several theories have evolved to explain the still unknown etiology of clubfoot. More than 2400 years ago, Hippocrates believed that intrauterine pressure and rapid skeletal growth were responsible for the malposition of clubfoot.[11] Brown[12] attributed congenital clubfoot to a mechanical deformity of intrauterine crowding or packaging. However, deformities caused by intrauterine crowding, also known as postural defects (e.g., congenital hip dislocation, metatarsus adductus, and calcaneovalgus) are more common in firstborns, which is not the case with clubfoot.[5,6,13]

In 1929, Bohm[14] noted that in the fifth week of gestation, there is no difference between the normal foot and the eventual clubfoot. Thus, Bohm felt that the cause of clubfoot was a developmental arrest, which occurred during pregnancy. A study of 147 specimens from the eighth to the twenty-first week of gestational age showed that at the ninth week of pregnancy the normal foot was structurally similar to a clubfoot, but by the eleventh week the normal foot developed out of the clubfoot position.[15]

The germ plasm defect theory states that a defect in the primary germ plasm of the talus results in plantar flexion and inversion of the talar head and neck with secondary soft tissue changes.[16-19] The talar deformity is now considered secondary to muscle imbalance, soft tissue contractures rather than the primary deformity.

There may be a primary deformity in neurogenic tissue creating a type I fiber predominance leading to contractile imbalances, which eventually result in

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Figure 1. Congenital clubfoot with characteristic deformed small foot with hindfoot equinus and inversion of the foot.

clubfoot.[20-22] Studies have found a defect in innervation of muscles of the lower extremity in infants with clubfoot.[23-24] Other neurologic theories include peroneal nerve compression[25], and enteroviral infection of the anterior horn cells during pregnancy.[26]

Muscular and collagen dysfunction localized to the posterior and medial aspect of the foot and leg may induce the development of clubfoot some time during the middle of pregnancy.[27] Ippolito and Ponseti[28] found that the distal muscles on the posteromedial aspect of the foot showed decrease in size and number of muscle fibers and increased fibrous connective tissue within the muscles, tendon sheaths and fascia with shortening to the tendoAchilles (retracting fibrosis). After also finding that the spinal cord from a 17-week old fetus was normal histologically, they concluded that clubfoot was not secondary to neuromuscular defects.

The posterior tibial artery is the most dominant vessel in the clubfoot with the dorsalis pedis being hypoplastic.[29] This is theorized to result in medial foot and ankle tethering with secondary scarring, which results in the clubfoot.

Pathoanatomy

The clubfoot is a small, deformed foot with rigid hindfoot varus, forefoot adductus, forefoot varus, and ankle equinus. The head and neck of the talus is deviated medially and plantarly.[17,30-32] The navicular is dislocated medially and in severe clubfoot may abut against the medial malleolus.[33] Although the talar head and neck are medially and plantarly deviated, the body of the talus is actually laterally rotated on its longitudinal axis and the ankle mortise.[31] This results in posterior displacement of the fibula, and the lateral malleolus may be posteriorly displaced off its articular talar facet, which is known as a horizontal breach.

Both the talus and calcaneus are in equinus. The calcaneus is in a plantarflexed and inverted position. The talonavicular and calcaneocuboid joints are deviated medially and plantarly. The tendo Achillis, tibialis posterior, and toe flexor are shortened while the peroneal muscles are stretched and weakened.[34]

The posterior muscle group, the invertors and the intrinsic foot muscles are tight. Contracted ligaments include the long and short plantar ligaments, the spring ligament, the calcaneofibular ligament, talofibular ligament. The posterior ankle joint capsule, the talonavicular joint capsule, the calcaneocuboid capsule, and the plantar fascia are also contracted.

Clinical & Radiographic Characteristics

The clinical diagnosis of clubfoot is obvious (Figure 1), especially when unilateral presenting with a

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small, short, stiff, deformed-looking foot with prominent ankle equinus as compared to the non-affected side. In some infants, there is a deep plantar medial transverse and posterior crease. The heel of the clubfoot stays in a fixed varus and equinus position. Hindfoot equinus is caused by plantarflexion of the talus, contracture of the posterior ankle capsule and shortening of the tendoAchilles. The heel looks small and high, and, upon palpation, feels like the heel pad is empty. The forefoot is adducted and held in a fixed varus attitude. The forefoot position is due to and follows the medially and plantarly directed talar head and neck deformity.

The calf muscles are shortened and underdeveloped. Calf atrophy, formerly thought to be caused by wearing a cast for a long period, is an inherent part of clubfoot[35] and is noticeable in older children particularly with unilateral clubfoot, with the clubfoot side also having a slightly shorter limb and shorter foot. We have found that in children with clubfoot the foot length, limb length and calf girth are approximately one inch less on the affected side.[36]

The authors prefer a modified Turco procedure, ideally performed between the ages of about 9 months and 2 years.

The most common radiographs are the weight bearing anteroposterior (AP) and lateral radiographs with the foot held in maximum dorsiflexion. The AP talocalcaneal angle (angle of Kite) is a reflection of varus deformity of the rearfoot (Figure 2). The normal value for the AP talocalcaneal angle is between 20 to 40° and is reduced in a clubfoot. The lateral x-ray demonstrates equinus deformity. In the lateral view of forced dorsiflexion, the calcaneus and talus are both in equinus and almost parallel to each other (Figure 3). The normal value for the lateral talocalcaneal angle is 20 to 40° and is also reduced in the clubfoot. The values of the AP talocalcaneal angle and the lateral talocalcaneal angle can be added together to give the talocalcaneal index, which is thought to be more accurate than one value alone. Normal values for the talocalcaneal index are from 40 to 70°. The degree of adduction of the forefoot is measured by the AP talar first metatarsal angle. Normal is zero degrees to minus 20°. The clubfoot shows increased adduction of the forefoot.

