"AVIATOR'S ASTRAGALUS"

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The talus [astragalus] is less important as the keystone of an arch than as the chief component of a universal joint in the foot, and the crippling that may follow an injury to the bone is due to this mechanical importance.

The first account of an accident to the talus was made by Fabricius of Hilden in 1608, who wrote: "the Rev. Master Woolfbrand of Duisburg, a man strong and fleshy, in jumping from a bank three feet high so twisted and broke his right foot that the whole of the os tali was not only displaced but the ligaments by which it is bound to the other bones, being broken, it burst through the skin and hung out."

Sir Astley Cooper wrote at considerable length on fractures and dislocations of the talus, and since he published his "Surgical Essays" (1818) many surgeons here and abroad have referred to the subject in their works, but most refer to an experience of one or two cases and fill up space with many quotations from the literature. There is, however, an excellent account by Baudet in the *Revue de Chirurgie* of 1914, although he, like other earlier authors, has obviously been handicapped by a lack of good radiographs. Nowadays this difficulty does not exist and we gain a much clearer picture of the injuries that occur. Since 1914, although many descriptions have appeared in the American literature, accounts by British surgeons are few and I have been able to trace only those by Anderson (1919), Ollerenshaw (1921), Mercer (1928), Hosford (1932), Bonnin (1940) and McCurrich (1941). Again, these authors (except Anderson) refer to a clinical experience of one or two cases, and Miller and Baker (1939) stated: " In reviewing the literature of fracture and fracture-dislocations of the astragalus one finds many case reports but few recent long series of cases." The explanation lies in the rarity of the more severe and complicated injuries of the talus, so that surgeons, even those with a wide experience in accident surgery, cannot claim to have treated more than a few isolated cases. This lack of individual experience has meant a dearth of accurate description or classification in the medical literature and an absence of any real guidance on the treatment of accidents to the talus.

In 1919 Anderson, who was consulting surgeon to the Royal Flying Corps in the war of 1914–1918, described eighteen cases of fracture and dislocation of the talus. He was so impressed by the association of injuries of the talus with the aircraft crash that he named them collectively " Aviator's Astragalus." After remarking that falls from a height on to the foot are common in civilian occupations but that in those the calcaneum [os calcis] is usually broken, he proceeds: " On the other hand, the aviator usually falls with his machine and strikes the ground at an angle. The sole of the foot rests on the rudder bar and with the impact the latter gets pressed into the instep just in front of the heel. There the astragalus takes most of the force and becomes the seat of fracture. Before the actual fracture occurs, the foot may be in a position of acute dorsiflexion, plantar flexion, or may be inverted."

The clue provided by Anderson has been followed up in the last war and a large number of aviation injuries has provided the opportunity for a complete and fresh review of injuries of the talus.

CLINICAL MATERIAL

Between 1940 and 1945 approximately 25,000 fractures and dislocations were treated by surgeons working in orthopaedic units of the Royal Air Force. There were 228 injuries

to the talus—roughly 1 per cent of all injuries, or 6 per cent of 4,000 injuries affecting the ankle and foot. Survivors of air crashes seldom had bilateral injuries, only ten patients having injuries to each talus. The fact that 100 (43·8 per cent) of the injuries were sustained

TABLE I

CASES ADMITTED TO R.A.F. ORTHOPAEDIC CENTRES (1940–45)

Total number of fractures and dislocations		25,000
Total number of injuries to talus		228
Percentage of all injuries = 0·9		
Total number of fractures and dislocations of ankle and tarsus		4,000
Percentage of local injuries = 5·7		
Total number of patients with injuries to talus		218
Patients with unilateral injuries	208	
Patients with bilateral injuries of same type	3	
Patients with bilateral injuries of different type	7	

in accidents which had nothing to do with flying seems at first glance to belittle the significance of aviation in this condition, but if we consider only 154 serious injuries, leaving out the various chip and avulsion fractures and simple subtalar dislocations, we find that flying accidents accounted for 106, nearly 70 per cent of the more severe lesions, a figure that amply justifies Anderson's title of " Aviator's Astragalus " (Table I).

CLASSIFICATION

No previous account in the literature has included all the types of injury occurring in the present series, nor has any author hitherto described any injury of which examples have

TABLE II

CLASSIFICATION OF 228 INJURIES OF THE TALUS

Fractures	
Chip and avulsion fractures	56
Compression fractures of the head	6
Fractures of the body	15
Fractures of the neck	37
Fracture-dislocations	
Fracture of the body with subtalar dislocation	7
Fracture of the neck with subtalar dislocation	38
Fracture of neck with posterior dislocation of the body	31
Dislocations	
From ankle, subtalar and mid-tarsal joints	9
Miscellaneous injuries	11
Dislocation of tarsus at subtalar joint	18

not been found amongst this collection of 228 cases. For reasons that have already been mentioned, earlier classifications have been too scanty, including all types of injury as fractures of the neck, body or posterior process—too academic, such as that of Destot

(quoted by Baudet 1914)—or too complicated, as for example the classification included with an excellent account of a case of total dislocation by Bonnin (1940). With the advantage of a large, well documented series to study it was easily apparent that the injuries fell into three main categories—fractures, fracture-dislocations and total dislocations (Table II). There were inportant subdivisions to be made, particularly that between fractures of the neck of the talus with subtalar dislocation or subluxation of the tarsus, and fractures occurring at the same site but associated with complete posterior dislocation of the body of the talus from the ankle. A remarkable aspect of the subject is that, although the talus is as it were buried among the bones comprising the ankle and tarsus, it is nevertheless singled out for injury, whereas the other bones in the neighbourhood remain unaffected. There were, however, a few cases in which the talus shared in severe combined injuries to the local bones. These have been grouped together as " miscellaneous injuries " to avoid an over-detailed classification

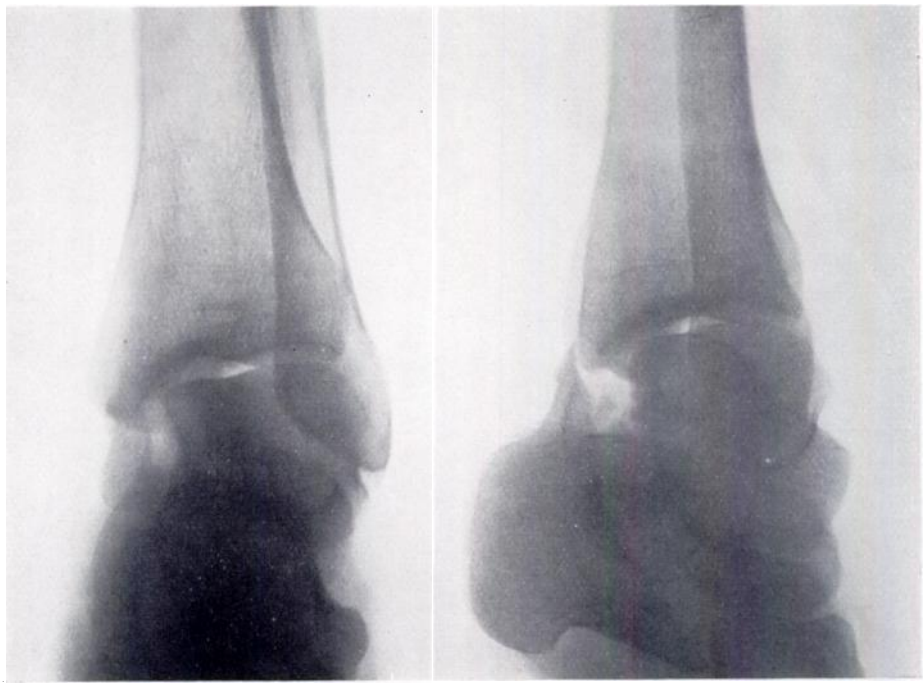

FIG. 1

Avulsion fracture of the talus. A large fragment is detached from the medial side of the bone.

(Table II). The disturbance of relationship in the subtalar joint is of considerable significance in the disablement which may follow injuries of the talus; because of this, subtalar dislocations have been included in the classification.

PATHOLOGICAL ANATOMY

Chip and avulsion fractures—In a twisting injury to the ankle, small fragments may be detached from the upper surface of the neck of the talus or from its medial and lateral walls. These may be regarded as minor complications of a " sprained ankle " and are revealed in the routine radiograph. Sometimes, however, a larger fragment, which includes part of the articular surface and the groove for the flexor longus hallucis tendon, is separated from the medial wall of the talus. The fragment is rotated and interferes with movement at the ankle. It is best removed by operation (Fig. 1).

