INTRA-ARTICULAR FRACTURES OF THE CALCANEUM

PART I: PATHOLOGICAL ANATOMY AND CLASSIFICATION

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We have studied the radiographic and CT features of 120 displaced intra-articular fractures of the calcaneum in order to define the pathological anatomy. In 96% of cases, the CT scans identified three main fragments: sustentacular, lateral joint and body. The sustentacular fragment was often rotated into varus, the lateral joint fragment into valgus and the body fragment impacted upwards, in varus and displaced laterally.

The displacement of these fragments varied according to which of three fracture types was present, as defined by the composition of the fractured lateral wall of the calcaneum. In type 1 it was formed by the lateral joint fragment alone; in type 2 by both body and lateral joint fragments; and in type 3 by the body fragment alone. Fracture fragment displacement differs from that previously described, in that true uniform depression of the lateral joint fragment is rare.

Calcaneal fractures account for 60% of tarsal bone injuries and 2% of all fractures. Most are intra-articular and, after conservative treatment, recovery is slow and generally unsatisfactory due to disruption of the subtalar joint and alteration in hindfoot mechanics (Rowe et al 1963; Nade and Monahan 1972; Slatis et al 1979). The ideal treatment, as for any displaced intra-articular fracture, is anatomical reduction, stable fixation and early joint mobilisation. Several approaches and methods have been described (Soeur and Remy 1975; Burdeaux 1983; Stephenson 1987) but results have been inconsistent and no single technique has been widely adopted.

A prerequisite for successful operative management is a sound knowledge of the fracture anatomy. Our aim was to define this by studying the radiographic and CT appearance of a consecutive series of displaced fractures, to relate these findings to those at operation, and to develop a classification which would help the pre-operative assessment of the injury.

PATIENTS AND METHODS

We studied 120 displaced intra-articular fractures of the calcaneum in 112 patients, 94 of whom were male. The average age was 46 years (18 to 76). Patients were derived from two sources: first, a consecutive series of patients who had presented to the Bristol Royal Infirmary since November 1988 or who had been referred to the senior author (RMA) for treatment and secondly, a consecutive series of patients who had presented to the Leicester Royal Infirmary.

Lateral, axial and oblique radiographs of the fractured calcaneum were compared with similar views of the uninjured foot and classified according to Essex-Lopresti (1952). Coronal CT scans (Lowrie et al 1988) of both feet were also performed. The main fracture fragments were identified and the amount and direction of their displacements measured with digital callipers and a protractor. Each measurement was made twice and the mean value recorded. Any anterior extension of the fracture lines and the degree of comminution were
noted from both plain radiographs and CT scans. In those patients from Bristol in whom open reduction and internal fixation was performed, the operative findings were compared with the radiographic features. Statistical evaluation used analysis of variance, unpaired t-tests or regression analysis as appropriate.

RESULTS

Plain radiographs. The general appearance of the primary and secondary fracture lines on plain radiographs was similar to previous descriptions (Palmer 1948; Essex-Lopresti 1952; Thoren 1964; Burdeaux 1983). In all 120 cases a primary fracture line crossed the posterior facet of the subtalar joint, separating a medial sustentacular fragment from a large inferolateral fragment as described by Palmer (1948). This creates a two-part fracture. In addition, in 115 of the 120 cases a secondary fracture line divided the inferolateral part of the bone into a lateral joint fragment (the thalamic fragment: Soeur and Remy 1975) and a body fragment, thereby generating a three-part fracture.

The Essex-Lopresti (1952) classification further divides three-part fractures into two groups according to the position of the secondary fracture line on a lateral radiograph. In a 'tongue-type' fracture, this line passes posteriorly along the body of the calcaneum to exit laterally below the tendon Achilles (Fig. 1), creating a tongue-shaped fragment. In contrast, in a 'joint-depression' fracture the secondary fracture passes down to the lateral side of the calcaneum immediately behind the posterior facet of the subtalar joint (Fig. 2). In both groups, the appearance suggests depression of the centre of the calcaneum at the level of the subtalar joint, flattening Böhler’s angle subtended by its upper surface (Fig. 2).

CT scans. Our review of 120 fractures imaged by CT in the coronal plane revealed more details of the fractures. An anterior extension of the primary fracture line into the calcaneocuboid joint was visible on the oblique radiographs in only 22 cases. It was not always easy to assess this on the coronal CT images, but involvement was demonstrated significantly more frequently, in 49 of the 120 cases (p < 0.001).

Two-part fractures. In the five two-part fractures the lateral fragment, equivalent to both lateral joint and body fragments in three-part fractures, was minimally displaced in three and subluxed lateral to the talus and in extreme varus in two (Fig. 3).