Conservative Treatment

Treatment of congenital clubfoot generally consists of manipulation and serial casting followed by surgical intervention in approximately 50% of cases (Figure 4).[36-39] Recently, there has been a resurgence of non-surgical techniques as the sole treatment for clubfoot.[27,41,42] Results of studies of conservative treatment report success rates as high as 95 to 100%.[41-45]

Treatment begins shortly after birth or approximately three to five days after birth[46] taking advantage of the favorable fibroelastic properties of the connective tissue, which forms the ligaments, joint capsules and tendons.[40] Clubfeet become stiffer with delay in onset of treatment.[34] Mild clubfoot treated immediately after birth may easily correct, but may take months of serial casting if treatment is delayed for only a few weeks.[47]

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TABLE 1: HEREDITY OF CLUBFOOT

	INCIDENCE	PERCENT
General population	1/1000	0.1%
Risk to 2nd child after 1st child born with clubfoot	1/20*-1/50	2-5%
Risk to 3rd child after 1st two children born with clubfoot	1/7*	14%
Risk to 4th child after three children born with clubfoot	1/2*	50%
One parent has clubfoot/1st child born with clubfoot-Risk to 2nd child of being born with clubfoot	1/4**	25%
Risk to first degree relatives (I.e., brother)	~1/50	2.5-2.9%
Risk to second degree relatives (I.e., aunt)	5-6/1000	.5-.6%
Risk to third degree relatives (I.e., cousin)	2/1000	.2%
Fraternal twins (both affected)	~1/20	2.9-5%
Identical twins (both affected)	1/3	33%
Associated with malformations of the extremities	1/20	4-5%

*Wong HB: Genetic Aspects of foot deformities. J Sinapore Paediatr Soc 29: 13-22, 1987.

**Cowell HR: The genetics of foot disorders. Orthop Rev 7: 55-8, 1978.

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Above knee casts are required by some,[27] but others prefer below knee casts.[34] Although a plaster cast molds better, recently some surgeons have found that fiberglass casts hold the foot better than plaster casts.[48]

Magnetic resonance imaging has demonstrated that the talonavicular and calcaneocuboid joints remodel and become congruent in the corrected position after four to six weeks of manipulation and serial casting.[27] The need for casting much beyond three months is indicative that non-surgical treatment is unlikely to be effective.[49] Further casting past the point of resistance or relapse increases the risk of developing a rocker bottom foot.

Figure 2. Angle of Kite (talocalcaneal angle), on dorsoplantar (DP) radiograph, is reduced.

Ponseti Technique

The Ponseti technique involves serial casting combined with tendoAchilles lengthening when necessary.[50] Denis-Browne Bar splinting is used for three months full-time and at night for two to four years to prevent relapse. A recent thirty year follow-up of 71 clubfeet treated with the Ponseti technique showed that 85% of individuals functioned as well as a comparative non-clubfoot group.[51] However, patients with clubfoot who were engaged in sedentary occupations and were non-obese, tended to have the best functioning feet.[51]

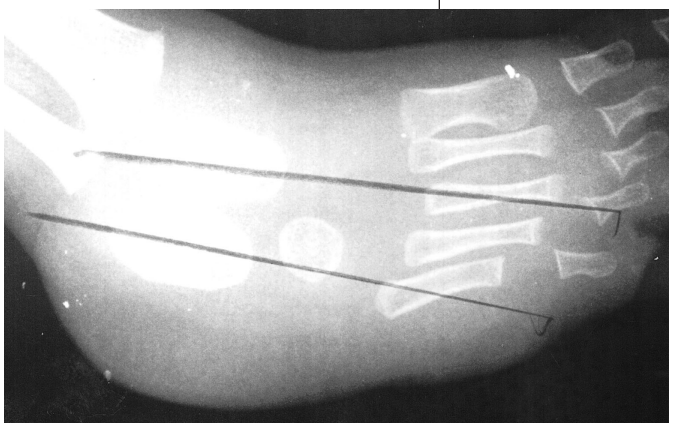

Figure 3. Lateral Talocalcaneal angle is reduced to zero degrees due to calcaneus and talus being parallel to each other.

Surgical Correction

Treatment for the true clubfoot invariably requires surgery. In fact it is not uncommon for a second surgery to be necessary three to four years after the original operation.[52,53] The second surgical procedure frequently involves repeat soft tissue release with additional bone work as needed. In a recent study we found that more than one clubfoot operation was required in 56% of 27 clubfeet.[53]

Age for Surgery

The exact age for surgery is a controversial subject and quite variable. While neonatal clubfoot surgery has produced good results[54], it is not frequently performed because of the increased incidence of postoperative fibrosis, scarring and stiffness. Surgery between three and six months of age may optimize realignment of the talus, calcaneus, and navicular and results in better remodeling of the articular surfaces.[49] The risks of general anesthesia are reduced after the age of six months.[77] Turco[76] thought that children should be operated on when they are older than 1 year of age. He felt that operations in very young children were technically more difficult to perform and that errors of over-correction or under-correction would be magnified with subsequent growth. If the child was ready to walk when the casts were removed, the natural dorsiflexion force produced by weightbearing would make recurrence less likely. In another large study good or excellent results were obtained in 94%

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Figure 4. Twister cables with braces, corrective shoes, and casts used in the conservative treatment of clubfoot in this child.