Compression fractures of head of the talus—This injury is uncommon but characteristic. The radiographic appearances suggest that fracture is the result of a compression force

acting in the long axis of the foot. Four of the six cases occurred in flying accidents, and the position of full plantar-flexion with the foot stretched out against the rudder bar is one often assumed during efforts to prevent a crash. Radiographic diagnosis may be difficult unless

FIG. 2
Compression fracture of head of talus. The comminution is not easy to see.

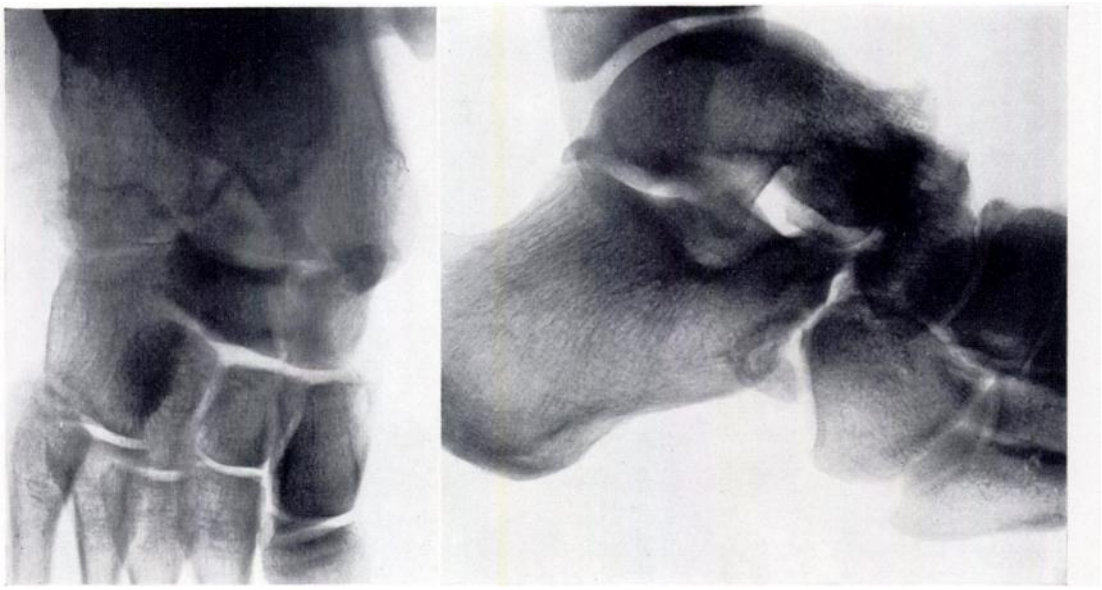

FIG. 3
Compression fracture of head of talus; another type, with an associated fracture-dislocation of mid-tarsal joint.

there is a clear antero-posterior view of the foot. In the simpler injuries there is a contusion fracture of the head alone, but sometimes the forefoot is forcibly abducted, the mid-tarsal joint is dislocated and a large fragment is broken from the head of the talus (Figs. 2 and 3).

Fractures and fracture-dislocations of the neck of the talus—If the foot is forcibly extended at the ankle the talus is impacted against the anterior lip of the distal end of the tibia and a fracture occurs through the neck. In addition there may be radiographic evidence

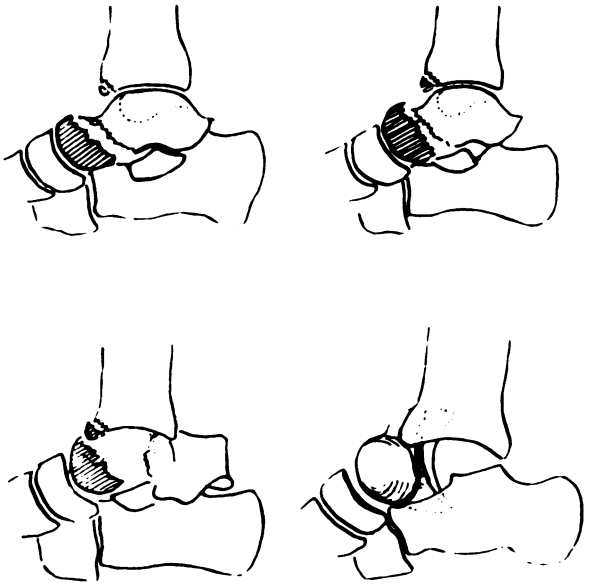

FIG. 4

FIG. 5

Figure 4—Diagrams showing the three types of injury produced by dorsiflexion and (bottom right) total dislocation, which is a plantar-flexion injury. Figure 5—Fracture of neck of talus. The effect of an impacting force can be seen in the neck of the talus and the lower end of the tibia.

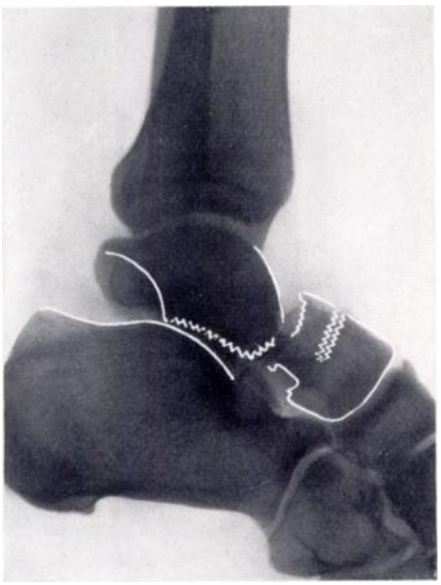

FIG. 6

FIG. 7

Radiographs before (Fig. 6) and after (Fig. 7) reduction of a fracture of the neck of the talus with subtalar dislocation.

of damage to the contiguous margin of the tibia. This sort of violence is common in aviation accidents. If extension is forced still further, the line of stress may extend from the neck of the talus to the ligaments of the subtalar joint, which rupture, and the rest of the tarsus

subluxates forwards. In the final stage the body of the talus becomes dislocated backwards out of the ankle joint (Fig. 4).

It is easy, with the aid of radiographs, to distinguish between a fracture of the neck and a fracture-dislocation in which the body of the talus is displaced backwards out of the ankle joint; but it is important, although not so easy, to recognise those fractures of the neck of the talus which are complicated by subtalar dislocation. Examples are shown in Figures 5 and 6. In Figure 5 the effect of an impacting force can be seen in the neck of the talus and at the lower end of the tibia, but the contours of the subtalar joint remain unaffected and there is no displacement of the head of the talus on its neck. In contrast, Figure 6 shows a case in which the distal fragment of the talus has been displaced upwards and forwards with the rest of the tarsus; the proximal fragment has fallen into plantar flexion. As well as the

FIG. 8

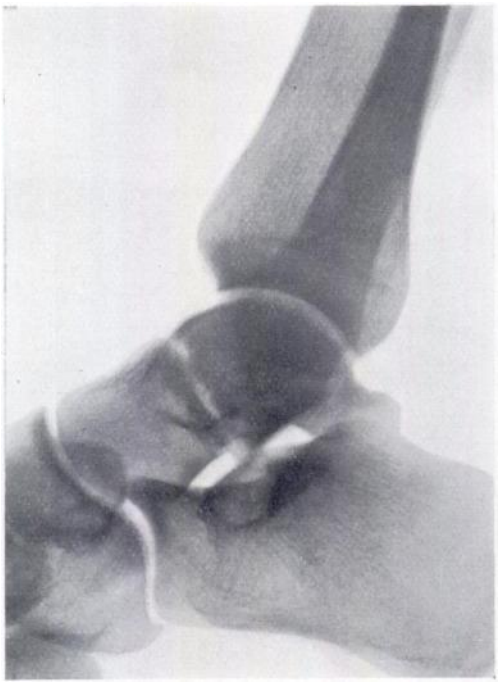

FIG. 9

Figure 8—Fracture of neck of talus with complete medial dislocation of tarsus (pseudo-transverse fracture). Figure 9—The same case as Figure 8 after reduction, showing that this was not a " transverse " fracture of the body of the talus.

forward and upward displacement there is usually some medial, or less commonly lateral, displacement of the tarsus. In an extreme example there may be a fracture of the neck of the talus with a complete medial dislocation at the subtalar joint (Fig. 8). This injury has sometimes been described as a transverse fracture of the talus, but that is not its true nature, as can be seen from the radiograph taken after the dislocation had been reduced (Fig. 9).

