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THE ARTERIAL SUPPLY OF THE TALUS

A Study on the Relationship to Experimental Talar Fractures

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In a previous paper we described the arterial supply to the talus (Peterson et al. 1974 a). We were able to confirm earlier findings (Wildenauer 1950, Haliburton et al. 1958, Mulfinger et al. 1970). The main arterial supply has been assumed to originate from the arteria canalis tarsi and from the arteria sinus tarsi (Wildenauer 1950, Mulfinger & Trueta 1970). In addition we observed numerous arterial connections between the tibial and talar marrow spaces by way of the interconnecting capsule and ligaments. Our study indicated that the talus receives a great amount of arteries from many different sources, and its position is in the center of a large vascular net-work.

In fractures of the talus, osseous necrosis may arise whether the fracture is displaced or not. It has been stated that the greater the displacement the higher the rate of necrosis (Hawkins 1970). An occurrence of between 2 and 91 per cent has been reported (Coltart 1952, Hawkins 1970, Kenwright & Taylor 1970, Brinkmann et al. 1973). In undergoing a necrosis a bone which has been deprived of its vascular supply will soon re-establish its circulation and a remodelling of bone will occur (Phemister 1940, Haliburton et al. 1958). The necrosis is believed to be due to the deprivation of the blood supply, though the true pathogenesis is as yet not entirely clear (Hawkins 1970). The importance of the blood supply has indeed been demonstrated in some instances, e.g. when after a triple arthrodesis, by which the main arteries become destroyed, talar necrosis has developed. This has been observed in not quite 10 per cent of cases (Marek & Schein 1945, Larsson et al. 1961).

Despite being in the center of a rich vascular network it thus appears that the talus is sensitive to an alteration in its blood supply. For this reason we have undertaken this investigation to study how experimentally produced fractures of the neck of the talus might influence the arterial supply to this bone.

MATERAL AND METHODS

The material consisted of 11 feet. Clinically there was no evidence of vascular disease, nor of any other illness which might influence the vascular tree. The reasons for amputation were local bone and soft-tissue tumors well away from the foot. The ages of the patients from whom feet were taken varied between 8 and 55 years. Seven specimens were obtained from people between 20 and 40 years of age.

The procedure of filling the arteries was exactly the same as in a previous study (Peterson et al. 1974 a), which in short was as follows: the arteries were filled with one part micropaque mixed with two parts 10 per cent formaldehyde solution. The injection was made under a constant pressure of 140 mmHg. The foot was placed in a bath with 10 per cent formaldehyde solution, and the infusion of contrast medium was carried on for 24 hours under the same pressure. The filling of the feet for this study was as satisfactory as for the previous one dealing with the analysis of the arterial supply. To facilitate the vascular analysis the feet were cut in sagittal sections 1–2 cm thick and studied by X-ray, with transparencies obtained by the Spalteholz procedure (Peterson et al. 1974 a). Fractures were experimentally produced in the same way as has been described in a previous study (Peterson et al. 1974 b).

> "The foot was placed in an ordinary shoe, to the sole of which two transversal steel bands were riveted firmly, one under the heads of the metatarsals and one under the heel. In those bands four rigging screws were attached and anchored to the stand by chains, two medially and two laterally. This gave full control of the inversion-eversion and the degree of dorsiflexion. It also gave possibility to apply varying pretension to the foot. The striking point and the direction of the pendulum was checked with X-ray in lateral and antero-posterior view and adjustments were made. Fractures of the talar neck were achieved by striking the sole of the foot with the pendulum at a given velocity and load."

For the present study the feet were first filled with the micropaque contrast medium, and when X-rays had confirmed the satisfactory filling of the talus the experimental fractures were produced. It soon became evident that some difficulties arose in obtaining fractures with the same ease as in the previous study (Peterson et al. 1974 b). We interpreted this difficulty as being due to the formaldehyde preparation of the feet, which increased the elasticity of especially the soft but also the osseous structures (the consistency of the foot resembled hard rubber). Similar observations have been made by Moseley & Goldie (1963). In all feet, where fractures were obtained, an analysis of the vessels was made on X-rays of the entire foot as well as of the individual sections. Further study was made on the individual sections after subjecting them to the Spalteholz procedure (Peterson et al. 1974 a).