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of patients operated on between the ages of six months and five years.[78] Simons[60] recommends that the foot should be at least 8 cm long (3 inches) prior to surgery. Giurini and Carroll[34] operate when the child is more than three months old, weighs at least 12 pounds and is thriving well.

Figure 5. Notice the small size of the infant foot at the beginning of surgical procedure.

Nature of the Surgical Procedure

The initial clubfoot surgery almost always involves pure soft tissue release of the deforming contracted tight structures with no bony procedures. There are a variety of soft tissue releases, which differ mostly in degree.

Turco Procedure

Turco introduced the one stage soft-tissue posteromedial release[82] with internal fixation, which is still used widely today.[36] The Turco procedure serves as the baseline from which many modifications and variations have evolved. The posterior and medial soft tissue contractures are released to permit the realignment of the abnormal anatomy of the bones and the corrected realignment is fixed with a single Kirschner wire through the talonavicular joint. The postoperative stiffness of the foot with the Turco procedure is considerably less than the more extensive soft tissue releases.[33]

Modified Turco Technique

The authors prefer a modified Turco procedure, ideally performed between the ages of about 9 months and 2 years (Figure 5). A tourniquet is not used because of the irregularities of vasculature in the clubfoot.[29,83-85] A 15-centimeter hockey stick incision is made starting from above the malleolus and running to the base of the first metatarsal (Figure 6). A medial linear incision should never be done because it is

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Figure 6. 15 centimeter hockey stick incision on medial aspect of foot.

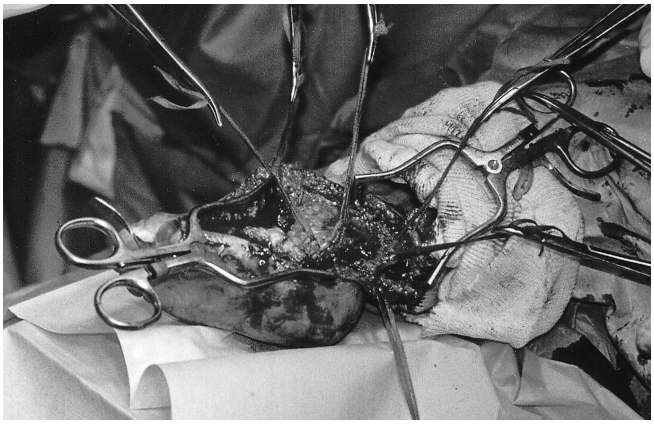

Figure 7. Identification of flexor digitorum longus, flexor hallucis longus, Achilles tendon, and vascular bundle.

Figure 8. At the end of the surgical procedure the foot can be dorsiflexed to a right angle to the leg and the talonavicular joint is relocated from its subluxed position and percutaneously fixed with .45 k-wire to maintain correction.

Figure 9. Above knee plaster cast applied immediately postoperatively.

not long enough to open the desired areas.

The medial release is performed first to correct the hindfoot varus and adductus. The medial release includes: posterior tibial tendon lengthening, talonavicular joint capsulotomy, superficial deltoid ligament release, spring ligament release, subtalar joint release of capsules and navicular realignment, which requires K-wire fixation (Figure 7).

The master knot of Henry is attached to the navicular and encloses the FHL and the FDL as they cross each other under the navicular. This fibrous tissue must be released to allow for an adequate soft tissue release although lengthening of the FDL and FHL may not be necessary. Of these two tendons the FDL is the more deforming factor.

The childhood clubfoot has frequently been altered by serial casting and surgical correction.

The posterior release corrects ankle equinus and includes "Z" plasty of the tendoAchilles for lengthening, ankle and subtalar joint capsulotomy, calcaneofibular ligament release, and superficial deltoid ligament release, interosseous ligament release, and tibiofibular ligament release. Note that if the clubfoot will not reduce unless the interosseous ligament is released. Avoiding release of the deep deltoid ligament will prevent over-correction.

A plantar release may be added to help to reduce residual metatarsus adductus. This involves release of the first layer of plantar intrinsic muscles to include the abductor hallucis, the abductor digiti quinti, the flexor digitorum brevis, and the plantar fascia. At the end of the surgery the foot should reduce to a neutral position (90° foot to the leg) (Figure 8).

An above knee cast is applied postoperatively during the first four to six weeks (Figure 9). A plaster cast is used for the best molding with a fiberglass top layer to make the cast more durable. A second above knee cast is applied for another three weeks bringing the patient to the eighth week of surgery. Below knee casting may be continued for up to six months to correct any residual deformities. Tone reducing ankle foot orthoses during the day, clubfoot shoes, and night splinting are frequently used until maturity to prevent relapse.

Cincinnati Incision

The Cincinnati incision is a transverse incision for increased exposure to the medial, lateral, and posterior aspect of the foot and ankle. The incision extends from the medial to

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the lateral aspect of the foot over the posterior aspect of the ankle.[86] Crawford and associates[86] used the Cincinnati incision to perform a posteromedial release in 38 clubfeet and reported excellent results.