Fractures and fracture-dislocations of the body of the talus—Figure 10 shows an injury in which the fracture line is approximately vertical and which appears at first glance to be another example of those fractures through the neck of the talus which have just been described. But the fracture line is through the upper articular surface, involves the ankle joint and is a fracture of the body of the talus. As in the case of fractures of the neck, this fracture of the body may be complicated by subtalar dislocation. The displacement is often more severe than when the fracture is through the neck of the talus (Fig. 11).

Severely comminuted fractures of the body are rare. There were but two cases in this series—one, the result of an aviation injury, is shown in Figure 12. In both cases the comminution was so severe that fusion of the ankle and subtalar joints was required. A

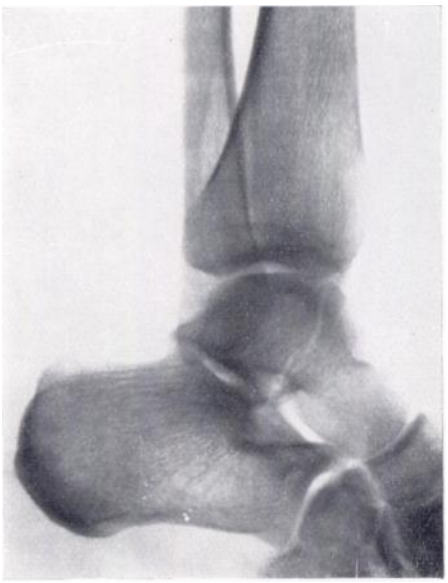

FIG. 10

FIG. 11

Figure 10—Vertical fracture through the body of the talus. Figure 11—Fracture of body of talus with subtalar displacement.

FIG. 12

FIG. 13

Comminuted compression fracture of the body of the talus. Figure 13—" Dome fracture " of the body of the talus.

fracture of the articular surface of the body of the type shown in Figure 13 may be described as a " dome fracture." The shape of the fragment is variable, but in a typical example the fragment was found to be upside down in the joint and was removed.

Fractures of neck of talus with posterior dislocation of the body—In many ways this is the most interesting of all injuries to the talus. In the thirty-one cases reviewed, one was caused by the unexpected detonation of a 4,000-lb. bomb, one by a motor cycle accident

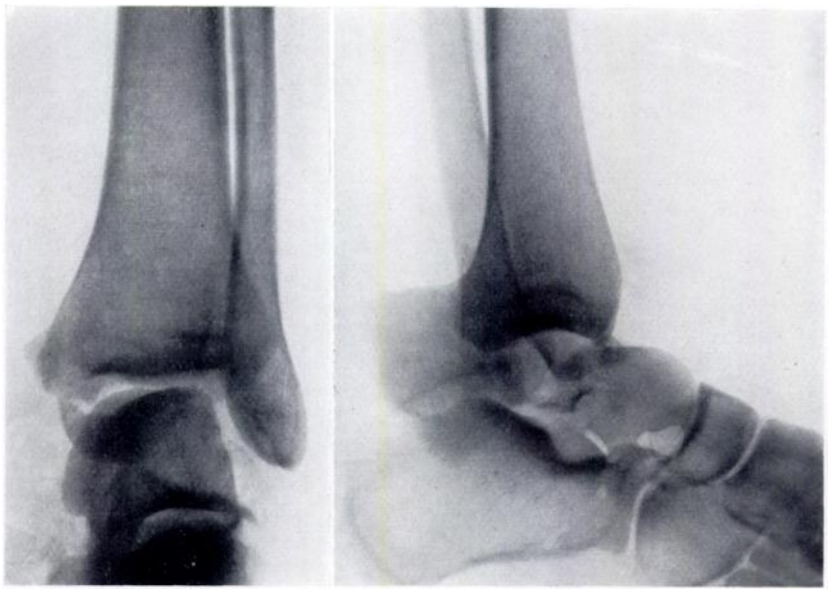

FIG. 14
Fracture of neck of talus, with posterior dislocation of the body. In this case the usual medial displacement has not occurred.

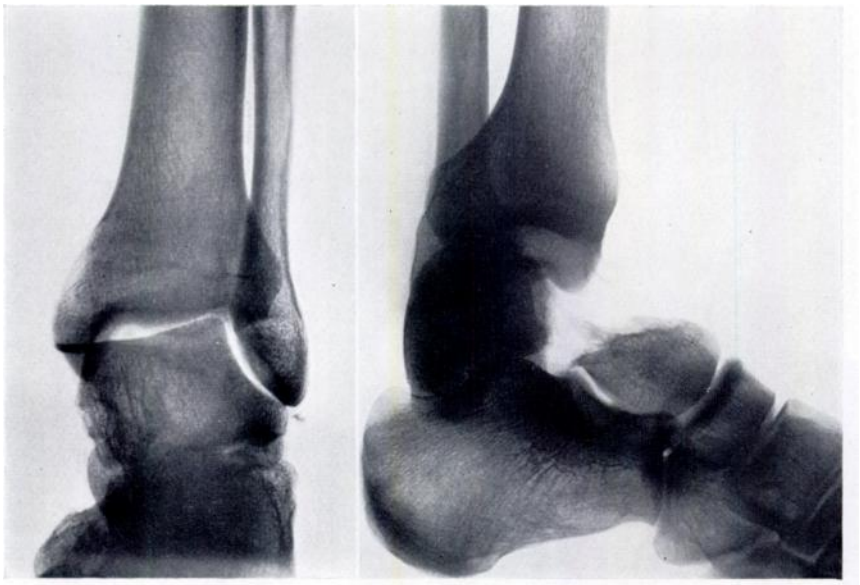

FIG. 15
Incomplete backward dislocation of the body of the talus.

and twenty-nine by aviation accidents. Descriptions of the typical clinical appearances had been made long before the invention of the flying machine, so that the injury is one which has occurred and still does from ordinary misfortune.

In a typical example (Fig. 14) the neck of the talus is fractured and the body, dislocated from ankle and subtalar joints, is displaced backwards on the upper surface of the calcaneum and is rotated through 90 degrees on its vertical axis so that the fractured surface points laterally. The whole body is usually displaced medially. In addition, the medial malleolus is fractured, but the lateral malleolus remains intact. In most cases this deformity is typical and constant. Occasionally backward dislocation of the talus is incomplete and the body remains unrotated and caught beneath the posterior articular margin of the tibia (Fig. 15). Rarely displacement is to the lateral side of the ankle.

Operation reveals that all the ligamentous and capsular attachments of the dislocated bone are torn off except those to the medial [deltoid] ligament, which may often be preserved. Injuries to the vessels, nerves and tendons at the medial side of the ankle are unusual despite the gross violence of the accident and the degree of displacement. This is probably because the body rotates away from them and, when it finally becomes displaced medially, remains behind the tendon of the flexor hallucis longus which protects the neurovascular bundle from harm.

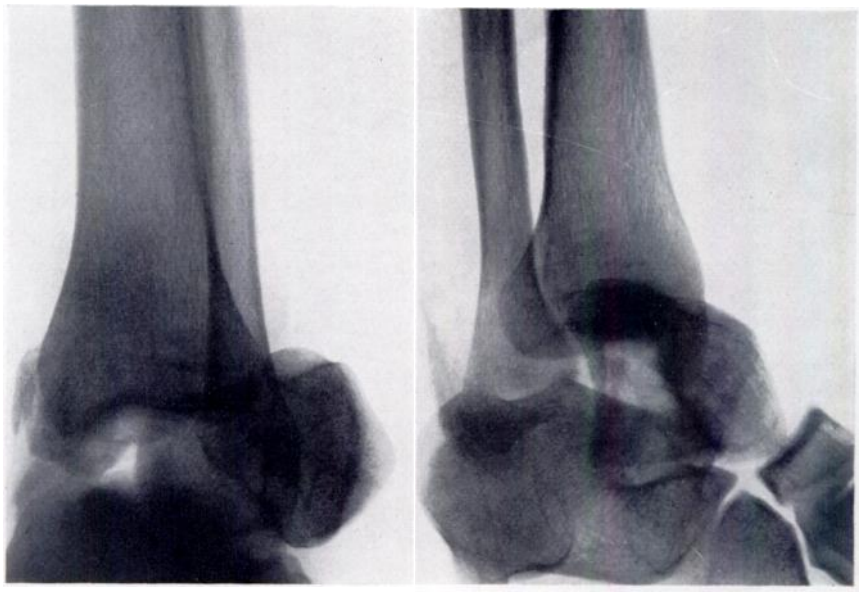

FIG. 16
Total dislocation of the talus.

