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THE SUROPLANTAR PROJECTION IN THE CONGENITAL CLUB FOOT OF THE INFANT

Its clinical and radiological significance

By

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The addition of the roentgenogram to the study of the club foot has furnished us with a valuable aid in clearing up the important relations existing between the talus and the calcaneus. The roentgenogram serves as diagnostic element in establishing the degree of inversion of the latter and during corrective treatment of deformity it is the surest guide by which the anatomical restoration of the foot is determined.

In 1932, Wisbrun (1) suggested the dorso-plantar projection, in order to make clear the mutual position of both the talar and calcaneal nuclei in the club foot. In his work he shows how to measure the talo-calcaneal angle, its approximate value in the normal foot (35°), its decrease or inversion in the club foot, and finally he shows the results of correction. He points out especially that no foot should be considered corrected if the reconstruction of the talo-calcaneal angle has not been achieved. Otherwise it is only a pseudo-correction obtained at the expense of some other components and subject to recurrence.

After Wisbrun, all the authors who dealt with the subject – Kite (2), Guntz, among others – used the roentgenogram not only for the diagnosis but also to evaluate the results of the corrective treatment.

Divergencies of opinion have arisen concerning the part talo-calcaneal angle plays in the pathogeny of the club foot. While Wisbrun considers that the decrease of that angle is related to the degree of adduction of the foot, Kite relates it to the inversion of the calcaneus. Thomasen (3) completes Kite's study and shows that the decrease of the talo-calcaneal angle is due to the inversion and internal subluxation of the os calcis. In a previous paper (4), we have accepted Thomasen's interpretation as correct. The os calcis is not only rotated inwardly on

its longitudinal axis but is also displaced towards the medial part of the foot.

Wisbrun's conception should be accepted as a whole. Based on previous studies it establishes the analogy between the club foot and internal subastragalar luxation. Thus for the correct interpretation of this very fundamental component we should include the talus fixed in the tibio-fibular mortise and forming part of the mass of the ankle joint. The inversion and supination takes place under and in front of

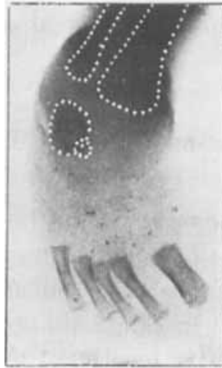

Fig. 1.
Age: 15 days. Dorso-plantar roentgenogram.
Hypoplasia of the astragalar nucleus.

the talus. This opinion coincides with Ombredanne's (5) and differs from Marique's (6) and from those of others who consider the talus the principal element of the deformity.

In roentgenograms of the infant it is not infrequently observed a well marked hypoplasia of the astralagar nucleus. It is known that the nuclei of the calcaneus and the astralagus are perfectly visible and well developed in the new-born child. This hypoplasia also constitutes a significant element in the diagnosis of the club foot.

The disadvantage of the dorso-plantar projection is that very often, due to the small size of the astralagar nucleus, this is superimposed on the calcaneal nucleus, thus interfering with the angle reading and making it impossible to measure the axes (Fig. 1).

The difficulty in the control is increased if we consider that our object is to obtain total correction within the first three months of life; at this time excellent results are obtained by manipulative correction with the right procedure, as has long been proved. It is precisely at this stage that the reading of the dorso-plantar roentgenogram leaves much open to doubt for it is not always possible to measure the

35 degrees necessary before the infant can be discharged from hospital and its relatives assured that the deformity will not recur.

In order to overcome this disadvantage we have experimented with the suro-plantar projection. A description of the results follows.

TECHNIQUE

The infant is held in a vertical position or bending forward. The sole of the foot rests on the chassis and is kept on a level with the fore-foot. When the equinus is well marked it is usually difficult to make the whole sole of the foot rest on the surface. In that case, a moderate elevation of the calcaneus neither alters the view nor the relations. The tube is placed behind, with an inclination of 40° so that the ray goes through the lower quarter of the leg. This posterior projection is the same as that used to obtain roentgenograms of fractures of the os calcis.