Complete Subtalar Joint Release/ Circumferential Release

The major difference between the Turco procedure as described above and so-called complete circumferential soft tissue releases is that the latter involves total release of the subtalar joint. When this is done surgical pin fixation and casting must be left in place for three to four months. Complete subtalar joint release has been advocated by a variety of authors.[60,66,87,88-90] McKay believes that the calcaneus is rotated around a vertical axis with the anterior calcaneus internally rotated and the posterior calcaneus externally rotated.[87] The operation involves rotating the calcaneus at the subtalar joint level.[89,90] The McKay one-stage subtalar soft-tissue release is a circumferential soft-tissue release which involves releasing the posterior, medial, lateral, and plantar soft tissues of the foot.[78,87,91]

In one study comparing the McKay complete circumferential release with the Turco posteromedial release, patients with the more com-

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TABLE 2: Calf Girth, Foot Length, Limb Length Discrepancy, Results of Studies

CALF GIRTH	CALF GIRTH (INCHES)
Laveeg & Ponseti, 1980 (96)	0.9
Ghali, Smith, Clayden, Silk, 1983 (97)	0.5
Ricciardi-Polini, Ioppolito, Tudisco, Farsetti, 1984 (98)	1.4
Magone, Torch, Clark, Kean, 1989 (88)	1.3
Aronson & Puskarich, 1990 (35)	0.3
Atar, Lehman, Grant, Strongwater, 1991 (61)	1
Devalentine & Blakeslee, 1992 (99)	1.1
Cohen-Sobel, Caselli, Giorgini, Giorgini, Stummer, 1993 (36)	1
Blakeslee, 1997 (100)	0.83
Uglow & Clarke, 2000 (71)	.5 (mild clubfoot) .72 (moderate clubfoot) .72 (severe clubfoot)
Reichel, Lebek, Milikic, Hein, 2001 (80)	0.6

FOOT LENGTH	FOOT LENGTH (INCHES)
Bjonness, 1975 (101)	0.8
Laaveg & Ponseti, 1980 (96)	0.5
Magone, Torch, Clark, Kean, 1989 (88)	0.5
Atar, Lehman, Grant, Strongwater, 1991 (61)	0.6
Aronson & Puskarich, 1990 (35)	0.5
DeValentine & Blakeslee, 1992 (99)	0.8
Cohen-Sobel, Caselli, Giorgini, Giorgini, Stummer, 1993 (36)	0.8
Blakeslee, 1997 (100)	0.6
Huang, Lei, Zhao, Wange, 1999 (78)	0.6
Reichel, Lebek, Milikic, Hein, 2001 (80)	0.4

LIMB LENGTH DIFFERENCE	LIMB LENGTH DIFFERENCE (INCHES)
Laaveg & Ponseti, 1980 (96)	0
Ghali, Smith, Clayden, Silk, 1983 (97)	0.5
Hutchins, Foster, Paterson, Cole, 1985 (55)	0.4
Atar, Lehman, Grant, Strongwater, 1991 (61)	0.5

*Numbers in parenthesis refer to reference list.

plete release had more complete correction and greater range of motion.[92] More recently, Haasbeek and Wright[93] compared the results of posterior release with those of comprehensive release with an average 21-year follow-up. They found that the group with comprehensive releases had fewer surgeries, more

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TABLE 3: CLINICAL RESULTS OF CLUBFOOT STUDIES

(Forefoot Adductus/Heel Varus/Heel Valgus/Cavus/ Ankle Dorsiflexion)

FOREFOOT ADDUCTUS	PERCENT
Attenborough, 1972 (102)*	79%
Low & Hannon, 1973 (103)	52%
Main & Crider, Polk, Lloyd-Roberts 1977 (56)	78%
Main & Crider, 1978 (104)	69%
Hutchins, Foster, Paterson, Cole, 1985 (55)	20%
Otremski, Salama, Khermosh, Wientraub, 1987a (62)	48%
Otremski, Salama, Khermosh, Wientraub, 1987b (105)	9%
Brougham & Nicol, 1988 (66)	66%
Yamamoto & Furuya, 1988 (106)	34%
Lau, Meyer, Lau., 1989 (68)	17%
Magone, Torch, Clark, Kean, 1989 (88)	51%
Porat & Kaplan, 1989 (69)	18%
Yngue, Gross, Sullivan, 1990 (74)	28%
Tarraf & Carroll, 1992 (70)	81%
DeValentine & Blakelee, 1992 (99)	41%
Cohen-Sobel, Caselli, Giorgini, Giorgini, Stummer, 1993 (36)	60%
Blakeslee, 1997 (100)	41%
Rumyantsev & Ezrohi, 1997 (75)	12%
Simbak & Razak, 1998 (107)	63.9% (Metatarsus adductus)
Joseph, Ajith, Varghese, 2000 (79)	24%
Uglow & Clarke, 2000 (71)	18.5% mild clubfoot
	39% moderate clubfoot
	22% severe clubfoot
Reichel, Lebek, Milikic, Hein, 2001 (80)	13%
Faraj & Nevelos, 2001 (81)	31% mild forefoot adductus

HEEL VARUS	PERCENT
Laaveg & Ponseti, 1980 (96)	27%
Hutchins, Foster, Paterson, Cole, 1985 (55)	17%
Otremski, Salama, Khermosh, Wientraub, 1987b (105)	9%
Yamamoto & Furuya, 1988 (106)	11%
Lau, Meyer, Lau., 1989 (68)	5%
Magone, Torch, Clark, Kean, 1989 (88)	6%
Tarraf & Carroll, 1992 (70)	38%
Cohen-Sobel, Caselli, Giorgini, Giorgini, Stummer, 1993 (36)	35%
Blakeslee, 1997 (100)	3%
Rumyantsev & Ezrohi, 1997 (75)	3%
Simbak & Razak, 1998 (107)	11%
Joseph, Ajith, Varghese, 2000 (79)	7%

HEEL VALGUS (Excessive)	PERCENT
Turco, 1979 (76)	8%
Ghali, Smith, Clayden, Silk, 1983 (97)	12%
Otremski, Salama, Khermosh, Wientraub, 1987b (105)	4%

*Numbers in parentheses refer to reference list.