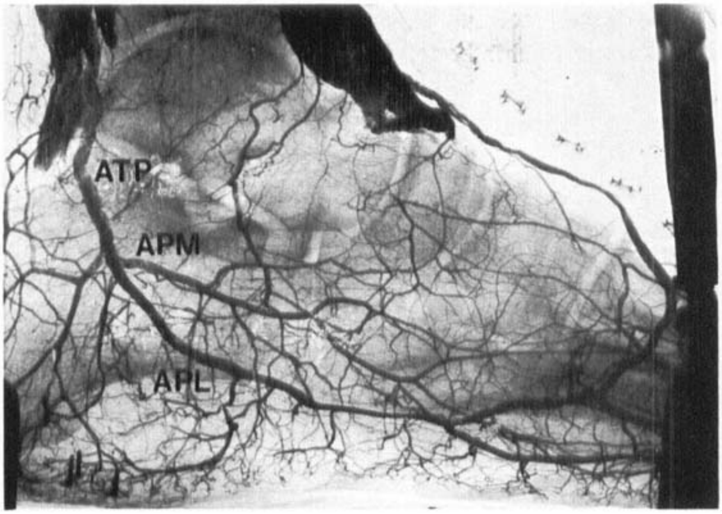

Figure 1 a. Angiogram of left whole foot from a 48-year-old woman before production of fracture. ATP = arteria tibialis posterior, APL = arteria plantaris lateralis, APM = arteria plantaris medialis. The leakage of contrast medium seen at the top occurred during filling of vessels.

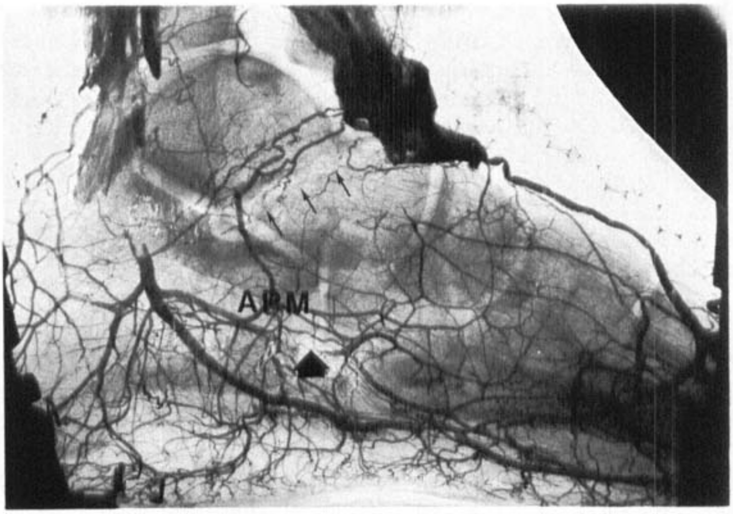

Figure 1 b. Same as Figure 1 a but after production of fracture without displacement. Fracture line is marked by arrows. There is now a defect in the filling of the arteria tibialis posterior corresponding to the talocrural and talocalcanear joints. A localized defect is also seen in the arteria plantaris medialis (APM) marked by a large arrow and limited by the impact on the sole of the foot.

RESULTS

Some difficulties arose in the interpretation of the course of the vessels in connection with the fracture. There was a disarrangement of the arteries in and around the fracture. Some vessels became stretched, others ruptured. By comparing the X-rays before fracture with those after fracture it was possible, especially in the individual sections, to identify each vessel and its change of course and/or its disruption after fracture.

Arteria tibialis posterior

In four feet there was an interruption in the filling of this vessel behind the talus on a level with the talocrural and talocalcanear joint spaces (Figures 1 a & b). It was not evident that this was due to a rupture of the vessel, but there was a local disappearance of contrast probably due to compression. In the remaining feet normal conditions prevailed.

In the further course of the arteria tibialis posterior, after its division into the arteria plantaris medialis and arteria plantaris lateralis, it became evident that the impact load of the pendulum influenced the filling of the vessel. Within an area corresponding to the limitations of the impact body on the footsole the contrast medium disappeared (Figure 1 b) from the arteria plantaris medialis without any signs of vascular rupture. (There was no leakage of contrast medium outside the vessel.) The arteria plantaris lateralis was also affected in a similar way.

