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Review Article

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Ultrasonographic evaluation of clubfoot and it's correction by Ponseti method: a review

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ABSTRACT

Ultrasound is a relatively simple, non-invasive and easily available, inexpensive procedure for objective documentation of clubfoot correction without exposing the baby to radiation risk. Also with clinical classifications it is difficult to quantify precisely and objectively the degrees of medial displacement of the navicular in relation to the talar head or of the calcaneocuboid joint deformity which can be assessed by dynamic sonography. Ultrasound shows to be a promising technique for assessing deformity & monitoring of clubfoot treatment. Clinical scoring method by Pirani scoring is commonly practiced and quite popular. The validity of this clinical Pirani score could be reinforced if supplemented by sonographic assessment, before and after treatment, to confirm return of normal anatomic relationships between the different bones.

Keywords: Ultrasound, Clubfoot, Ponseti maneuver, Pirani score

INTRODUCTION

Congenital talipes equinovarus (CTEV) or clubfoot is one of the most common congenital orthopaedic disorder that surgeons encounter in their day to day clinical practice. Since Hippocratic times (300 B.C.) clubfoot has remained one of the difficult and most perplexing problems for the orthopaedic surgeons to treat successfully. Various operative and non-operative treatment modalities where recommended from time to time achieving variable success rates but still there was no consistency in results. Most orthopaedic surgeons agree that the initial treatment of congenital clubfoot should be non-operative and should be initiated as soon as possible after birth, so as to take advantage of the fibroelastic properties of the connective tissues that forms the ligaments, joints, capsules and tendons. Herzenberg et al. reintroduced Ponseti's principles of clubfoot management¹ and popularized it worldwide. It is now considered as the gold standard in management of clubfoot.

Assessment of the degree of initial deformity along with monitoring of correction of its various components is another crucial component in the management of clubfoot. Assessment of the non-ossified components of clubfoot had not been possible until the advent of new imaging modalities such as US Ultrasonography (US) as radiation free, easily available, non-invasive imaging modality has shown to be a promising tool in assessment of initial deformity and evaluation of clubfoot correction by Ponseti maneuver. With additional role during percutaneous sectioning of

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Achilles tendon for correction of congenital clubfoot residual equines and evaluation of tendon repair.

Several clinical scoring system can objectively quantify severity of disease before and after the treatment.²⁻⁵ Pirani scoring system has been widely used before, during and after the treatment, serving both as guide to treatment and for clinical confirmation of completion of treatment. Ultrasonographic assessment supplements the validity of Pirani scoring by evaluating the change in the anatomic relationship of different bones during the course of treatment. Various studies have been performed for sonographic examination of clubfoot. 6-18 Descriptive assessment of the alignment of various cartilaginous anlage, comparing clinical or radiological assessment with sonography, classification of the deformity. Work on quantification of the deformity either angular or linear, is limited. The field of sonographic assessment of clubfoot still demands a lot because only the surface has been scratched since the introduction of US probe to clubfoot.

This article is an author's attempt to lay emphasis on serial evaluation of correction as done by clinical scoring system, sonography as a tool supplementing present clinical system and importance of evaluation of tenotomy, which has been widely neglected over other sonographic parameters, to develop a standard approach in assessment and sonographically relate clinical parameters.

METHODS

The US examination is performed with an ultrasound machine using 5-15 MHz linear probe with a 26 mm and 45 aperture and a standoff pad; with baby in mother's lap preferably feeding (without sedation). The examiner held the clubfoot in neutral and maximally correct position with one hand and ultrasound probe by other hand, occasionally with parent's help in stabilizing the leg. The contra lateral normal foot on babies with unilateral clubfoot should be investigated and assessed at the same occasion as when the deformed foot is examined. Each foot is to be examined through four standard projections before initiating the treatment and during the course of treatment, while performing percutaneous sectioning of Achilles tendon and after completion of treatment. Each feet has to be assessed clinically prior to treatment and on each visit using either six point Pirani scoring or Dimeglio scoring system, for clinical reference of completion of treatment.