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complete correction of heel varus, and better subtalar motion than those with posterior releases.

Simons also advocates a one-stage circumferential subtalar joint release, which differs from the McKay procedure in emphasizing the release of the interosseous talocalcaneal ligament as well as the posterior talofibular ligament. He stresses intraoperative radiographs to verify the correction.[89,90] Most recently, Simons' complete subtalar joint release was found to be the most efficient method of surgery both functionally and radiogologically, in cases of idiopathic clubfoot in infants, as compared with Turco's posteromedial release.[65] Over-correction and secondary multi-planar foot deformities are the main problems with extensive complete subtalar release[75] and in one study were avoided by the use of perioperative radiographs.[65]

Figure 10. Residual rearfoot varus in child with clubfoot.

Inaccurate talocalcaneal pinning, when the calcaneus is displaced laterally beneath the talus, causes severe valgus deformity.[75] Over-correction is prevented by preserving the deep anterior portion of the deltoid ligament and the interosseous ligament between the talus and calcaneus, avoiding over displacing the navicular laterally, and not over-lengthening the tendo Achilles or the tibialis posterior.[49]

Carroll's surgical technique involves internally rotating the talus in the ankle mortise, which requires extensive soft tissue release with complete plantar, lateral, medial and posterior release.[94] Posteroplantar and posterolateral release are additional variations of soft tissue release procedures.[80,81,95]

Results & Evaluation of Surgery

Treatment for clubfoot never results in a normal foot. Calf atrophy, difference in foot size, limb-length difference (Table 2), limitation of ankle joint and subtalar joint mo-

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bility, and in-toe gait are common regardless of treatment (Table 3).[36,53] However, treatment should result in a painless, aesthetically pleasing and functional plantigrade foot (Table 4).[36]

The patient's gender, whether the deformity is unilateral or bilateral, age at which the child first walked, age at which surgery is performed, the exact nature of the operation, and the type of postopera-

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TABLE 3:
CLINICAL RESULTS OF CLUBFOOT STUDIES
(Forefoot Adductus/Heel Varus/Heel Valgus/Cavus/ Ankle Dorsiflexion) *(Continued)*

HEEL VALGUS (Excessive)	PERCENT
Yamamoto & Furuya, 1988 (106)	11%
Lau, Meyer, Lau., 1989 (68)	6%
Porat & Kaplan, 1989 (69)	9%
Yngue, Gross, Sullivan, 1990 (74)	4%
Cohen-Sobel, Caselli, Giorgini, Giorgini, Stummer, 1993 (36)	9%
Rumyantsev & Ezrohi, 1997 (75)	9% (>10 degrees)
Reichel, Lebek, Milikic, Hein, 2001 (80)	13%

CAVUS	PERCENT
Attenborough, 1972 (102)*	16%
Otremski, Salama, Khermosh, Wientraub, 1987b (105)	15%
Magone, Torch, Clark, Kean, 1989 (88)	40%
Tarraf & Carroll, 1992 (70)	30%
Cohen-Sobel, Caselli, Giorgini, Giorgini, Stummer, 1993 (36)	18%
Blakeslee, 1997 (100)	22%
Simbak & Razak, 1998 (107)	11%

EQUINUS	PERCENT
Thompson, Richardson, Westin, 1982 (108)	13%
Addison, Fixsen, Lloyd-Robert, , 1983 (109)	38%
Otremski, Salama, Khermosh, Wientraub, 1987b (105)	2%
Tarraf & Carroll, 1992 (70)	15%
Blakeslee, 1997 (100)	3%
Rumyantsev & Ezrohi, 1997 (75)	3%
Joseph, Ajith, Varghese, 2000 (79)	0%
Reichel, Lebek, Milikic, Hein, 2001 (80)	2%

ANKLE DORSIFLEXION	DEGREES
Laaveg & Ponset, 1980 (96)	13 degrees
Hutchins, Foster, Paterson, Cole, 1985 (55)	0 degrees
Porter, 1987 (110)	15 degrees
Yamamoto & Furuya, 1988 (106)	12 degrees
Lau, Meyer, Lau., 1989 (68)	7.3 degrees
Porat & Kaplan, 1989 (69)	12 degrees
Yngue, Gross, Sullivan, 1990 (74)	11 degrees
Aronson & Puskarich, 1990 (35)	9.3 degrees
McHale & Lenhart, 1991 (111)	5 degrees
Cohen-Sobel, Caselli, Giorgini, Giorgini, Stummer, 1993 (36)	4 degrees
Hudson & Catterall, 1994 (95)	15 degrees
Faraj & Nevelos, 2001 (81)	20 degrees

*Numbers in parenthesis refer to reference list.

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tive management are all related to the outcomes of surgery.[71] However, it seems that the outcome of treatment in idiopathic clubfoot has also been strongly linked to the severity of the initial clubfoot deformity.[57,70,71,78,112-114] For this reason, there has been emphasis on dividing clubfoot into categories of simple and resistant cases in an attempt to predict which will correct most easily.

Attenborough[112] separated clubfoot into easy and difficult clubfoot. He felt that cases which resolved with strapping or serial casting involved the sole deformity of excessive medial deviation of the talar neck at birth.

Harold and Walker[113] grouped the clubfoot into three grades based on foot flexibility. Dimeglio et al.[114] divided the clubfoot into four categories of increasing severity. The first group was the completely correctable soft postural clubfeet which these authors felt should not even be included in rating the results of clubfoot surgery because they tend to increase good results. Grade 2 were considered moderate clubfoot. Grade 3 are the resistant but partially reducible clubfeet. Grade 4 were the total stiff teratological clubfeet usually associated with a syndrome such as arthrogryposis. This grading system has been used in studies of the functional outcome of surgery.[71]

Figure 11A. Left clubfoot is one inch shorter than other side, resulting in pes planovalgus right foot.