Arteria canalis tarsi and arteria sinus tarsi

The arteria canalis tarsi and arteria sinus tarsi are in the midst of the danger zone, and apparently disintegrate during the actual fracture process. In all specimens the ascending branches from these arteries were ruptured (Figure 2 a). The more the displacement the more disruption was observed, and in two specimens with displacement there was rupture of the anastomoses between arteria canalis tarsi and arteria sinus tarsi (Figure 2 b).

Arteria dorsalis pedis

The branches from the arteria dorsalis pedis descending to the talus were ruptured in their course through the fracture area. No rupture of the arteria dorsalis pedis was observed (Figure 3).

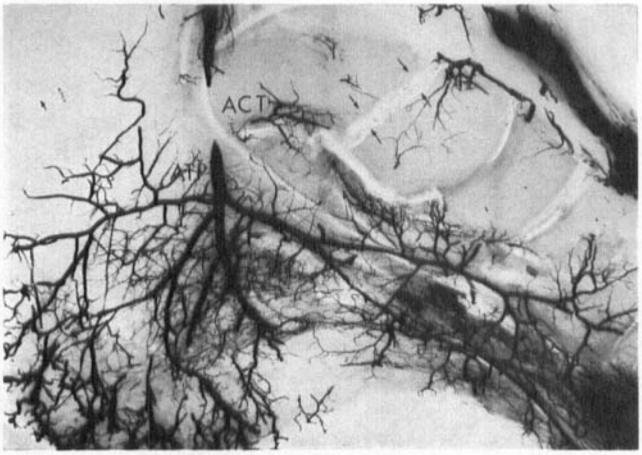

Figure 2 a. Angiogram of section II of left foot from a 17-year-old boy after production of fracture, which is slightly displaced. Fracture line indicated by arrows. The arteria canalis tarsi (ACT) is not here ruptured, but becomes ruptured in its more anterolateral course (cf. ACT Figure 2 b). ATP = arteria tibialis posterior. (Spalteholz preparation).

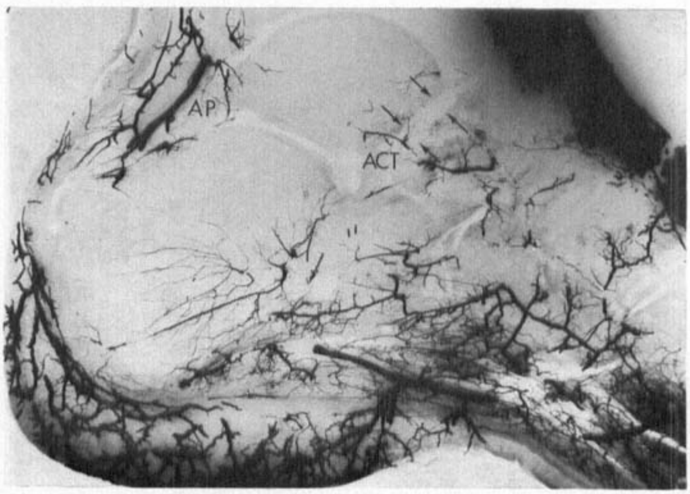

Figure 2 b. Same as Figure 2 a but section III. The arteria canalis tarsi (ACT) has become ruptured at level of fracture (arrows). AP = arteria peronea. (Spalteholz preparation).

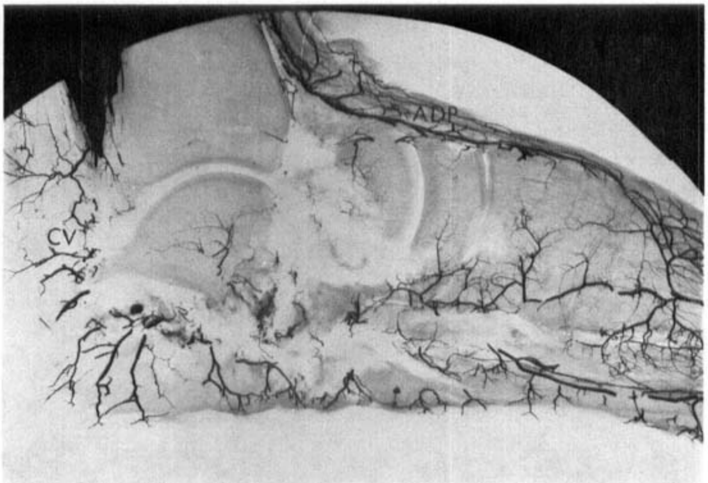

Figure 3. Angiogram of section II of left foot from a 45-year-old woman. Fracture of talus with displacement. The descending vessels from the arteria dorsalis pedis (ADP) have been destroyed. Only small remnants can be seen. CV = capsular vessels in posterior capsule intact. The calcaneus was fractured and displaced laterally. (Spalteholz preparation).