Projections and measurements

The feet are examined through four standard projections (medial, dorsal, lateral and posterior) medial, dorsal, posterior projection as described by Aurell et al. 8,9 and Posterior projection as described by Bhargava et al. 18

Measurements are done by the radiologist defining the end points on sonographic monitor of the best images recorded in optimally correct position. There are various parameters that are assessed on dynamic sonography and these are dealt separately. On sonography ossification centre appear as bright white in colour because of increased echogenicity as compared from hypoechoic cartilaginous component.

Medial projection

Medial projection is attained by placing the transducer on medial side of the foot in a slightly oblique/vertical direction (i.e. almost in line with tibia) to match the degree of equines as shown in Figure 1. Shortest distance between medial malleolus and medial part of navicular is measured to assess the severity of deformity in the talonavicular complex. This distance is termed as Medial Malleolus-Navicular Distance (MM-N Distance). Echogenic band termed as "gristle", is observed between medial malleolus and navicular as shown in Figure 2. Medial displacement of navicular in relation to the head the talus is scored on a 3 grade scale as shown in Table 1.



Figure 1: Medial projection: transducer on medial side of foot - vertical direction.

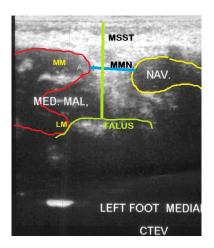


Figure 2: Medial projection: gristle is observed between MM and navicular and measured; medial soft tissue thickness, is also measured on medial view.

Table 1: Showing grading of medial displacement of navicular in relation to head of talus.

Grading	Displacement
Grade 1	No displacement
Grade 2	<50% displacement
Grade 3	>50% displacement or complete subluxation

Medial soft tissue thickness at the level of talar ossification center can also be evaluated. Range of mobility of talonavicular joint is assessed dynamically and is discussed later.

Dorsal projection

For dorsal projection the probe has to follow the main direction of the talus i.e. be placed more laterally then on a normal foot, when the head of talus is directed laterally as shown in Figure 3. The length of talus can be measured as shown in the Figure 4. Navicular is described by subjective assessment on dynamic sonography as in alignment, plantar or dorsal displacement.



Figure 3: Dorsal projection: probe slightly lateral compared from normal foot to follow the direction of talus.

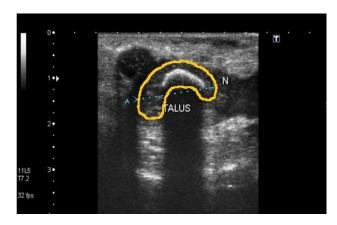


Figure 4: Dorsal view of talus with the foot held in full plantar flexion to determine maximum length.

Lateral projection

Calcaneo-Cuboid relationship is assessed by measuring Calcaneo-Cuboid distance (CC distance) and the Calcaneo-Cuboid angle (CC angle) as shown in Figure 5. Lateral projection is obtained with probe at lateral border of foot lateral to its plantar aspect (Figure 6) as demonstrated by Aurell et al. 8,9 and Calcaneo-Cuboid relationship can be visualized. A tangent is drawn along the lateral border of calcaneum and a perpendicular is drawn from the tangent to the lateral border of cuboid over the midpoint of ossification, this distance denotes CC distance. The angle subtended by the tangent to lateral border of calcaneum and cuboid denotes Calcaneo-Cuboid angle.



Figure 5: Lateral projection: probe over lateral aspect of foot parallel to its plantar aspect.

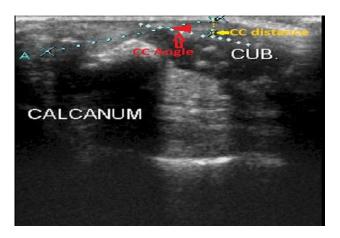


Figure 6: Tangents over Calcaneum and Cuboid subtend CC angle and perpendicular distance from tangent over calcaneum to surface of midpoint of cuboid.