Figure 11B. Posterior view of patient from Figure 11A showing compensatory right hindfoot valgus.

Childhood Clubfoot

The childhood clubfoot has frequently

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been altered by serial casting and surgical correction. However, residual deformities are extremely common (Table 2 & 3).[3,36] Paradoxically, while rearfoot equinus deformity is the most common reason for initial surgery, forefoot adduction is the most common residual problem after clubfoot surgery and results in a noticeable in-toe gait. In-toe gait is the most frequent sequelae of the Turco procedure, reported to occur in one-third of all patients. Compensatory lateral tibial torsion may develop to correct the in-toe gait. Residual equinus, varus, and mild cavus deformity is also common (Figure 10).

Generally, ankle and subtalar joint range of motion is found to be reduced in children with clubfoot. Children who can bring their foot to a right angle with the leg (0 degrees dorsiflexion) usually function quite well (Table 3).[36]

During childhood, differences in size between the clubfoot side and the normal side become more apparent. As compared to the normal lower extremity, the lower extremity with the clubfoot is about 1/2 inch shorter, the calf is about one inch thinner and the clubfoot is about an inch shorter in width than the normal foot (Figure 11A/B). Smallness of the foot and calf are an inherent and permanent part of the clubfoot and are not improved by exercises or surgery. These differences are less pronounced when the clubfoot is bilateral.

Treatment of Childhood Clubfoot

In-toe gait can be treated with shoes with a straight or abducted last. In young children, the Bebac shoe can be used. The Wheaton Brace and other forms of night-splinting may also be helpful.

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Figure 12. Left hindfoot varus in adult with clubfoot.

Figure 13A. Neglected clubfoot in an adult male. Notice nonplantigrade left foot.

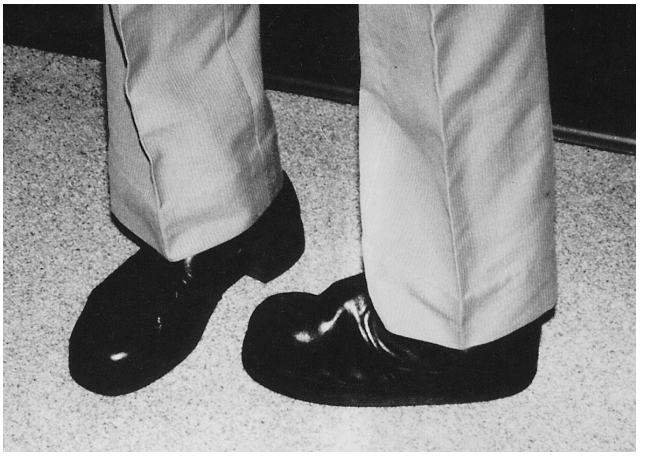

Figure 13B. Same patient from Figure 13A. When this man walks forward he has a -60° angle of gait on the left.

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If residual equinovarus is severe, daytime bracing may be necessary. Bracing may include the plastic shoe insert type orthosis, which cannot be seen under slacks, or the double or single upright Phelp's brace. If residual equinovarus and forefoot problems become particularly severe so that the child is tripping and having difficulty walking, repeat clubfoot surgery may be necessary. Approximately 25-50% of all patients require repeat surgery for clubfoot.

Clubfoot in Adults

The adult with clubfoot usually has some of the same deformities that are seen in children (Figure 12).[3] The side with the clubfoot is shorter, the calf is thinner and the foot is smaller. The forefoot may actually be quite wide in relation to the heel from years of walking more on the front part of the foot. Calluses on the outer aspect of the foot, especially the base and head of the fifth metatarsal and the lateral heel, as a result of increased pressure on the lateral side of the foot, are deep and painful. Patients may complain of lateral ankle sprains, and pain from frequently walking on the outside of their feet. Range of motion of the ankle joint and subtalar joint are usually limited. A recent study found that adults with clubfoot usually gravitate to more sedentary occupations.

At skeletal maturity, the corrected clubfoot is one-half shoe size smaller than the non-affected foot.

Treatment of Adult Clubfoot

In treating the adult with clubfoot who has had casting and surgery, residual deformities such as hindfoot varus and equinus and forefoot adductus must be addressed. Initial debridement of painful calluses on the plantar lateral aspect of the foot brings the patient great relief. Patients with ankle sprains and lateral instability are helped by high-top shoes and additions to the lateral aspect of the shoe, such as lateral valgus wedging on the sole of the shoe and lateral buttressing on the outer side of the shoe. Stirrup and cloth ankle braces may be used to support the laterally unstable ankle.

At skeletal maturity, the corrected clubfoot is one-half shoe size smaller than the non-affected foot. Usually buying shoes to fit the larger foot is sufficient. A 1/4 inch heel lift inside the shoe is generally enough to balance a limb length

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discrepancy. If more than a 1/2 inch lift is required, it must be placed on the outside of the shoe.

Foot orthotics should have good shock absorption, as the clubfoot is often somewhat rigid and is not a good shock absorber. Foot orthoses may also contain lateral valgus wedging and high lateral flanges.