In order to complete the examination it is useful to supplement it with the dorso-plantar roentgenogram, which shows the adduction, and with the lateral X-ray showing the anterior astragalar subluxation and the degree of equinus.

INTERPRETATION OF THE ROENTGENOGRAMS

a) Normal X-ray: The suroplantar projection of the normal foot of a newly born child shows the following image. Two ossification centres are found. One is oval with flattened poles and a vertical main axis. Its position is plantar and it is perfectly aligned along the longitudinal axis of the fibula at a good distance from its inferior metaphysis. This is the nucleus of the calcaneus. The other nucleus is placed under the tibial metaphysis. It appears either round or slightly oval and with a transverse main axis. It corresponds to the astragalar nucleus (Figs. 2–3.)

The relative position of both nuclei is the most important thing in the projection. Normally, the astragalar nucleus is medially situated on the same level as the upper pole of the nucleus of the calcaneus, with which it forms a right angle and from which it is separated by a space of a few millimeters. This position is invariable and appears in every normal case.

Both nuclei appear perfectly distinct and their structure is characterized by a denser central area and a broad and less dense peripheral ring.

b) The X-ray of the club foot: The photograph is quite different

Fig. 2.
Suroplantar X-ray.
Age: 14 days. Normal foot.

Fig. 3.
Suroplantar X-ray.
Age: 2 months. Normal foot.

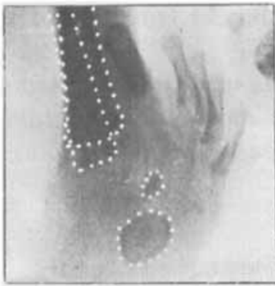

Fig. 4.
Suroplantar X-ray of the same foot as in fig. 1.
Hypoplasia of the astragalar nucleus.
Superolateral position.

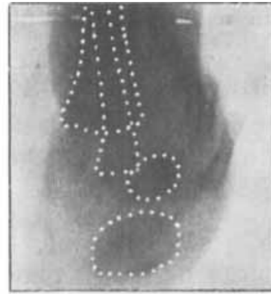

Fig. 5.
Suroplantar X-ray.
Age: 54 days. Untreated club foot.

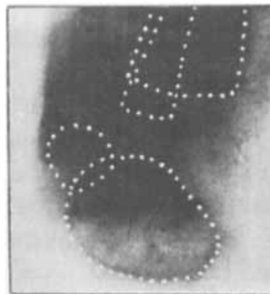

Fig. 6.
Suroplantar X-ray.
Age: 1 year. Deficiently treated foot. The deformity persists.
Internal subluxation of the calcaneus.

and has the following characteristics. The tibia and the fibula appear superimposed on each other. This defect in the photograph is only apparent and is due to the internal rotation of the leg. In order to make the rigid clubfoot rest horizontally on the chassis it is absolutely necessary that the whole limb rotates and bends inwardly. Hence the tibio-fibular overlapping has in itself an element of diagnostic interest (Figs. 4–5–6).

The main difference between the club foot and the normal foot lies in the relative positions of the two nuclei. The calcaneus appears under and quite near the tibial axis. The talus changes its position

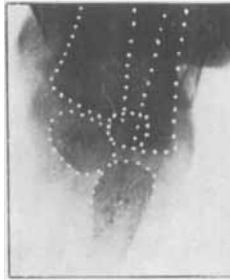

Fig. 7.
Same case as in fig. 5, after three months manipulative treatment. The normal conditions have been reestablished.

completely in relation to the calcaneus. Whether it be hypoplastic or normal, it lies laterally to the upper pole of the os calcis and in the less serious cases directly over it, but never in a normal position, that is, medially to the upper pole of the calcaneus.