Posterior projection

Bhargava et al. demonstrated importance of this projection for assessing various parameters as an indicator of equinus. Transducer is placed vertically on the back of foot in midline partly on heel and partly on leg (Figure 7), to assess Tibiocalcaneal relationship,

posterior compartment soft tissue thickness and length of tendoachilles (Figure 8). Posterior projection is also important for evaluation of Achilles tendon percutaneous sectioning²⁰ and its repair as shown in study by Maranho D et al.²⁰ Apart from these above discussed above Desai et al.¹¹ also measured, talo-cuneiform angle, i.e. angle between a line drawn along the medial border of the talar ossific nucleus and another line along the medial border of the cuneiform at the anterior end of the talar nucleus. This angle gave an idea about how the medial border of the foot would look irrespective of the position of the navicular. Foot seems normal if this angle is zero or negative, although the navicular is not fully reduced over the talus, which indicates spurious correction. A negative value of talo-cuneiform angle indicates normal lateral displacement of the forefoot over the talus, whereas a positive value indicated residual medial forefoot adduction.



Figure 7: Posterior projection: probe partly on heel and partly on leg.

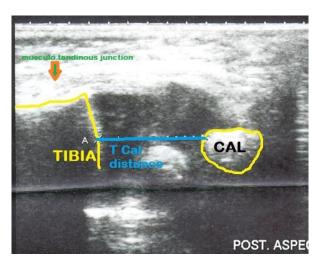


Figure 8: Posterior projection: Tibiocalcaneal relationship can be observed assessing degree of equinus.

Dynamic sonography

The range of mobility of talonavicular joint was evaluated on medial projection by subjectively assessing to which degree the navicular displacement could be reduced by passive adduction of forefoot being graded as shown in Table 2.

Dynamic sonography has ability to visualize the reducibility of the deformity in real time sonography prior to initiation of treatment. These feet which are initially rigid later on showed spurious correction in some cases in study by Desai et al. 11 and El-Adwar KL et al. 21

Dynamic sonography thus can also guide to the timely need of operative intervention in unresponsive cases.

Table 2: Grading of range of mobility of talonavicular joint.

Grading	Reduction to normal position
Grade 1	No reduction
Grade 2	Intermediate reduction
Grade 3	Complete reduction to normal position

Percutaneous sectioning of tendoachilles

D. Maranho et al.²⁰ showed that it is necessary to ensure complete sectioning of the tendon, sometimes clinically unapparent connection may remain between the stumps which can theoretically influence the equinus correction. Therefore these connections if visualized need to be sectioned under ultrasound guidance. Three weeks after tenotomy, the dynamic evaluation showed continuity between the tendon stumps, with transmission of motion during the Thompson maneuver and ankle flexion-extension. Ponseti's long-term results indicate that divided human Achilles tendons display a normal surface anatomy with no adhesions and no tendency to rupture, suggesting that a complete tendon recovery does take place.²²

DISCUSSION

Author lays no attempt to diminish the importance of clinical scoring system. Author emphasizes, Sonography as a tool to supplement the present clinical scoring systems. Wainwright et al.²³ studied the clinical classification systems described by Catterall, Dimeglio et al., Harrold and Walker, and Ponseti and Smoley, but found none to be up to the mark.

Sonography can also be used to classify the deformity on various parameters discussed by R. Suda et al. as shown in Table 3, points are assigned against each of four angles and the total sum of points determines the grade of clubfoot as shown in Table 4. However Aurell et al. questioned the reproducibility of these angles.

Table 3: Four	point scale -	 for each 	angle for	classifying	clubfoot.

Angle	Normal feet	Idiopathic cl	ubfeet		
Talus nucleus cuneiform	-20°< -5°	$-5^{\circ} < +10^{\circ}$	$+10^{\circ} < +20^{\circ}$	$+20^{\circ} < +30^{\circ}$	>+30°
everted	(0 point)	(1 point)	(2 point)	(3 point)	(4 point)
Talus nucleus 1 st metatarsal	-15°< -5°	$-5^{\circ} < +10^{\circ}$	$+10^{\circ} < +25^{\circ}$	>+25°	
everted	(0 point)	(1 point)	(2 point)	(3 point)	
Tibia tuber calcanei dorsal	$+10^{\circ} < +20^{\circ}$	$+20^{\circ} < +30^{\circ}$	$+30^{\circ} < +45^{\circ}$	>+45°	
extended	(0 point)	(1 point)	(2 point)	(3 point)	
Calcaneus nucleus cuboid	-5° < -0°	-5°< -20°		<-20°	
everted	(0 point)	(1 point)		(2 point)	

Table 4: Sonographic classification of clubfoot.