Three-part fractures. In the other 115 patients, there were three-part fractures. The three main fragments showed varying degrees of impaction vertically, mediolateral broadening, and rotation of the individual fragments (Fig. 4). The appearance of depression of the sustentacular and lateral joint fragments on plain radiographs was mainly due to impaction of the body fragment.
upwards towards the talus. Depression of the lateral joint fragment in relation to the intact talus was rare and usually relatively minor.

There were two main variations within the three-part fracture group. The first was the mediolateral position of the primary fracture line as it crossed the posterior facet of the subtalar joint, separating the sustentacular fragment from the lateral joint fragment. This was in the central third of the subtalar joint in 63 cases, the lateral part in 38 and the medial part in 14.

The second variation was in the line of the secondary fracture which separated the lateral joint fragment from the body fragment. In most cases, it passed obliquely downwards and laterally to produce a lateral joint fragment which lay lateral to the impacted body a quadrilateral lateral joint fragment which was often impacted into the body fragment and trapped within it. In these cases the residual lateral wall was formed by the lateral cortex of the body fragment alone (Fig. 7). In some of the cases (n = 8, 7% of the whole series), the lateral joint fragment was not rotated but displaced downwards from the articular surface of the talus, giving the appearance of depression in relation to the sustentacular fragment. This corresponds to the description of the fracture dissected by Malgaigne in 1843 (reported by Essex-Lopresti 1952), which has subsequently been accepted as applying to most calcaneal fractures. **Classification.** The lateral wall of the fractured calcaneum is the first part of the bone exposed when a lateral approach is employed. We found that its composition, fragment: the remaining lateral wall of the fractured bone was formed exclusively by the lateral joint fragment (Fig. 5). In these cases the lateral joint fragment was often rotated outwards into a valgus position. When this occurred there was sometimes a similar, although normally less marked, inward rotation of the sustentacular fragment (see Figs 4, 5).

In an intermediate group of fractures the apparent lateral wall of the fractured calcaneum was formed in part by the lateral joint fragment above and in part by the body fragment below (Fig. 6).

In a third, smaller group the secondary fracture line ended high on the lateral wall of the calcaneum, forming found at operation, could be predicted preoperatively from the coronal CT scan cut at the level of the lateral malleolus. This was very important in terms of access for the reduction of the lateral joint and sustentacular fragments. We therefore classified the three-part fractures into three types:

**Type 1.** The apparent lateral wall is formed solely by the lateral joint fragment (Fig. 5).

**Type 2.** The lateral wall is formed by the lateral joint fragment superiorly and the body fragment inferiorly (Fig. 6).

**Type 3.** The lateral wall is formed solely by the body fragment (Fig. 7).
Displacement of the individual fragments (see Figure 4). We measured the displacement of each fragment with respect to the other fragments and to the talus. The results are given in Table I.

**Body fragment.** The body fragment was often wedge-shaped. It had been driven upwards in 111 of 115 cases by a mean of 6 mm (2 to 12) as measured by displacement at the medial wall. In the other four cases there was no significant displacement. The normal varus angulation of the body fragment (mean 10°, range 0 to 30) was increased in 104 cases to a mean of 20° (5 to 50) and reduced in five. In six fractures there was no measurable rotation.

The body fragment was displaced laterally with respect to the sustentacular fragment by a mean of 8 mm (−6 to 17); this displacement accounted for most of the overall increase in width of the fractured calcaneum (mean 9 mm, −1 to 23), the remainder being due to rotation of the lateral joint fragment.

**Sustentacular fragment.** This fragment includes the sustentaculum tali and the superomedial wall of the calcaneum. As reported by other authors (Burdeaux 1983; Gilmer et al 1986) it is usually undisplaced in relation to the talus because of its ligamentous attachments. In 40 of our cases, however, this fragment had rotated into varus by a mean of 7° (2 to 24) so that the lateral edge of the fragment had moved away from the talus. The fragment was comminuted in 29 cases but in only nine was this severe. Comminution at the site of the medial wall fracture was present in 44 cases (see Fig. 6) and was severe in four.

**Lateral joint fragment.** True depression of the lateral joint fragment from the talus, due to impaction into the body fragment, was rare, occurring in only eight cases, by a mean of 8.4 mm (3 to 20). In a further 70 cases rotation had caused the medial edge of the fragment to be "depressed" with respect to the articular surface of the sustentacular fragment by a mean of 5 mm (1 to 15). In 17 cases there was no displacement of this edge and in the remaining 20 the medial edge of the lateral joint fragment had risen above the articular surface of the sustentacular fragment (Fig. 6) due to the opposite rotation of the fragment. In total, with respect to the articular surface of the talus, 93 lateral joint fragments were lying in valgus rotation (mean 25°; range 5 to 58, Fig. 5a); 11 fragments were in varus (mean 8°; range 2 to 15, Fig. 6); and 11 were not rotated.