In about half the cases in this series the injury was compound and then the talus was visible in the wound or hanging out on the surface; in a few cases the fractured and dislocated body had been completely avulsed and was lost.

Total dislocation of the talus—In this injury the talus is dislocated from all three joints of which it forms a part. The characteristic feature is that displacement is forwards and laterally so that the bone comes to rest under the skin in front of the ankle on the dorso-lateral aspect of the foot. There was often complete avulsion of the talus, but the wound through which the extrusion had occurred was invariably in the same situation, in front of the ankle and to the lateral side.

Dislocation is the result of considerable violence. All nine instances in this review occurred in flying accidents. The domestic accidents which have been observed by others seem most often to occur in heavy men or women. Most cases—six out of nine reviewed here—were compound and the talus was removed. The typical displacement is shown in Figure 16. The talus has been dislocated forwards and laterally so that it lies in front of the lateral

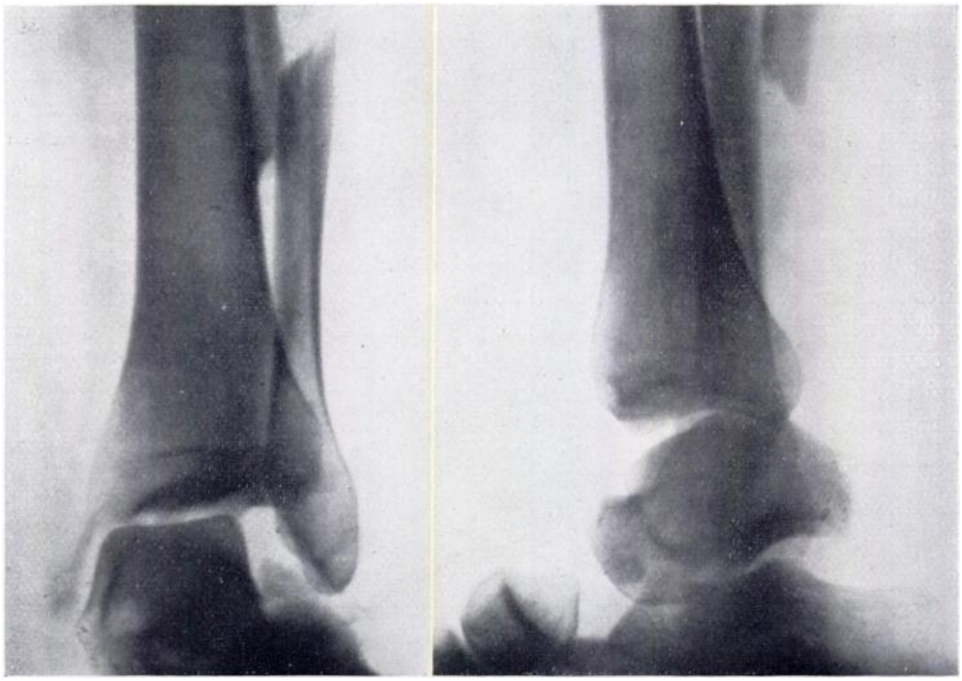

FIG. 17
There has been a fracture-dislocation of the ankle combined with subtalar dislocation. As a result the talus is dislocated.

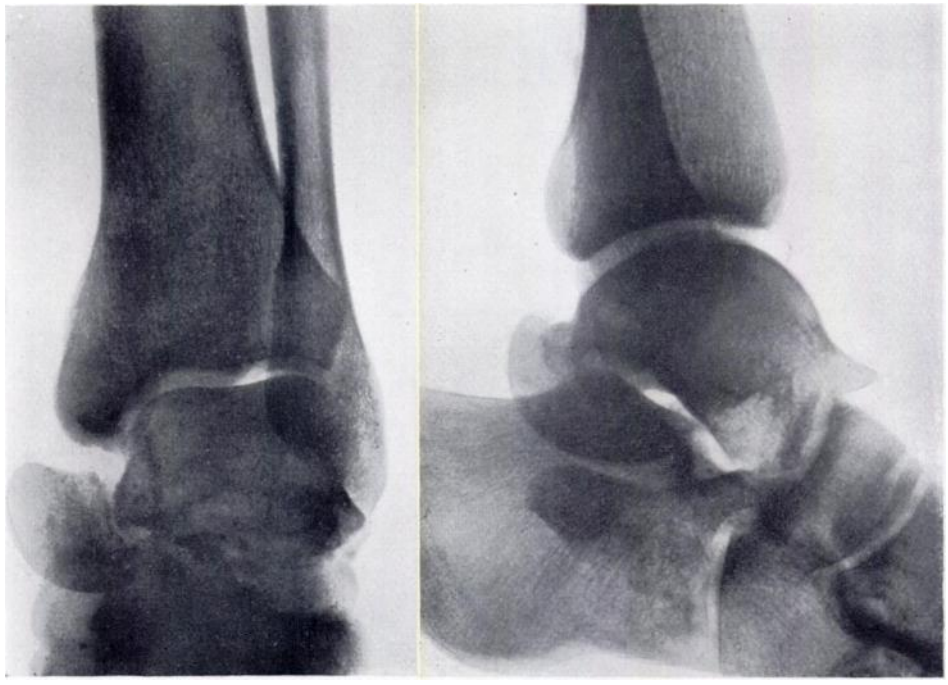

FIG. 18
Fracture through neck of talus with mid-tarsal fracture-dislocation.

malleolus and is rotated through 90 degrees in both its vertical and longitudinal axes, with the head pointing medially and the under-surface backwards. Probably this represents the greatest displacement, and rotation may not always be so complete in both directions. Occasionally the bone may be broken through its neck—but the injury is distinguished from other fracture-dislocations by displacement forwards instead of backwards.

Miscellaneous injuries—There were two cases in which fracture-dislocation of the ankle was combined with subtalar dislocation of the tarsus—so that the talus was left totally dislocated (Fig. 17). This injury is important because the talus may undergo avascular necrosis—which it will not do after either a Pott's fracture or subtalar dislocation alone.

In four cases a fracture through the neck of the talus was associated with dislocation at the mid-tarsal joint (Fig. 18). It will be observed that the line of fracture is oblique, with the fragment grossly displaced, and quite different from an ordinary vertical fracture of the neck.

FIG. 19
Combined comminuted fractures of talus and calcaneum.

Finally, there is an injury which appeared to be common as the result of the explosion of land-mines. This is a severe comminution of the calcaneum with a fracture through the neck of the talus (Fig. 19). The body of the talus is inverted and embedded in the calcaneum. The injury is usually compound and infected, and three of the five patients in this series suffered below-knee amputations.

Subtalar dislocation—This well known condition does not require further description here, but the radiographic appearances (Fig. 20) should be compared with those of fracture-dislocation, and especially total dislocation, of the talus.

DIAGNOSIS

Injuries of the talus are often the result of such a severe accident that the skin and soft tissues are burst and the bone in whole or part projects from the wound. Occasionally the talus is torn completely from its socket and lost, or may be found at some distance from

its owner. In these compound injuries a diagnosis is made by direct examination, but in closed injuries the patient presents a swollen, maybe deformed, ankle and foot. Swelling obscures minor displacements at the subtalar joint, which so frequently occur and which it is so important to recognise and reduce. Only by radiography can the true state of affairs be revealed. In ordinary dislocations of the tarsus at the subtalar joint, the head of the talus, uncovered by medial displacement of the navicular, is palpable beneath the skin on the dorsum of the foot; in total dislocation of the talus the whole bone presents under the skin in the same situation; and in fracture-dislocation, when the bone has been broken through its neck and the body has been displaced backwards from the ankle joint, this large posterior fragment may be felt as a bony hard mass between the medial malleolus and the tendo calcaneus [achillis].