Points	Sonographic classification
0	I, Normal foot
1,2	IIa, Slight clubfoot
3-6	IIb, Moderate clubfoot
7-10	IIc, Severe clubfoot
11,12	IId, Very severe clubfoot

Angles are often used to describe clubfoot malformation quantitatively on radiographs as well as in MR imaging. One of the main objections to this is that in those irregular-shaped and partially ossified bones it is difficult to find reproducible ways to define the long axis of the bones not only on plain radiographs but also in MR imaging, and concerning the medial bowing of the talus it is very difficult to determine the "breaking point". This is especially true for the very young infants whose skeletons are rounded and irregular in shape even if one includes the cartilaginous components. Authors investigating the use of ultrasound for clubfoot evaluation have not always used angles, 9,10,17,24-26 Tolat et al. 17 discussed the abnormal positions of the talus and navicular but they make no attempt to correlate their findings with radiographs or clinical classification of severity. Maiza et al. 14 reported their investigations of the sonographic anatomy of the clubfoot in several planes. They offer a descriptive assessment of the alignment of various cartilaginous anlage. No quantification, neither angular nor linear, is described. Hamel and Becker¹³ used three angles TnMT1e (talus nucleus metatarsal 1 everted) angle, TnCe (talus nucleus cuneiform everted) angle and TTd (tibia tuber calcanei dorsal extended) angle for determining forefoot adduction, equinus and medial and lateral subluxation of clubfoot. Suda et al. 16 proposed a classification system using three angles as stated by Hamel and Becker and introducing fourth angle - CanCue (calcaneus nucleus cuboid everted) angle. Calculating angles to describe the degree of clubfoot deformity, poses difficulty as the reliability of these measurements turns out to be too poor to be useful.9 In MRI and CT studies with 3D modeling²⁷⁻³⁰ this problem seems to be possible to overcome by a computer program determining the long axis of the talus and the calcaneus, but as the navicular and the cuboid by their shape escape any attempt to

mathematically establish any long axis, this model could not be used to assess either the navicular or the cuboid displacement in mathematical terms. Therefore only angle (CC angle) which is easily reproducible is advocated by the author.

Desai et al. reported spurious correction in 15.6% feet that were initially rigid and severely deformed in infants older than 6 weeks, i.e. with a break at the naviculocuneiform joint, where the medial cuneiform shifts lateral to the navicular leaving the later subluxated medially over the talus. Similar findings were reported in 16% cases in study by El-Adwar KL et al. While manipulating very rigid feet, the forces applied to the forefoot may not be transmitted to the navicular, the risk of developing a midfoot break is always present. The development of a midfoot break has been described earlier in a sonographic study by Hamel and Becker¹³ who mentions that, instead of realignment of the talonavicular joint, the medial cuneiform shifts in a lateral direction to the navicular. The latter remains prominent at the medial border of the foot and seems fixed to the talar head especially during dynamic examination. Ponseti²² acknowledges that "in severe clubfeet, complete reduction of the extreme medial displacement and inversion of the navicular may not be possible with manipulation..... and this "spurious" correction may provide good functional and cosmetic results". Feet in these cases of spurious correction appear clinically corrected but sonography is able to identify the deformity and predict the relapse of deformity. Thus truly justify the need of sonographic supplementation of clinical clubfoot scoring system.

Sonographic parameters are to supplement the clinical scoring system as they themselves cannot completely assess the deformity, the varus component is difficult to assess by US as the talus and the calcaneus are in different planes and a great deal of the calcaneus is ossified thus creating an acoustic shadow that hides most of the extent of this bone. A different plane can be identified in real time by which varus component can be assessed by measuring distances between tuber calcanei and the lateral malleolus, while holding the heel first in a maximally corrected position and then in a maximally deformed position however, these examinations are too

complicated and long lasting. In addition these distances vary according to the age group and cannot be used to create an objective classification system.¹⁶

CONCLUSION

Ultrasound holds to be promising emerging and effective tool for clubfoot assessment both as for initial deformity grading, guide throughout the treatment, to rule out any unprecedented spurious correction, need for any operative intervention and to determine complete sectioning of tendoachilles and its repair following tenotomy. More work is required in this field to lay down standard norms for approach in performing US and set the guidelines for classification of the deformity.

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