The suroplantar projection also shows the internal subluxation of the calcaneus.

RESULTS OF THE TREATMENT

In our experience the manipulative correction re-establishes normal conditions. We consider that the foot is completely cured when its suroplantar projection shows distinctly a) a free tibio-fibular space, b) that the calcaneal nucleus with its vertical axis is placed under the fibula, c) that the astragalar nucleus is situated under the tibia in an upper medial position with its main transverse axis at a right angle to the calcaneus (Fig. 7).

This picture gives assurance of complete recovery, demonstrates the impossibility of a recurrence, allows the foot to be released and, on the whole, agrees with the clinical signs of recovery laid down by R. Jones

(7), that is to say, morphologically the back foot and the forefoot are in line with the normal axis and the plantaris reflex turns the foot over in pronation.

The correction of the backfoot is of fundamental importance although the other components also should be taken into consideration as their reduction is greatly facilitated by the eversion of the os-calcis.

A later paper will disclose the clinical and X-ray evolution of a number of cases examined in accordance with the aforementioned technique. For the time being the results obtained on the basis of a preliminary study can be given. This study involved a series of nine

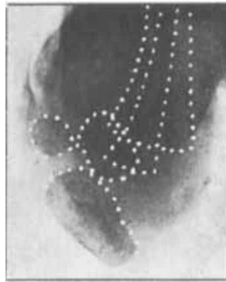

Fig. 8.
Suroplantar X-ray of a pseudo-correction. Tibio-fibular overlapping. Marked inclination of the os calcis and the astragalus.

cases covering the treatment of fifteen club feet from the date of birth until the age of one and a half years. In each case the first X-ray check prior to treatment revealed an abnormal position of the nuclei. After treatment the suroplantar X-ray showed a complete realignment of the nuclei, no relapse being observed after several months since the discharge of the patients.

The suroplantar projection is not less important in detecting the pseudo-corrections. In these cases the calcaneal astragalar relation is not re-established. In Fig. 8 a case of pseudo-correction may be observed. Clinically the back foot looked pronated if observed from behind.

The X-ray shows tibio-fibular overlapping. The nucleus of the calcaneus although outside that of the astragalus, is extremely inclined while the axes are out of normal alignment. The main axis of the calcaneus is slanting downward and inward and that of the astragalus is vertical instead of horizontal.

This being the case the orthopedic or surgical treatment must be continued until a perfect result is achieved.

THE SUROPLANTAR PROJECTION IN THE STUDY OF THE MOVEMENTS OF THE POSTERIOR PART OF THE BACK FOOT

Pronation and supination movements take place from the back foot. Normally the possible degree of pronation is very slight. Instead, the supination or inversion of the os calcis is far greater. It allows the sole of the foot to be turned inward and its inside edge to be raised.

The suroplantar roentgenogram allows all these movements to be followed clearly and shows that they are produced at the level of the subastragalar joint, the calcaneus being the mobile component. In Fig. 9 a normal foot can be seen with its sole in a normal position of

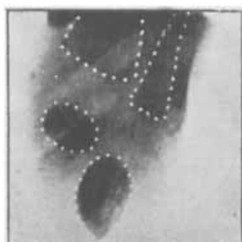

Fig. 9.
Age: 40 days.
Sole in normal position of rest.
Suroplantar projection.

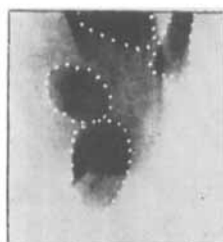

Fig. 10.
The same foot forced in inversion.
The calcaneus is turned inward, but retains the normal relation to the astragalus.

rest. The calcaneal-astragalar relation corresponds to the above description.

In Fig. 10 the same foot is inverted. The os calcis has been turned inward and the astragalar nucleus is nearer the upper pole, although retaining its upper medial position. That is to say, the calcaneus has been rotated in an internal direction. As it can be seen from the roentgenogram this movement takes place at the level of the subastragalar joint.

