CONGENITAL CLUB FOOT
An Anatomical Study

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Congenital club foot remains even today an unsolved problem. In the latest reviews of treatment (Debrunner 1957; MacEwen, Scott and Shands 1961; Wynne-Davies 1964; Waisbrod and Steiner 1966) only 50 per cent of the cases showed good results. As Lloyd-Roberts (1964) stated: "This is an undeniably disheartening state of affairs which is in no way redeemed by the knowledge that little or no improvement has occurred since Brockman’s review was published thirty-five years ago". And he added: "What are the features that are likely to make a club foot resist treatment?" There is no ready answer.

With this problem in mind, a study of the anatomy of club foot in the different stages of foetal development was carried out.

REVIEW OF PREVIOUS REPORTS

Müller (1968), reviewing the literature of the last 120 years, found sixty-five dissections of club feet, forty-one of them in foetuses. The youngest were a twelve-week-old foetus dissected by Settle (1963) and another of the same age by Bechtol and Mossman (1950). The rest were all over the age of twenty-six weeks. Thirty-nine of the dissected specimens showed talar deformity, especially distortion of the head and neck. In four cases there was no talar deformity, but only abnormal insertions, or undefined degenerative signs (Bechtol and Mossman 1950, Stewart 1951, Flinchum 1953).

In the more detailed reports (Settle 1963, Irani and Sherman 1963) it was agreed after careful dissection that the basic deformity in congenital talipes equinovarus was located in the neck of the talus, which was deviated medially.

Embryological review—Gardner, Gray and O’Rahilly (1959) showed that in a foetus of seven weeks the tarsal elements began to transform into cartilage, and at nine weeks this process was complete. The various skeletal elements of the foot closely resemble those of the adult in their characteristic relations. At the eleventh or twelfth week the talus is the first to show vascular invasion with appearance of vascular canals in the cartilage. The vessels within these canals arise from arteries of the sinus tarsi, their number increasing with age. Around the twenty-fourth to twenty-sixth week of embryological development ossification begins and is always present by the twenty-eighth week.

According to Gardner (1956) the neck of the talus points towards the medial side of the foot in the young foetus; the head-body angle increases throughout the foetal period from the sixteenth week onwards. Paturet (1951) called this the "Declination Angle" and said that it was between 150 and 160 degrees in the adult human.

PRESENT STUDY

Eight foetuses were dissected, six of them belonging to the collection of human embryos of the Department of Anatomy of the Medical School, University of Tel-Aviv (Table I). They all showed unilateral club foot. The gestational ages were estimated by the crown-rump length. At necropsy no other major anomalies were found. The legs were cut at the level of the knee, and in every case gentle manipulation of the deformed foot was tried in order to attempt to restore normal shape. The soft tissues were dissected in the normal and in the deformed legs. Thereafter the tali were removed and photographed, care being taken to place
them in the original position. At the beginning of this study an attempt was made to inject the vascular trees of the legs with diluted barium sulphate, but the contrast medium did not penetrate any further than the posterior tibial artery at the level of the medial malleolus without damaging the arterial walls. Therefore an attempt was made to demonstrate the vascular canals of the talus by two other methods. A horizontal section 1 millimetre thick was cut through the middle of the talus and first was placed on x-ray screen and photographed; then a microradiograph was obtained.

Measurements were made of the head-neck angle of every talus by the same technique. A copy was made from the photograph of the bone. One axis passed through the head and neck, perpendicular to the base of the neck; the second passed through the body of the talus perpendicular to its posterior border.

### TABLE 1
**DETAILS OF EIGHT CASES**

<table>
<thead>
<tr>
<th>Case number</th>
<th>Uterine age (weeks)</th>
<th>Sex</th>
<th>Side of club foot</th>
<th>Crown-rump length (millimetres)</th>
<th>Declination angle of talus (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16</td>
<td>Male</td>
<td>Left</td>
<td>110</td>
<td>156-134</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>Male</td>
<td>Left</td>
<td>170</td>
<td>154-154</td>
</tr>
<tr>
<td>3</td>
<td>22</td>
<td>Male</td>
<td>Left</td>
<td>180</td>
<td>154-154</td>
</tr>
<tr>
<td>4</td>
<td>22</td>
<td>Female</td>
<td>Right</td>
<td>190</td>
<td>153-152</td>
</tr>
<tr>
<td>5</td>
<td>24</td>
<td>Male</td>
<td>Left</td>
<td>—</td>
<td>157-140</td>
</tr>
<tr>
<td>6</td>
<td>26</td>
<td>Female</td>
<td>Left</td>
<td>220</td>
<td>150-137</td>
</tr>
<tr>
<td>7</td>
<td>26</td>
<td>Female</td>
<td>Right</td>
<td>—</td>
<td>155-124</td>
</tr>
<tr>
<td>8</td>
<td>36</td>
<td>Male</td>
<td>Left</td>
<td>Newborn</td>
<td>150-136</td>
</tr>
</tbody>
</table>

### FINDINGS

**Effect of manipulation**—Only three of the feet (Cases 2 to 4 (Table 1)) could be manipulated into the plantigrade position without difficulty (Fig. 1). In the other five cases it was impossible to correct the deformity even by exerting considerable force. Not even the foot of the sixteen-week-old foetus could be corrected.