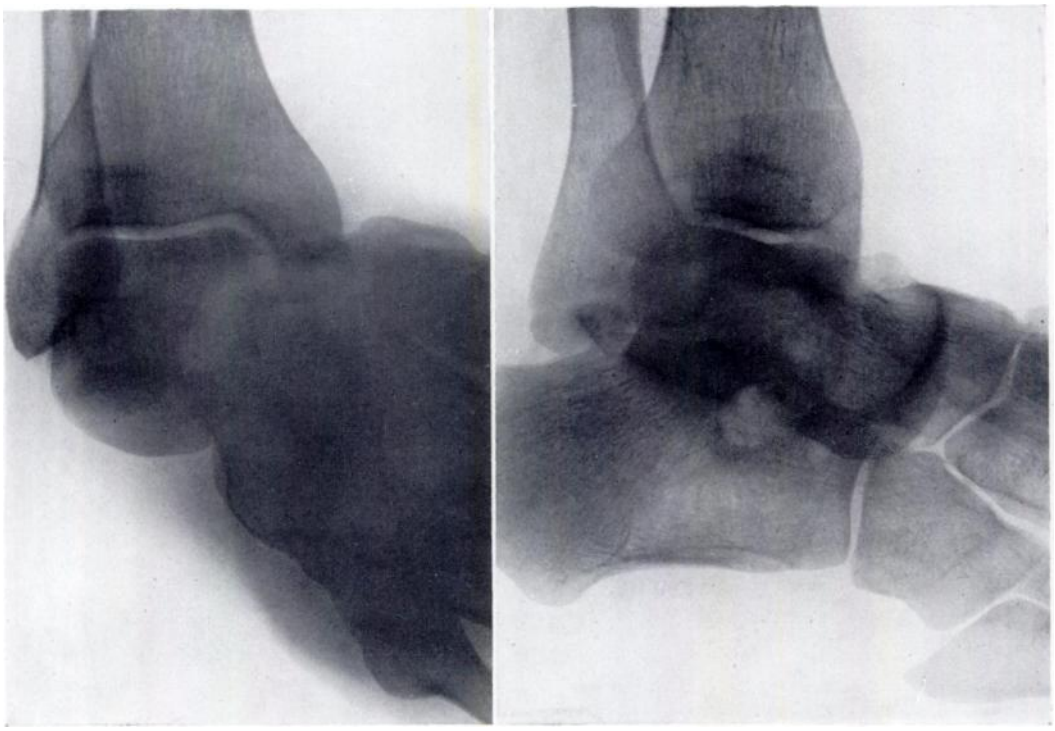

FIG. 20
Subtalar dislocation of tarsus.

COMPLICATIONS

Wound infection—Often the more severe injuries are compound. Because of lacerations or swelling, suture of the skin is seldom possible and the wound is likely to become infected. The violence of the injury may have been sufficient to strip the talus of most of its soft tissue attachments; the blood supply to a large part of the bone becomes impaired and consequently resistance to infection is low. Once the talus itself becomes infected resolution is unlikely and removal of the bone as a sequestrum is usually necessary. Besides an actual wound there is another important source of infection. Reference has been made to protrusion of the talus beneath the skin in subtalar dislocation, total dislocation and posterior dislocation of the body. In these cases the skin is tightly stretched over the projecting bone, and sloughs rapidly unless tension is relieved by reduction of the deformity. The danger calls for an early diagnosis of the injury and for prompt action. Once the skin sloughs, infection spreads into

the deep tissues, and even if the talus itself is not involved, the resulting fibrosis militates against restoration of good function to the ankle and foot.

Avascular necrosis—The body of the talus, like the head of the femur and the proximal pole of the scaphoid bone, exhibits an aseptic form of bone necrosis under certain conditions of injury. This morbid change is recognised by increased opacity in the radiographs (Fig. 21). The blood supply to the talus, however, does not resemble that of the femoral head or of the proximal pole of the scaphoid. In these two the blood supply is, as it were, by a single channel which is severed by the fracture. Examination of a talus shows that it is well supplied with vascular foramina in three main groups: on the upper surface of the neck; in the sinus tarsi; and on the medial surface below the comma-shaped articular facet. This threefold supply does not protect the talus from the effect of those injuries which may destroy two-thirds or

FIG. 21

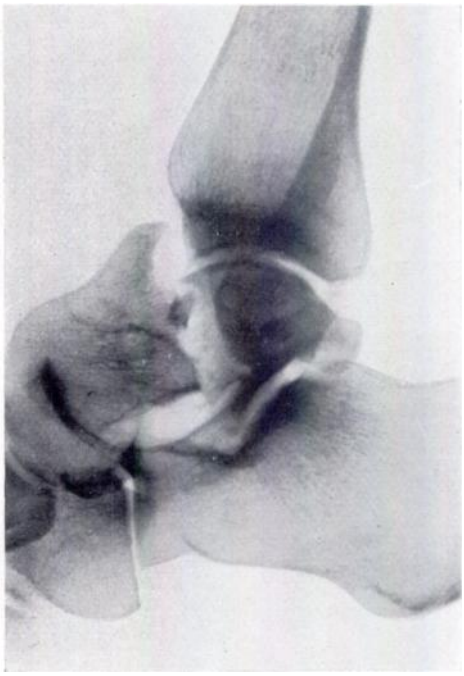

FIG. 22

Figure 21—Avascular necrosis. Well marked changes in the body of the talus ten weeks after a fracture-dislocation. Figure 22—" Apparent " avascular necrosis. Within a few hours of injury opacity of the body of the talus cannot be due to avascular changes. The apparent density is due to overshadowing by the fibular malleolus.

all of the vascular channels. Again differing from the neck of the femur and the carpal scaphoid, fractures of the neck and body of the talus unite without much difficulty, usually in about eight weeks; this rapid union is probably accounted for by the ease with which the fragments of a fractured talus may be immobilised. Allied to this observation is the further one that regeneration of the avascular body of the talus will take place, and proceed smoothly, under conservative treatment, to complete revascularisation, and this must be, anyhow partly, because the blood supply to the body is restored rapidly across the fracture of the neck.

Aseptic necrosis of the talus is not always easy to recognise. There is a tendency to diagnose the condition when it is not really present. This confusion arises because even in the normal foot a lateral radiograph must penetrate layers of denser cortical bone beneath the articular cartilage on the lateral malleolus, both sides of the talus and on the medial malleolus. Careful examination will distinguish between the diffuse avascular changes (Fig. 21)

and the localised apparent density (Fig. 22). If possible a film of the normal side, taken with the same exposure, should be available for comparison.

The incidence of avascular necrosis is shown in Table III. It occurred most frequently in the more severe injuries; in fact, with very few exceptions, in all those severe injuries in which the body of the talus had not been lost or removed. Since the talus receives its blood supply by three main channels we need not expect necrosis of the body if but one group of vessels is damaged. Necrosis did not occur after uncomplicated fracture of the neck, or after simple dislocation at the subtalar joint; in the former the blood supply is preserved through the

TABLE III

INCIDENCE OF AVASCULAR NECROSIS IN THE DIFFERENT TYPES OF INJURY

	Number of cases	Avascular necrosis	No avascular necrosis	Talus removed
Fracture neck of talus	37	—	37	—
Fracture body of talus	15	—	15	—
Fracture of body with subtalar dislocation	7	5	1	1
Fracture of neck with subtalar dislocation	38	12	26	—
Fracture of neck with dislocation of body	31	14	1	16
Total dislocations of talus . . .	9	1	1	7
Subtalar dislocation	18	—	17	1
Miscellaneous	11	2	9	—

sinus tarsi and the medial ligament, and in the latter the vessels entering via the neck and the medial wall of the bone remain intact although those passing through the sinus tarsi may have been destroyed. Avascular necrosis was a complication in one-third of the cases of fracture of the neck with displacement at the subtalar joint. Possibly in those cases that escaped, the blood vessels entering through the sinus tarsi had remained intact. In a case of fracture with posterior dislocation that was examined at operation, the whole body of the talus had been denuded of soft tissue attachments, except for the medial ligament. In this instance avascular necrosis did not develop, so that evidently the blood supply through the medial ligament may be enough to preserve the vascularity of the whole body of the talus. This is not always so because, in four other cases in which a similar state of affairs was discovered, necrosis did subsequently develop. In the cases of avascular necrosis, a study of serial radiographs showed that the onset of the condition was always within eight weeks from the date of injury.