In normal inversion, even if forced to the maximum degree, the calcaneal-astragalar joint is never inverted as in the club foot, in which the degree of inversion is much greater than that which can be obtained in a normal supinated foot. Besides the rotation, in the club foot the calcaneus is subject to an actual internal displacement that must be corrected.

ANATOMICAL INVESTIGATION

In the new-born child the ossified nuclei that are visible in the roentgenogram constitute a relatively small part of the cartilaginous whole.

In order to make clear whether the position of the nuclei has any relation to the true anatomical position of the future bones, we have made many frontal, horizontal and anteroposterior sections of formalised feet of fetuses. These sections have all demonstrated the following:

1) Frontal sections: The position of the nuclei is central in the transverse plane. The astragalar nucleus is usually placed in the lower quarter of the cartilaginous mass. The surrounding cartilage of both bones corresponds to the position of their nuclei; that is to say, the calcaneus is below and outside the astragalus, and that the respective nuclei are lying along the axes af the tibia and the fibula. Fig. 11.

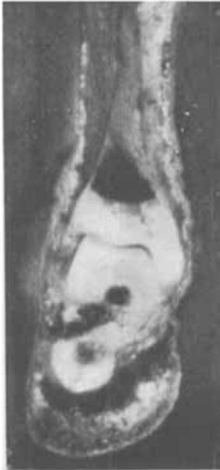

Fig. 11.
Fully developed fetus.
Frontal section on a level with the sustentaculum tali.

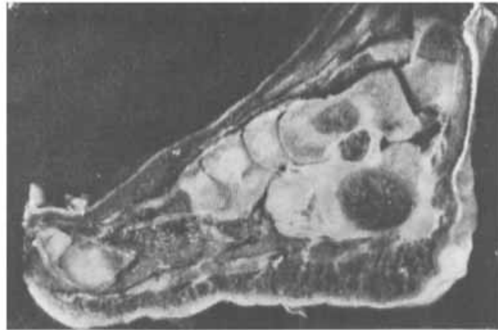

Fig. 12.
Fully developed fetus.
Anteroposterior section.

The frontal sections, made from back to front, show that the posterior subastragalar area, the cartilaginous mass of the calcaneus is placed in the lateral part of the astragalus. But, at the level of the sustentaculum tali, the contact and the overlapping of both bones is much greater, retaining however the relationship described above.

2) Anteroposterior sections: Fig. 12. The nucleus of the astragalus lies forward and is smaller and rounded.

Apart from the sections, the investigation has been supplemented with an anatomico-roentgenologic study of the movements forcing the calcaneus to inversion. The pictures confirm the above description of

the movements. A real inversion can only be obtained after having severed the strong calcaneal-astragaloid ligament and all the tissues, and having turned the calcaneus inwardly. It must be said that the result of the experiment does not conform with what can be seen in the articulated foot in whose subastragalar joint the bones remain always in contact.

The interpretation of this anatomical research applied to radiology shows that the position of the nuclei gives the real position of the respective bones.

HYPOPLASIA OF THE ASTRAGALAR NUCLEUS

In many cases the nucleus is very small. Its structure also differs. The normal reticulation of the spongy part is not seen. It is dense and fragmentary instead.

Böhm and Vilhelm consider the astragalar hypoplasia to be a part of the deformity due to an interruption in growth, that in a lesser degree affects the whole foot. Müller attributes it to mechanical stresses and says that the hypoplasia is not to be observed in feet treated very early. Empirical observation of roentgenograms and clinical cases persuades us to consider Böhm's theory more acceptable.

Attention has been attracted to the fact that other feet with a similar deformity have an astragalar nucleus which is normal in size and shape. Clinically in both kinds of feet and in the way in which they react to the treatment we have found some differences that may be for the present summed up as follows:

A) Foot with a well developed nucleus: The deformity is less rigid and the components are not so marked. The correction is easier and quicker. Usually the foot is definitely reconstructed in the first three months.