Arteria peronea

This artery was never damaged by the fractures. The ramus perforans from the arteria peronea became stretched in two cases, with localized disappearance of contrast medium, without evident rupture. In the remaining specimens there was no damage to this artery.

Intra-osseous vessels

The experimental fracture had a most destructive effect on the intra-osseous arterial supply limited to the fracture region. The vessels appeared as if they had been sharply cut off. In the areas adjacent to the fracture site the vessels remained intact.

Interosseous vessels

In five cases of talar neck fracture with no or only slight displacement there was no involvement of the capsular vessels. In one case with great displacement there was a rupture of the anterior capsule vessels but none in the posterior capsule (Figure 3). The calcaneus was fractured and displaced laterally. The arteries between the talus and the calcaneus and the navicular, respectively, were intact.

DISCUSSION

There are clinical implications that the experimentally produced fractures much resemble the mechanism of production as exemplified by the following case-history:

A 27-year-old nurse was driving a car. She noticed at some distance a car approaching which suddenly started skidding in a direction towards the nurse driver. It became obvious to her that a head-on collision was inevitable. Realizing this she instantly pressed her left foot against the clutch and her right foot against the brake. At the same time she stretched out her arms and pressed her hands against the wheel. At the collision the nurse driver sustained a talar neck fracture in her right foot and a medial malleolar fracture in her left foot. The clutch went down with the foot flat on the floor. The brake, however, stopped at a distance from the floor and thus acted as an impact body at the moment of collision, thus creating conditions similar to the experimental model by which talar neck fractures could be produced.

The arterial supply of the talus under normal conditions has previously been studied (Wildenauer 1950, Haliburton et al. 1958, Crock 1967, Mulfinger & Trueta 1970). It has become evident that a rich supply of arteries surround and furnish the talus. It has been stated (Phemister 1940, McKeever 1943, Mindell et al. 1963, Kenwright & Taylor 1970, Hawkins 1970) that an interruption of the supply by a fracture of the neck of the talus can have a deleterious effect on the osseous structure by the development of an avascular necrosis. This is thought to be especially true in those cases where a displacement has occurred (Hawkins 1970, Kenwright & Taylor 1970, Brinkmann et al. 1973).

In this investigation the object has been to study what effect a fracture of the neck of the talus may have on the arterial supply.

Experimentally produced fractures without displacement showed ruptures of especially the intra-osseous arterial network. The main contributing arteries to this network, i.e. arteria dorsalis pedis, rami deltoidei from the arteria canalis tarsi and this artery as well as the arteria sinus tarsi remained intact. This no doubt has an effect on the future fate of the talar osseous structure. The rate of avascular necrosis following non-displaced fractures is, as could be expected, very low e.g. 2 per cent (Brinkmann et al. 1973), and in those cases where there is such a development it is hard to explain, considering the intact rich arterial supply from outside which no doubt can maintain the circulation of the bone.

In displaced fractures the situation is quite different. It has previously been believed that a displaced fracture causes a disruption of the arterial supply to the body of the talus (Hawkins 1970, Kenwright & Taylor 1970, Brinkmann et al. 1973). The results of this investigation disclosed that when a displaced fracture of the neck of the talus was produced, branches from the arteria dorsalis pedis were disrupted, as well as the arteria canalis tarsi and the arteria sinus tarsi. In other words, what has been regarded as the main arterial supply to the talus becomes injured in a displaced fracture of the neck. The degree of displacement is of some importance as it became evident that the more the displacement the more the vascular disarrangement. Hence the development of avascular necrosis can be expected to be related to the degree of displacement, which has been verified clinically (Brinkmann et al. 1973).

SUMMARY

After filling the arteries of the talus with contrast medium, fractures of the neck were produced to study the effect on these vessels. It was found that the ascending branches from the main arteries, arteria canalis tarsi and arteria sinus tarsi, were ruptured in all cases. The vessels in the fracture area were all sharply cut off. Without fracture displacement the surrounding arteries were remarkably intact, whereas with displacement these became affected by varying degrees of disruption.

The vessels in the bone adjacent to the fracture remained intact.

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