In fifteen cases conservative treatment was impossible because some operative reconstruction of the ankle or subtalar joint was required for an unreduced displacement. In the nineteen cases in which conservative treatment was feasible, regeneration of the necrotic bone occurred over periods varying between sixteen and thirty-four weeks. The average time required was twenty-four weeks, and this figure was not substantially affected whatever the type of injury or whether reduction had been achieved by operation or simple manipulation. The conservative method used was a below-knee plaster after reduction of the displacement. In some instances the patient was allowed to walk in plaster, but this made no difference and regeneration of the necrotic talus progressed satisfactorily. In all but two cases the plaster was retained until there was radiographic evidence of complete restitution of the normal bony texture. In the two cases in which plaster was discarded before this evidence had been obtained, the talus subsequently disintegrated and a painful arthritis of

the ankle ensued. Once regeneration of the bone has occurred, there are no later effects of the condition and the functional results achieved depended on the type of injury. A late follow-up of the cases of aseptic necrosis was attempted, but it was not informative because only three patients were traced. These reported that there had been no deterioration in the condition of their ankles two, three and five years after their discharge from medical care.

Arthritis of ankle or subtalar joint—In both fractures and fracture-dislocations, the violence may be enough to produce arthritis or ankylosis, even when deformity has been accurately reduced. The subtalar joint is most often involved. Quite slight degrees of displacement are enough to give rise to a painful arthritis which ultimately entails arthrodesis. It is, therefore, important to recognise displacement at this joint as a complication of what may appear to be merely a fracture of the neck of the talus unless the radiographs are inspected with great care.

Arthritis of the ankle is a less frequent complication. In some vertical fractures of the body of the talus there may be a residual step deformity which is very likely to lead to a painful arthritis. If the body of the talus is allowed to disintegrate as the result of avascular necrosis, arthritis is inevitable.

In these cases it is often a matter of great difficulty to decide whether the ankle or the subtalar joint is the source of pain. Sometimes both joints are involved and both may require surgical treatment.

MECHANISM OF INJURY

Aviation accidents were the commonest cause of serious fractures and fracture-dislocations of the talus, although not of all fractures, in the Royal Air Force. Figures taken from an earlier review of this subject demonstrate how often the talus was the site of injury in aviation accidents which involved the foot (Table IV). Injuries of the talus were more common than fracture of the calcaneum and occurred almost as often as fracture-dislocation of the ankle. This is because of the frequency with which forced dorsiflexion at the ankle occurs in an aircraft crash. However, not all serious injuries to the talus were caused in aeroplanes, and Baudet (1914) observed that a fall from a height could cause a fracture of the talus if the sole of the boot is flexible and if the victim lands so that the foot is forcibly extended at the ankle.

TABLE IV

FREQUENCY OF AIRCRAFT ACCIDENTS AS A CAUSE OF INJURIES IN THE REGION OF THE ANKLE

(R.A.F. cases 1940–42)

Injury	Aircraft accidents		Other accidents	
	number	per cent	number	per cent
Injuries of the talus . . .	53	70·7	22	29·3
Fracture of the calcaneum .	18	16	94	84
Fracture-dislocation of the ankle	60	27	162	73

He pointed out that it is not the strain of dorsiflexion which causes the fracture but the forcible impact of the margin of the tibia on the neck of the talus which produces what is in reality a crush fracture. Ombrédanne (1902), and more recently Gibson and Inkster (1934), have conducted experiments on the cadaver which showed that forced dorsiflexion will produce fractures of the neck of the talus and, if sufficient force is applied, backward dislocation of the body of the talus. Normally the talus is held in the ankle mortise by its own shape, assisted by the attachments of the neck and head, the talo-calcaneal ligaments, the strong posterior talo-fibular ligament, and the posterior and deep fibres of the medial ligament of

the ankle joint. In an accident dorsiflexion of the foot and impaction of the tibia against the neck of the talus occur together; the former ruptures ligaments and the latter fractures the neck. It seems probable that the various events occur in the following order. First, excessive dorsiflexion causes the wide anterior part of the body of the talus to become jammed in the mortise of the ankle joint. The posterior talo-calcaneal ligaments rupture. The neck of the talus is impacted against the tibia and is crushed. The calcaneum dislocates forwards, and possibly also medially or laterally if the foot is twisted into inversion or eversion. The body of the talus is pressed backwards by the approximation of the wedge-like lower end of the tibia to the calcaneum. The posterior talo-fibular ligament then ruptures, especially if the foot is inverted. Until this ligament tears, the body of the talus cannot escape backwards from the ankle joint. Once the ligament has torn and the body has begun to dislocate, it cannot avoid taking up a position on the supero-medial surface of the calcaneum, and rotating with its fractured anterior surface turned outwards. This position and rotation are compulsory because of the shape of the upper articular surface of the calcaneum and because of the torque exerted against the postero-medial surface of the talus by the long flexor tendon of the hallux.

There are three degrees of injury from dorsiflexion (see Fig. 4) and the lesion incurred will depend on the amount and duration of the force which is exerted—but the anatomical feature which determines whether or not the body of the talus will dislocate backwards is the integrity of the posterior talo-fibular ligament. Gibson and Inkster (1934) claimed that in their two experiments they were unable to rupture this ligament, but observation at six operations in this series confirmed that all attachments to the body were ruptured except the deep fibres of the medial ligaments, and Baudet has made the same observation.

Sometimes the fibular malleolus breaks instead of the ligament but this is unusual. The medial malleolus, however, is almost invariably fractured, and this suggests that it cannot be the pull of the medial ligament that rotates the talus.

It is probable that subtalar dislocation and total dislocation are produced by forcible plantar-flexion of the foot. Subtalar dislocations occur when the foot is off the ground—for instance, in kicking a football or in landing heavily on the foot from a jump. Passive plantar-flexion can occur only when the body weight is not resting on the sole of the foot, and it is forced plantar-flexion together with inversion which, in this case, ruptures the talo-calcaneal ligaments, and produces a subtalar dislocation.

Every total dislocation of the talus in this series was caused in an aircraft accident and the exact mechanism is difficult to determine, but descriptions of the injury in the literature give clear accounts of plantar-flexion and inversion of the foot in patients who sustained a similar injury in ordinary domestic accidents. It is suggested that in these cases plantar-flexion is so extreme that complete forward dislocation of the whole foot at the ankle first occurs. The foot is then forcibly adducted and inverted so that the talus is rotated through 90 degrees on its vertical and longitudinal axes; the foot itself then recoils below the tibia, but the talus is left displaced in its rotated position, outside and in front of the ankle joint.

Injuries of the talus can be classified, according to the mechanism of their production, into traction injuries—direct violence injuries—and those due to extension or to flexion at the ankle joint. It will be understood that dorsiflexion or plantar-flexion seldom occurs alone; inversion, eversion or adduction are associated displacing forces, except in fractures of the neck of the talus, which appear to be pure dorsiflexion injuries. Dorsiflexion in one group, and plantar-flexion in the other, are, however, the essential and principal elements in producing the more important injuries.

TREATMENT

Chip and avulsion fractures and compression fractures of the head of the talus—These injuries seldom need reduction and a short period of immobilisation in a walking plaster is all

that is required. Occasionally a detached fragment may need removal either because of its size and projection under the skin, or because it is blocking movement at the ankle or mid-tarsal joint.

Fractures and fracture-dislocations of the neck of the talus—In simple fractures displacement between the proximal and distal fragments is minimal and insignificant. No reduction is necessary; the fracture will unite without fail in six to eight weeks and the patient can spend the greater part of that time in a walking plaster. In contrast to simple fracture of the neck of the talus, fracture-dislocation requires very careful and accurate reduction, not so much on account of the obvious displacement at the neck, but because of subluxation at the subtalar joint. Reduction is easy enough, if the case is treated early. It being remembered that the proximal fragment is plantar-flexed, the foot is manipulated into full flexion so that the distal fragment is brought into alignment with the proximal; in addition any inward or outward displacement at the subtalar joint must be corrected.