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TABLE 4: FUNCTIONAL RATINGS OF CLUBFOOT STUDIES

NEVER/RARELY HAVE PAIN	
Laaveg & Ponseti, 1980 (96)	59%
Hutchins, Foster, Paterson, Cole, 1985 (55)	80%
Yamamoto & Furuya, 1988 (106)	93%
Aronson & Puskarich, 1990 (35)	93%
Yngue, Gross, Sullivan, 1990 (74)	68%
Cohen-Sobel, Caselli, Giorgini, Giorgini, Stummer, 1993 (36)	93%
Sobel, Giorgini, Michel, Cohen, 2000 (53)	95%
PAIN ONLY AFTER ACTIVITY	
Green & Lloyd-Roberts, 1985 (58)	13% (pain during activity)
Porter (1987) (110)	50% (Aching legs after exercise)
Lau, Meyer, Lau, 1989 (68)	11% (pain with strenuous activity)
Ynge, Gross, Sullivan, 1990 (74)	26% (Pain with mild activity)
Devalentine & Blakeslee, 1992 (99)	40% (ccasional pain caused by limping)
CAN PERFORM FULL PHYSICAL ACTIVITY	
Bjonness, 1975 (101)	72%
Laaveg & Ponseti, 1980 (96)	72%
Addison, Fixsen, Lloyd-Roberts, 1983 (109)	76%
Hutchins, Foster, Paterson, Cole, 1985 (55)	90%
Porter, 1987 (110)	100%
Brougham & Nicol, 1988 (66)	75%
Lau, Meyer, Lau, 1989 (68)	90%
Cohen-Sobel, Caselli, Giorgini, Giorgini, Stummer, 1993 (36)	80%
Sobel, Giorgini, Michel, Cohen, 2000 (53)	95%
SAME SIZE SHOES	
Bjonness, 1975 (101)	95% (Shop shoes)
Laaveg & Ponseti, 1980 (96)	99%
Ghali, Smith, Clayden, Silk, 1983 (97)	10%
Yamamoto & Furuya, 1988 (106)	86%
Aronson & Puskarich, 1990 (35)	62%
Cohen-Sobel, Caselli, Giorgini, Giorgini, Stummer, 1993 (36)	84%
Uglow & Clarke, 2000 (71)	91% (for mild clubfoot) 61% (for moderate clubfoot) 25% (for severe clubfoot)
LIMPING	
Laaveg & Ponseti, 1980 (96)	0%
Yamamoto & Furuya, 1988 (106)	11%
Cohen-Sobel, Caselli, Giorgini, Giorgini, Stummer, 1993 (36)	9% (mild limp) 27% (marked limp)
Uglow & Clarke, 2000 (71)	11%

*Numbers in parenthesis refer to reference list.

Clubfoot...

Orthotic materials are variable and may include leather, thermoplastics, and polyethylene foams.

Adult Neglected Clubfoot

Many individuals in developing countries receive no treatment for clubfoot either through ignorance or lack of access to medical care.[115] In these countries, clubfoot is a major crippling disorder. Neglected clubfoot contains all the features of congenital clubfoot with secondary changes from weightbearing and walking. Rigid hindfoot equinus and varus and forefoot varus result in a stiff and non-plantigrade foot, which forces the individual to walk on the dorsum of the foot (Figure 13A/B). The skin on the dorsolateral aspect of the foot becomes hypertrophied and pigmented and develops a large subcutaneous bursa. The untreated adult clubfoot is small because the abnormally tight ligaments and tendons present during infancy act as a tether to prevent further growth. Although the foot is stiff and grossly abnormal in shape, pain and osteoarthritis are surprisingly minimal.

Treatment of Adult Neglected Clubfoot

The greatest challenge for these patients is wearing shoes. Their feet are severely deformed and they usually are unable to fit into off-the-shelf shoes. Molded shoes are a necessity for these individuals. Surgery is challenging in adults with neglected clubfoot, and is usually done for cosmetic appearance and to give the patient greater self-esteem. Operations for the neglected adult clubfoot involve major bony reconstruction and triple fusions. n

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TABLE 5: SUMMARY OF TREATMENT FROM INFANT TO ADULT

INFANT CLUBFOOT

- Serial casting for 3-6 months
- Surgical treatment—posterior medial plantar release performed between age 1 and 2

CHILDHOOD CLUBFOOT

- Straight last shoe, abducted last shoe or Bebac shoe for in-toe as a result of forefoot adductus
- High top shoes may be more comfortable if residual equinovarus is present
- Heel lift usually no greater than 1/4–1/2 inch is sufficient to balance limb length difference
- Nightsplinting after surgery may be required to maintain correction until maturity.
- Day time bracing to control residual equinus may be necessary until maturity.
- Repeat surgery soft tissue release is common for residual equinovarus, cavovarus, and forefoot adductus

ADULT CLUBFOOT

- Debridement of deep callosities on lateral plantar aspect of foot.
- High top shoes, valgus heel and sole wedges, lateral build up on outside of shoes, lateral buttress, lateral float for lateral ankle instability.
- Stirrup or cloth ankle brace to support varus foot and ankle.
- Heel lift from 1/4 to 1/2 inch usually sufficient to balance limb length difference.
- Shoe fitting to larger foot or two different size shoes may be necessary if pronounced difference in size of feet.
- Soft foot orthoses made of leather, foams, spenco, to accommodate and provide shock absorption for rigid clubfoot.

NEGLECTED ADULT CLUBFOOT

- Molded Shoes
- Radical surgery to include total realignment and possibly triple arthrodesis

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EXAMINATION

Continuing Medical Education

See answer sheet on page 153.

1) Which statement is INCORRECT about the incidence of clubfoot?
   A) 1/1000 neonates is born with a clubfoot.
   B) Males are affected with clubfoot two times more frequently than females.
   C) The left foot is more frequently involved with clubfoot than the right foot.
   D) 50% of clubfoot is bilateral.