The lateral joint fragment contained a mean 41% (9 to 80) of the subtalar joint articular surface; this did not vary significantly between the three fracture types, see Table I.

**Lateral wall.** The residual lateral wall of the fractured calcaneum was usually comminuted; this was extensive in 39 cases, but a classification could still be made.

**Results of classification.** Of the three-part fractures, 42 were type 1 (37%), 52 were type 2 (45%) and 21 were type 3 (18%). Statistical analysis confirmed that there were

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Figure 5 – Coronal CT scan and diagram of a three-part, type 1 fracture. The lateral wall of the fractured bone is formed by the lateral joint fragment, which is rotated into valgus away from the subtalar joint by the upward impaction of the wedge-shaped body fragment. The body fragment is in varus angulation. T, talus; S, sustentacular fragment; L, lateral joint fragment; B, body fragment. Figure 6 – Coronal CT scan and diagram of a type 2 fracture. The lateral wall of the fractured bone is formed by the lateral joint fragment above and the body fragment below. The sustentacular fragment has rotated into varus and the lateral joint fragment is ‘elevated’ with respect to the sustentacular fragment. There is some medial wall comminution. Figure 7 – Coronal CT scan and diagram of a type 3 fracture. The lateral joint fragment is impacted within the body fragment. The residual lateral wall is formed by the apparently intact lateral wall of the body fragment. The lateral joint fragment is depressed away from the talus. There is also comminution of the sustentacular fragment.
significant differences between these three fracture types in terms of the behaviour of the lateral joint fragment (Table I).

The patients with type 1 fractures were marginally younger (mean age 41 years) and the lateral joint fragment was in the most valgus position (mean 28°). The sustentacular fragment was in a varus position in 48%.

Compared with those suffering type 1 fractures, patients with type 2 fractures tended to be older (mean age 46 years), the lateral joint fragment was in less valgus (mean 18°), and the sustentacular fragment was angulated in only 27%. There was nearly always some comminution of the lateral wall, and this was severe in 34%.

Type 3 fractures were seen in the oldest patients (mean age 50 years). Seven of the eight cases of true uniform depression of the lateral joint fragment were in this group and overall there was no significant rotation of the fragment. The sustentacular fragment was angulated in only 29% of cases.

**Essex-Lopresti classification.** Joint-depression and the tongue-type fractures were evenly distributed between the three fracture types. Of all the variables that we measured only the angulation of the lateral joint fragment differed significantly between the joint-depression injuries (mean angulation 21°) and the tongue-type fracture (mean angulation 14°, p < 0.02). This probably relates to the greater bulk and soft-tissue attachment of the lateral joint fragment in the tongue-type fracture, which limits its angulation.

**DISCUSSION**

Our classification of the common three-part fracture by the composition of the lateral wall is important in respect of a lateral approach for open reduction. To provide access, formal osteotomy of this lateral wall is always necessary in type 3 fractures and is often required in type 2 fractures. When adequate exposure has been achieved, accurate reduction is possible of both the lateral joint and body fragments on to the sustentacular fragment. This position can then be held by a contoured AO plate and lag screws as detailed in part II of this paper.

Our general description of the fractures is similar to that previously reported, but the usual displacements of the three main fragments are different: the lateral joint fragment is rarely truly depressed away from the talus. Much of the literature has been based on the fracture described by Malgaigne in 1843 (reported by Essex-Lopresti 1952) in which there was true depression of the lateral joint fragment. Resulting from this the 'elevation' of this fragment has become a fundamental part of fracture reduction (Palmer 1948; Essex-Lopresti 1952; Thoren 1964; Soeur and Remy 1975; Burdeaux 1983; Stephenson 1987; Leung et al 1989). We found this pattern in only 7% of cases, and in these the mean upward impaction of the body fragment was greater than the mean depression of the lateral joint fragment: simple elevation of this fragment could not fully reduce the fracture. Even in these rare cases elevation of the lateral fragment through a lateral approach (Stephenson 1987) cannot reduce the fracture since the lateral wall is formed by the body fragment and not by the lateral joint fragment. In our type 1 and 2 fractures, the lateral joint fragment is not depressed with respect to the articular surface of the sustentacular fragment and attempts at reduction of the subtalar joint by simple elevation will inevitably fail.