FIG. 23

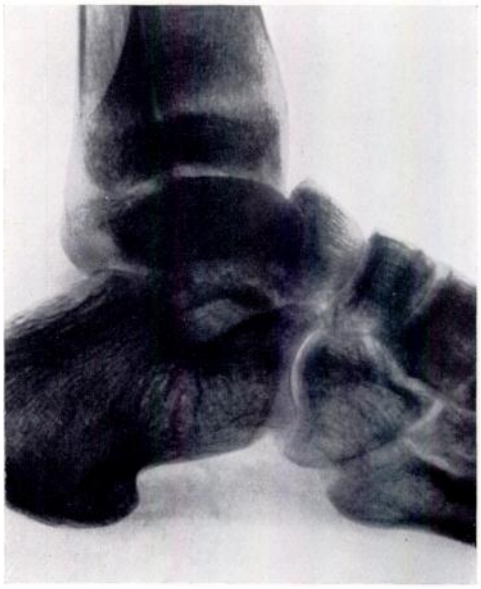

FIG. 24

Radiographs showing recurrence of deformity when the foot was brought up to a right angle four weeks after perfect reduction of a fracture-dislocation of the neck of the talus.

After reduction the foot can safely be immobilised in plaster in a position of equinus. This position is maintained for four weeks; the foot is then brought up to a right angle. At this stage the deformity may recur (Figs. 23 and 24).

Fractures and fracture-dislocations of the body of the talus—Comminuted fractures of the body are rare; when they occur the destruction is so considerable that fusion of the ankle and subtalar joint is advisable. Vertical fractures of the body may be complicated by talo-calcaneal displacement. Deformity can sometimes be overcome by manipulation with the foot plantar-flexed, as in fractures of the neck, but the displacement is usually severe, and complete reduction of both fracture and dislocation is difficult. The most usual end-result is a " step " deformity and subsequent arthritis of the ankle or subtalar joint, or of both (Fig. 25).

Out of forty-five examples of fracture of the neck or body of the talus complicated by subtalar displacement, there were only nine cases in which a good painless range of movement was restored to the foot, and in all these reduction had been perfect. In all other cases the

subtalar joint was painful, was ankylosed, or had been fused because of pain, and even this group included many cases in which there had been perfect reduction.

Fractures of neck with posterior dislocation of the body--More often than not this severe injury is compound and the body of the talus is avulsed and lost or has perforce to be removed because of gross comminution or soiling. However, the injuries are not all compound. It is sometimes possible to reduce the displacement by manipulation. The space between tibia and calcaneum is opened up by traction on the forefoot and heel, the foot is dorsiflexed and everted and then the body of the talus is twisted and pushed back into its place. An ingenious method of reduction was used by Armstrong, who exerted traction through the heel by means of a Kirschner wire and then manipulated the body of the talus into place after having transfixed it by a Steinmann's pin (Figs. 26, 27 and 28).

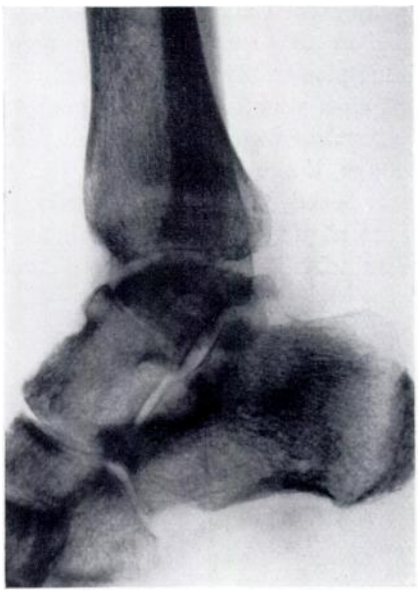

FIG. 25
"Step" deformity after a fracture through the body of the talus.

In closed injuries it is most important to relieve the pressure that the displaced talus exerts on the tightly stretched skin at the medial side of the foot. There should be no delay in resorting to operation if manipulation has failed to reduce the displacement. The bone is exposed through a curved incision directly over it, where it lies usually below and behind the medial malleolus. The neurovascular bundle and tendons are retracted out of danger, the ankle joint is widened by traction on the heel, and the talus rotated and manoeuvred into the ankle joint. Reduction is stable. Plaster is applied with the foot in a plantar-flexed position in order to restore the alignment of the head and body of the talus. It is important to relieve the dangerous pressure on the skin over the displaced bone when ordinary manipulation has failed but operative reduction is contra-indicated because of lack of facilities or because of the poor condition of the patient. In this event, the talus should be pushed into the soft tissue in the mid-line between the back of the ankle joint and the tendo calcaneus; there is plenty of room for it there and the tension on the skin will be relieved until operative reduction is feasible.

In this series the body of the talus was reduced by operation or manipulation in nine cases and the ultimate results have been satisfactory. In two other cases, although an open reduction was carried out operation could not be undertaken until some weeks after the injury and the body of the talus in each case had become markedly affected by avascular necrosis. The operation was completed by an arthrodesis of the ankle.

In the remaining twenty cases of this type of fracture-dislocation the body of the talus had either been avulsed at the time of the accident or was removed because of infection or as part of the toilet of a compound injury.

Total dislocation of the talus—Total dislocation of the talus presents a similar problem. The majority of the injuries are compound, but if not, relief of tension on the skin is just as urgent; here the talus cannot be displaced into some loose soft tissue area, and so must be reduced or removed at once if sloughing and infection are to be avoided. Manipulative reduction must be extremely difficult. There were two instances in which the procedure was carried out with success but unfortunately neither case was properly documented and it was not possible to discover what manoeuvres were used. Bonnin has reported a case in which the completely dislocated whole talus was reduced by operation, with good result.

Subtalar dislocation—The treatment of these comparatively frequent injuries calls for no special description here, except to draw attention once again to the danger of sloughing of the skin over the projecting head of the talus.

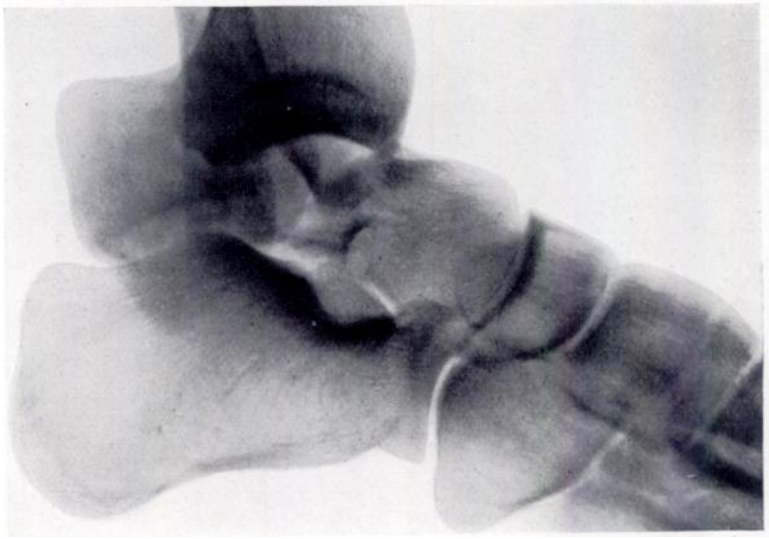

FIG. 26
Fracture-dislocation of talus before reduction.

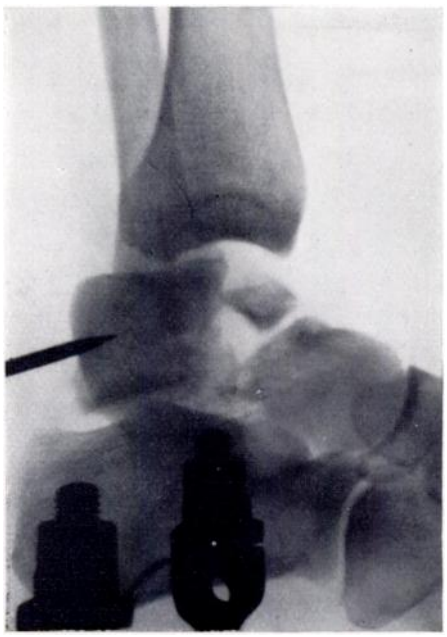

FIG. 27

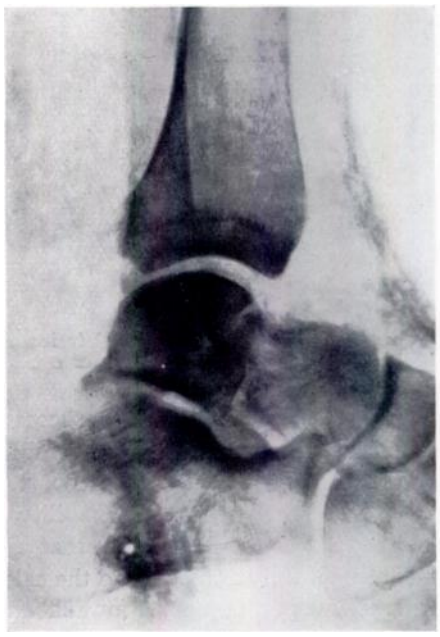

FIG. 28
The displacement was reduced by manipulation after transfixion of the body of the talus with a Steinmann's pin. (Mr J. R. Armstrong's case.)