B) Foot with a hypoplastic nucleus: The deformity is more complex and particularly rigid. Correction is harder. It requires vigorous and repeated manipulations for quite a long time, sometimes amounting to more than six months.

It is considered that feet with a normal nucleus have a varus equinus attitude, which in a certain way would correspond to an exaggeration of physiological fetal supination. Instead those with hypoplasia, because of their resistance to the treatment, constitute a really bad "posture". For the latter cases, the theory of the embryonic or fetal origin of the club foot sounds likely.

The treatment is the same for both types. It must be begun immediately after birth. If they are left to natural evolution, the bad varus equinus attitude gets fixed and develops quickly into a bad posture. The periods of recovery and ulterior control differ. In bad attitudes the recovery is usually definitive before the fourth month. On the contrary in bad postures, the tendency to recidivation is great. It is frequently observed, especially during the first stages of the treatment of these serious deformities, that if the foot is left unbandaged for two or three days this is enough to bring about recurrence of the deformity. This is why, in these cases, the cure takes longer and the after treatment must be continued at least until the child is a year and a half old.

SUMMARY

The suroplantar projection allows us to see distinctly the nuclei of the calcaneus and the astragalus in the infant and also to establish the relative position between them and in relation to the bones of the leg.

In this projection the picture of a normal foot shows: a) a free tibio-fibular space. b) an oval calcaneus nucleus with a vertical main axis placed along the fibular axis. c) a round or oval astragalar nucleus with its main transverse axis placed below the tibial metaphysis, situated on the upper medial pole of the calcaneus and at right angles to it.

The picture changes in the club foot. There is tibio-fibular overlapping, the astragalar nucleus is on the superolateral pole of the calcaneus and the latter is subluxated partially dislocated inwardly.

The club foot is said to be completely cured when the relative positions of both nuclei have been re-established.

The study of normal movements shows that the inversion of the back foot is produced at the subastragalar joint, the calcaneus being the mobile component. In the club foot the medial position of the calcaneus is exaggerated and accompanied by an internal subluxation.

Anatomical investigation confirms that the position of the nuclei coincides with the actual position of the bones.

There are two kinds of club foot: Some with a hypoplastic astragalar nucleus, and others whose astragalus is normal in size and shape. The former constitute a truly vicious posture of probable embryonic or fetal origin. The latter might be due to an exaggeration of the physio logical fetal attitude.

RESUME

La projection suroplantaire nous a permis de voir distinctement les noyaux du calcanéum et de l'astragale chez les nourrissons et aussi d'établir la position relative entre eux et en rapport avec les os de la jambe.

Dans la projection, l'image d'un pied normal montre: a) un espace tibio-fibulaire libre, b) un noyau calcanéen ovale avec un axe principal vertical placé de long de l'axe fibulaire, c) un noyau astragalien ovale ou rond dont l'axe principal transversal est placé au-dessous du metaphysis tibial situé sur le pôle médian supérieur du calcanéum et à angle droit avec celui-ci.

Le tableau est modifié dans le pied-bot. Il y a recouvrement tibio-fibulaire, le noyau astragalien se trouve sur le pôle supérolatéral du calcanéum et ce dernier est subluxé, partiellement disloqué vers l'intérieur.

Il est dit que le pied-bot peut être entièrement guéri lorsque les positions relatives des deux noyaux ont été rétablies.

L'étude des nouvements normaux montre que l'inversion de la partie arrière du pied est produite par l'articulation subastragalienne, dont le calcanéum est l'élément mobile. Dans le pied-bot la position médiane du calcanéum est exagérée et accompagnée d'une subluxation interne.

Des recherches anatomiques confirment que la position des noyaux coïncident avec la position des os plus tard.