**Dissection of soft tissues**—The vessels, nerves, muscles, tendons and ligaments were examined. No deformity could be found in the neurovascular bundles, including their anatomical pathways and ramifications. The shapes and insertions of the muscles and tendons were studied. The gastrocnemius was smaller on the affected side and the tendo calcaneus was thinner, but its insertion on the calcaneus was normal in all the cases.

The tibialis anterior was normal in all but one case in which the insertion was only on the first cuneiform bone. In all but Cases 2, 3 and 4 the tibialis posterior muscle was much smaller (Fig. 2). The tendon was shorter and thinner and the insertion on the navicular bone was preceded by a remarkable thickening which apparently enlarged the bone proximally. This part of the tendon was in intimate contact with the medial malleolus and could be separated from it with difficulty.

**Dissection of bones**—The general shape and relationship of all the bones were normal, including the talo-navicular joint where no dislocation was found in any of the cases (Fig. 3). The navicular bone was located over the head of the talus, covering it completely.

The most important finding was related to the talus, except in Cases 2, 3 and 4, in which the tali were normal. In the other five cases the tali were deformed (Fig. 4) and were found to be smaller; the body was less developed, with a thinner and longer neck and pointed head.
The most striking deformity was found to be in the angle of declination (Table 1). In Cases 2, 3 and 4 the declination angle was between 152 and 154 degrees, being the same in both feet. In the other cases, in the normal foot the angle measured 150 to 157 degrees whereas in the deformed tali the angle ranged between 124 and 140 degrees. The average angle on the normal sides was 153 degrees and on the deformed sides 134 degrees.

**Vascular channels**—In the normal feet the vascular channels were found to spread in fanlike distribution from the sinus tarsi backwards through the body of the talus. In the body they were found to be parallel to its long axis, and their number varied between four and six. They were well developed and constant. In the neck they had no special constant distribution and in the head they were fewer, being close to the periphery, short and without particular direction (Fig. 5).

In the deformed tali these channels were seen to run without any special pattern. In the body they were fewer, and in three cases there appeared to be one large canal dividing into two or three smaller ones. The heads were almost devoid of channels in all but the oldest foetus (Fig. 6).
Ossification centres—The youngest foetus showing an ossification centre was twenty-four weeks old. In two cases (Cases 5 and 6) the ossification centre was present on the normal side but absent on the abnormal (Fig. 5). In Case 8 the ossification centre was round and normally situated in the normal foot, but small and eccentric in the neck close to the sinus tarsi in the club foot (Fig. 6).

FIG. 3
To show the relationship between talus and navicular bone in a normal foot (Case 5) and in a club foot (Case 7).

FIG. 4
Case 5—The normal talus (left) compared with the deformed bone.

DISCUSSION AND CONCLUSIONS

The most striking anatomical finding here was the deformity of the talus, and specially the change in the declination angle. This agrees with previous findings (Irani and Sherman 1963, Settle 1963, Müller 1968) and may explain the anatomical deformity of the whole foot.
Those feet which had the clinical appearance of club foot and could be manipulated to a normal plantigrade position were found on dissection to have completely normal tali. These could be named the clinical type of club foot.

The rest of the feet, which could not be manipulated into normal shape, included the group with deformed tali; these might be named the structural type of club foot. Could this be an answer to Lloyd-Roberts's question, the latter group being the one resistant to treatment?

Gardner's (1956) finding that the angle of declination increased during foetal development was not confirmed by the present work. In the sixteen-week-old foetus the angle was already 156 degrees in the normal foot, and remained within the normal range (150 to 160 degrees) in all normal feet irrespective of age. It is possible to imply from that finding that there is no arrest of growth but a real defect in the talus of the club foot. As there was no foetus under the age of seven weeks in this series, it is impossible to state if the defect is blastemal or if it appears after the embryonic period is completed. The facts that the vascular channels are fewer and arranged in a disorganised fashion, and that the ossification centre is smaller and appears later in the talus of real club foot, support the view that the defect is probably blastemal in origin.
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SUMMARY

1. An anatomical study of congenital club foot in various stages of foetal development is presented, and the literature is reviewed.
2. The most striking finding was deformity of the talus and in particular a change in its angle of declination.
3. That deformity was present in feet whose deformity could not be corrected by gentle manipulation; it was absent in feet whose deformity could be so corrected.
4. Abnormality of the tendon and insertion of the tibialis posterior muscle was found in most cases.
5. Speculations are advanced concerning the nature and cause of the talar deformity.

We want to thank Professor E. Spira for his encouragement throughout the present study, which was performed in the Experimental Surgery Laboratory, under his direction; and to Professor H. Nathan for allowing us to study the material of his department.

REFERENCES