The place of excision of the talus and arthrodesis in treatment—Some authors have recommended excision of the talus as the method of choice in the treatment of total dislocation or fracture-dislocation of the talus. There are cases, of course, in which there is no choice,

for the talus may be extruded and lost, it may be essential to remove a grossly damaged and soiled bone as part of the surgical treatment of a wound, or the talus may sequestrate in an infected compound injury, either primarily compound or when there has been necrosis of the skin over the displaced bone. However, in many cases the talus can be preserved with reasonable safety, provided some shred of soft tissue remains attached suggesting a possible blood supply—and often the attachments of the medial ligament do in fact remain. In this series excision of the talus never produced a painless mobile joint between tibia and calcaneum. Out of twenty-two cases of complete or partial excision, six could be regarded as " good " results because there was neither deformity nor pain and function was satisfactory, but in each case there was firm ankylosis between tibia and calcaneum. In other cases there was either so marked a deformity that a supporting steel and T-strap were necessary or there was a painful pseudarthrosis and bad function. These results should not be regarded as a condemnation of excision of the talus. In these cases the talus was removed after an injury to bone and soft tissues often in the presence of gross destruction and infection—all conditions

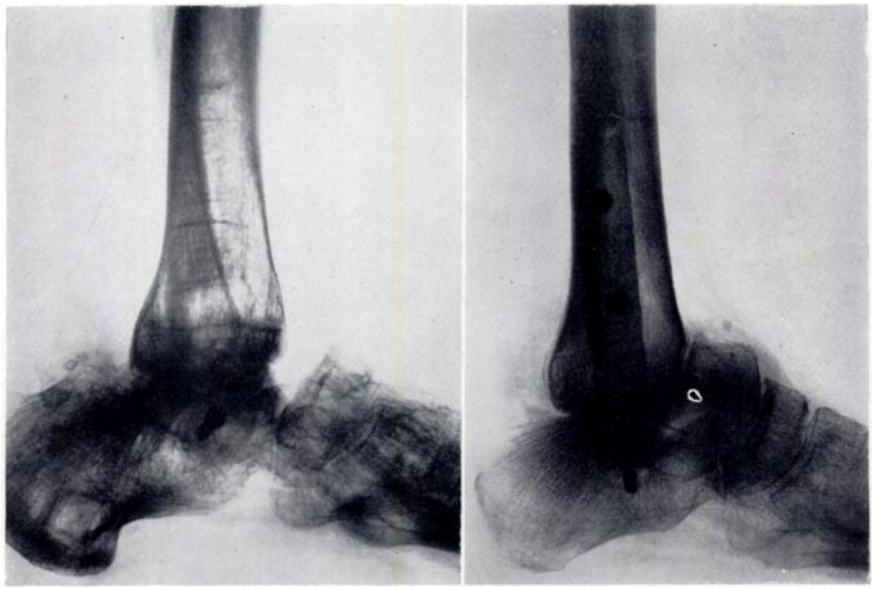

FIG. 29

Two examples of tibio-calcaneal fusion after removal of talus. The fusion is completed by fixing the fibular malleolus or a tibial graft to the lateral wall of the calcaneum.

which militate anywhere against a successful arthroplasty. Most recent opinions on the subject agree that excision of the talus fails in the treatment of fractures and dislocations of the talus. Good results have been reported, but it seems quite probable that the results refer only to function and not to mobility so that there may have been ankylosis between the tibia and calcaneum. If it is true that a better foot results after excision of the talus when the tibia becomes fully ankylosed to the calcaneum—and the observations made here suggest this—then there is an argument for deliberate operative fusion of the tibia to the foot as a secondary procedure in those cases in which the talus has been lost or removed.

It is surprising that the foot can remain so useful after complete obliteration of the ankle and subtalar joints. There were thirteen cases in which deliberate fusion of both joints was carried out either after loss of the talus, or because of traumatic arthritis of ankle and subtalar joints.

Talo-calcaneal fusion—Operation is carried out through a lateral incision which provides the exposure of the space between the tibia and calcaneum. The fibula is divided about two

inches above the ankle, and the distal fragment is removed. The under-surface of the tibia and the upper surface of the calcaneum are removed and the intervening space filled with chips of cancellous bone. A cortical bone graft is applied and fastened to the lateral surfaces of the tibia and calcaneum. The graft may be taken from the tibia or the removed portion of fibula may very easily be used (Fig. 29).

Tibio-talo-calcaneal fusion—Although the result—that is fusion of the tibia to the calcaneum—is the same whether the body of the talus is retained or not, with the talus still present the foot is of better shape, and some shortening is avoided. As before, the joints are exposed through a lateral incision. After removal of the remaining articular cartilage, fusion is completed with the aid of cancellous chips and a cortical graft from tibia or fibula (Fig. 30).

In both operations best results were obtained when the head of the talus was deliberately removed. It has been recommended that the head of the talus be preserved and fixed to the front of the tibia, but this tends to produce a varus deformity of the foot. The benefit of retaining the head of the talus to preserve the arch of an already disorganised foot seems doubtful.

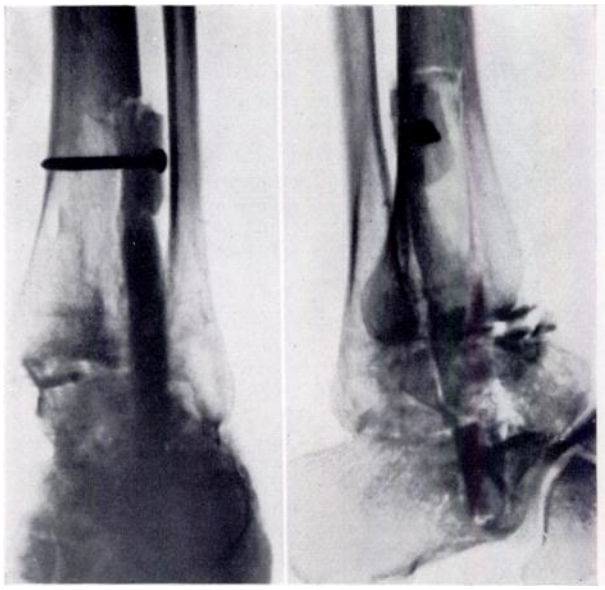

FIG. 30

Tibio-talo-calcaneal fusion. The talus is retained in position and fusion is completed with the aid of a tibial graft and iliac chips.

Of the thirteen cases in which one or other of the fusion operations was carried out good functional results were obtained in all except one, in which bony anyklosis was defective. Each patient is walking more than two miles with ease, some can walk five miles and one still climbs mountains.

SUMMARY

1. Although fractures and dislocations of the talus have been described since 1608 the rarity of the more severe and complicated injuries has meant a dearth of accurate descriptions or classification in the literature.

2. A series of 228 injuries of the talus occurring in members of the Royal Air Force between 1940 and 1945 has been reviewed.

3. A simple but comprehensive classification of injuries of the talus is presented, together with a review of the pathological anatomy, clinical features, and methods of treatment. The importance of distinguishing between fractures and fracture-dislocations, and of watching carefully for displacements of the subtalar joint, is emphasised.

4. The important complications—infection, avascular necrosis and traumatic arthritis of the ankle or subtalar joint—are discussed. Infection may be the result of a compound injury, or may follow sloughing of the skin stretched over a displaced talus. Early reduction is, therefore, of great urgency in closed injuries. Avascular necrosis of the talus occurs in gross injuries when all or most of the soft-tissue attachments to the bone are severed. Revascularisation and regeneration will take place with patient conservative treatment.
5. The mechanism of injury is discussed.
6. The results of excision of the talus are poor. Every effort should be made to preserve the body of the talus, but if its loss is inevitable a useful foot can be regained by deliberate fusion of the tibia to the calcaneum.

I am grateful to the Medical Authorities of the Royal Air Force for their permission to use clinical material; to my colleagues who have allowed the study of cases that they have treated with such care and consequent success; and to Sir Reginald Watson-Jones for his inspiration.

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