2) Although females are less frequently affected with clubfoot deformity, when a female does have a clubfoot, it is likely to have a more severe clubfoot deformity than in males with clubfoot. This is due to:
   A) Autosomal dominant inheritance
   B) Autosomal recessive inheritance
   C) Sex-linked threshold effect
   D) Polygenic multifactorial inheritance

3) The risk of clubfoot to a second child after the family has given birth to a first born with clubfoot is:
   A) 1 in 100
   B) 1 in 20
   C) 1 in 7
   D) 1 in 5

4) What is the cause of congenital clubfoot?
   A) Multi-factorial genetics, but the actual etiology is largely unknown
   B) Retracting fibrosis
   C) Muscular
   D) Primary germ plasm defect of talar neck resulting in plantar flexion and inversion of the talar neck

5) Which muscle/tendons are stretched and weakened in clubfoot deformity?
   A) TendoAchilles
   B) Tibiales posterior
   C) Flexor digitorum longus and flexor digitorum brevis
   D) Peroneus longus and peroneus brevis

6) When a child has a unilateral clubfoot, the clubfoot as compared to the unaffected "normal" side is usually:
   A) Shorter leg and thinner calf girth than the normal side
   B) Shorter leg, but not thinner calf girth than the normal side
   C) Thinner calf girth, but not shorter leg than the normal side
   D) Approximately the same leg length and calf girth as compared to the normal side

7) You are x-raying an infant with a left clubfoot. The angle of Kite is 15°. The lateral talocalcaneal angle is 20°. What conclusions can you draw from these results?
   A) The infant does not have clubfoot.
   B) There is a severe equinus deformity with little or no rearfoot varus but the talocalcaneal index is normal.
   C) There is a rearfoot varus deformity, the angle of Kite is abnormally low and the talocalcaneal index is abnormal.
   D) There is both rearfoot varus and equinus deformity, but the talocaneal index is normal.

8) Which of the following is INCORRECT regarding serial casting for clubfoot?
   A) Serial casting may involve above knee or below knee casts.
   B) Serial casts can be constructed of plaster or fiberglass.
   C) Ideally casting should be performed immediately after birth or may be delayed to five days after birth.
   D) For very severe rigid clubfoot serial casting should be avoided.

9) What is the Ponseti Technique?
   A) Serial casting combined with tendoAchilles lengthening when necessary.
   B) Soft tissue release.
   C) Posterior medial release.
   D) Combines only conservative measures to correct clubfoot, including serial casting for long periods and Dennis Brown splinting.

10) The best time for a child with clubfoot to undergo surgery is:
   A) As soon after birth as possible.
   B) After the child begins walking.
   C) Before the child begins walking.
   D) Between 3 months and 1 year of age.

11) The initial clubfoot surgery is usually:
   A) Soft tissue release
   B) Soft tissue release combined with appropriate bony procedures
   C) Ponseti procedure
   D) Soft tissue release and calcaneal osteotomy

12) What is the Turco procedure?
   A) Posterior plantar release
   B) Posterior medial release
   C) Posterior medial plantar release
   D) Medial release

13) What is a key advantage of the Turco procedure in correction of clubfoot over more extensive soft tissue releases?
   A) It requires no internal fixation.
   B) There is less postoperative stiffness.
   C) It can be performed at an earlier age.
   D) It requires only one incision.

14) What type of incision is used for the Turco procedure?
   A) Hockey stick incision
   B) Medial linear incision
   C) Cincinatti incision
   D) Double incision

Continued on page 152

Continuing Medical Education

EXAMINATION

(cont'd)

15) When performing a complete subtalar joint release, over-correction can be prevented by preserving the:
- A) Spring ligament
- B) Subtalar joint
- C) Master knot of Henry
- D) Deep Deltoid Ligament

16) The purpose of the plantar release as part of the Turco procedure to correct clubfoot is to:
- A) Correct rearfoot varus
- B) Correct equinus
- C) Correct metatarsus adductus
- D) Correct calcaneus

17) The main problem in extensive soft tissue release of McKay and Simons is:
- A) Over-correction
- B) Long-term reduced range of motion
- C) Poor radiographic results
- D) Patients tend to need more operations

18) Recent studies seem to show that surgical clubfoot patients who had more complete correction of heel varus and better subtalar motion had undergone:
- A) Comprehensive soft tissue releases
- B) Turco release
- C) Cincinnati incision
- D) Ponseti technique

19) According to the results of most studies it would appear that the most important factor which determines the outcome of surgery is:
- A) The age at which the initial operation is performed
- B) The initial severity of the clubfoot
- C) The type of soft tissue release performed at initial operation
- D) Whether the clubfoot is unilateral or bilateral

20) Neglected clubfoot refers to:
- A) Very severe clubfoot
- B) Clubfoot with a particularly strong equinus component
- C) Adult clubfoot with no surgical correction, generally most common in so-called developing or third world countries
- D) Any clubfoot partially corrected by serial casting only, with no surgery.

See answer sheet on page 153.

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EXAM #8/02
Clubfoot
(Sobel/Giorgini)

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2.	A	B	C	D	12.	A	B	C	D
3.	A	B	C	D	13.	A	B	C	D
4.	A	B	C	D	14.	A	B	C	D
5.	A	B	C	D	15.	A	B	C	D
6.	A	B	C	D	16.	A	B	C	D
7.	A	B	C	D	17.	A	B	C	D
8.	A	B	C	D	18.	A	B	C	D
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