The CT appearances of type 1 and 2 and most type

**Table I.** Details of fragments in 115 displaced three-part fractures

<table>
<thead>
<tr>
<th>Fracture type</th>
<th>1 (n = 42)</th>
<th>2 (n = 52)</th>
<th>3 (n = 21)</th>
<th>Significance of difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (yr) (range)</td>
<td>41 (20 to 76)</td>
<td>46 (18 to 71)</td>
<td>50 (20 to 76)</td>
<td>NS</td>
</tr>
<tr>
<td>Number of joint-depression fractures/number of tongue-type fractures</td>
<td>31/11</td>
<td>29/21 (2 mixed)</td>
<td>11/10</td>
<td>NS</td>
</tr>
<tr>
<td>Number with sustentacular fragment angulation (per cent)</td>
<td>20 (48)</td>
<td>14 (27)</td>
<td>6 (29)</td>
<td>NS</td>
</tr>
<tr>
<td>Mean sustentacular fragment angle, varus + ve (degrees) (range)</td>
<td>3 (0 to 13)</td>
<td>2 (0 to 14)</td>
<td>4 (-9 to 14)</td>
<td>NS</td>
</tr>
<tr>
<td>Mean percentage subtalar joint on lateral joint fragment (range)</td>
<td>37 (9 to 74)</td>
<td>42 (12 to 77)</td>
<td>48 (10 to 80)</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Number with lateral joint fragment angulation (per cent)</td>
<td>42 (100)</td>
<td>45 (87)</td>
<td>7 (33)</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>Mean lateral joint fragment angulation, valgus + ve (degrees) (range)</td>
<td>28 (5 to 58)</td>
<td>18 (-15 to 57)</td>
<td>-1 (-16 to 10)</td>
<td>p &lt; 0.0001</td>
</tr>
<tr>
<td>Number with lateral joint fragment depression (per cent)</td>
<td>0</td>
<td>1 (2)</td>
<td>7 (33)</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>Mean depression of lateral joint fragment (mm) (range)</td>
<td>1 (-3 to 5)</td>
<td>1 (-3 to 7)</td>
<td>3 (-2 to 13)</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Mean body fragment impaction (mm) (range)</td>
<td>6 (2 to 11)</td>
<td>8 (4 to 17)</td>
<td>6 (2 to 12)</td>
<td>NS</td>
</tr>
<tr>
<td>Mean body fragment medial displacement (mm) (range)</td>
<td>7 (-6 to 13)</td>
<td>6 (2 to 12)</td>
<td>7 (-5 to 13)</td>
<td>NS</td>
</tr>
<tr>
<td>Mean body fragment angulation (degrees) (range)</td>
<td>24 (0 to 42)</td>
<td>22 (0 to 50)</td>
<td>18 (0 to 38)</td>
<td>NS</td>
</tr>
<tr>
<td>Increase in heel bone width (mm) (range)</td>
<td>10 (5 to 19)</td>
<td>9 (0 to 15)</td>
<td>9 (2 to 23)</td>
<td>NS</td>
</tr>
</tbody>
</table>
3 fractures suggest splaying of the sustentacular and lateral joint fragments by the impaction of the wedge-shaped body fragment. To reduce the subtalar joint therefore the body fragment must be disimpacted and reduced downwards on to the sustentacular fragment with correction of its varus angulation. We agree with Burdeaux (1983) and Stephenson (1987) that reduction of the medial wall is important. Most of the broadening of the heel is due to this displacement of the fracture fragments at the medial wall, and reduction will therefore narrow the heel and reduce the incidence of fibular impingement. Burdeaux (1983) favoured a medial approach to the fracture using the McReynolds technique, arguing that anatomical reduction of the lateral joint fragment is unnecessary as it contains only a small portion of the articular surface of the subtalar joint. We have shown, however, that a mean 41% of the articular surface is found on the lateral joint fragment irrespective of fracture type. We therefore approach these fractures from the lateral side.

The use of a lateral approach requires full appreciation of the anatomy of the fractured lateral wall; our classification emphasises the importance of its composition. It is easily made from a coronal CT scan and in every operated case the preoperative classification was confirmed. The classification is intended as an aid to operative treatment, takes no account of fragment displacement or comminution, and is not intended to have a prognostic significance.

Conclusions. The sustentacular fragment is often rotated into varus, the lateral joint fragment is usually in valgus but rarely depressed, and the body fragment is impacted upwards in varus and displaced laterally. This understanding of the pathological anatomy and our classification have allowed us to develop a new method of operative treatment which aims to reverse the displacements of these main fracture fragments.

We are indebted to the orthopaedic surgeons of Bristol who have kindly referred calcaneal fractures to us for treatment. Without their co-operation this study would not have been possible.

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REFERENCES