Il y a deux sortes de pied-bot: chez certains, le noyau astragalien est hypoplastique, chez d'autres l'astragale est de forme et de grandeur normales. La première provient vraisemblablement d'une position vicieuse probablement d'origine embryonnaire ou fétale, la dernière peut être due à une exagération de la position fétale physiologique.

ZUSAMMENFASSUNG

Die suroplantare Projektion gestattet uns die Kerne des Calcaneus und Talus beim Säugling klar zu sehen und auch das gegenseitige Lageverhältnis dieser und der Unterschenkelknochen festzustellen.

In dieser Projektion zeigt das Bild des normalen Fusses: a) Einen freien tibio-fibularen Zwischenraum, b) einen ovalen Calcaneuskern mit einer vertikalen Hauptachse, die in der Richtung der Fibulachse verläuft, c) einen runden oder ovalen Taluskern mit seiner transversalen Hauptachse distal von der Tibia-metaphyse, der an dem oberen medialen Pol des Calcaneus und im rechten Winkel zu ihm gelegen ist.

Das Bild verändert sich beim Klumpfuss. Man findet hier tibiofibulare Überschneidung. Der Taluskern befindet sich am superolateralen Pol des Calcaneus und der letztere ist teilweise nach einwärts subluxiert.

Man nimmt an, dass der Klumpfuss vollständig geheilt ist, wenn die normalen gegenseitigen Stellungen der beiden Kerne wiederhergestellt worden sind.

Die Untersuchung normaler Bewegungen zeigt, dass die Inversion des Rückfusses im subtalaren Gelenk vor sich geht. Der Calcaneus ist dabei der bewegliche Teil. Beim Klumpfuss ist die mediale Lage des Calcaneous übertrieben und von einer inneren Subluxation begleitet.

Die anatomische Untersuchung bestätigt, dass die Lage der Kerne mit der wirklichen Lage der Knochen zusammenfällt.

Man findet zweierlei Arten von Klumpfüssen: Einige mit hypoplastischem Taluskern, und andere deren Talus normale Grösse und Form zeigt. Die erstere stellt eine wirklich hartnäckig, resistente Position von wahrscheinlich embrionalem oder fötalem Ursprung dar. Die letztere ist wahrscheinlich in einer Übertreibung der physiologischen, fötalen Haltung begründet.

RESUMEN

La proyección suroplantar permite visualizar en el lactante en forma distinta, los núcleos del calcáneo y del astrágalo, así como establecer la relación de posición entre ambos y con respecto a los huesos de la pierna.

La imagen de un pie normal en esta proyección presenta; a) el espacio interóseo, tibioperoneo, libre. b) el núcleo calcáneo, ovalado, con el eje mayor vertical y ubicado sobre el eje del peroné. c) el núcleo del astrágalo redondo u ovalado, con el eje mayor transverso colocado por debajo de metáfisis tibial, situado sobre el polo súpero-interno del calcáneo, haciendo escuadra con el mismo.

En el pié bot la imagen cambia. Existe superposición tibioperonea, el núcleo astragalino se encuentra sobre el polo súperoexterno del calcáneo. Y éste último se halla subluxado hacia adentro.

Se considera definitivamente curado el pie bot, cuando las relaciones y posiciones de ambos núcleos se han restablecido.

El e studio de los movimientos normales demuestra que la supinación del retropie se produce a nivel de la articulación subastragalina, siendo el calcáneo el hueso movil. En el pie bot, laposición interna del calcáneo se exagera y acompaña de subluxación interna.

Las investigaciones anatómicas confirman que la situación de los núcleos corresponde a la posición real de los huesos.

Existen dos categorías de pie bot: Unos con núcleo astragalino hipoplásico y otros cuya astrágalo es de tamaño y forma normales. Los primeros configuran una verdadera „posición" viciosa de probable origen embrionario o fetal. En los segundos, se trataría de una exageración de la „actitud" fisiológica fetal.

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