VASCULARITY OF THE HUMERAL HEAD AFTER PROXIMAL HUMERAL FRACTURES

AN ANATOMICAL CADAVER STUDY

C. H. BROOKS, W. J. REVELL, F. W. HEATLEY

From St Thomas’ Hospital, London, England

We studied the arterial anatomy and the effect of four-part fractures on the vascularity of the humeral head, using barium sulphate perfusion of 16 cadaver shoulders.

The main arterial supply to the humeral head was via the ascending branch of the anterior humeral circumflex artery and its intraosseous continuation, the arcuate artery. There were significant intraosseous anastomoses between the arcuate artery and: 1) the posterior humeral circumflex artery through vessels entering the posteromedial aspect of the proximal humerus; 2) metaphyseal vessels; and 3) the vessels of the greater and lesser tuberosities.

Simulated four-part fractures prevented the perfusion of the humeral head in most cases. If, however, the head fragment extends distally below the articular surface medially, some perfusion of the head persists by the posteromedial vessels. These vessels are important in the management of comminuted fractures of the proximal humerus.

Avascular necrosis of the humeral head may follow displaced fractures and fracture-dislocations of the proximal humerus, and Codman (1934) noted the importance of the soft-tissue attachments in proximal humeral fractures. Neer’s (1970a) ‘four-part’ classification of these fractures links their pattern to prognosis and the development of avascular necrosis of the humeral head.

About 85% of these fractures are undisplaced or minimally displaced (Neer group 1); these have a good prognosis and a low incidence of avascular necrosis. The results, however, after the more severe, displaced and comminuted fractures (Neer groups IV to VI, both three-part and four-part) are uncertain and they have been classified with fractures of the proximal femur as “unsolved” (Mills and Horne 1985). There is great variation in the reported incidence of avascular necrosis after these injuries (Table I).

Previous cadaver perfusion studies of the normal arterial anatomy of the humeral head (Laing 1956; Gerber, Schneeberger and Vinh 1990) have concluded that the ascending branch of the anterior humeral circumflex artery and its intraosseous continuation, the arcuate artery, provide the main arterial supply to the humeral head, but there have been no experimental studies on the effect of injury and fractures on the

Table I. Reported incidence of avascular necrosis of the humeral head after four-part fractures

<table>
<thead>
<tr>
<th>Author</th>
<th>Number</th>
<th>Per cent</th>
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<tr>
<td>Neer 1970a,b</td>
<td>6/13</td>
<td>46.2</td>
</tr>
<tr>
<td>Lee and Hansen (1981)</td>
<td>4/19</td>
<td>21.1</td>
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<tr>
<td>Sturzenegger, Fornaro and Jakob (1982)</td>
<td>5/14</td>
<td>35.7</td>
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<td>Leyshon (1984)</td>
<td>6/8</td>
<td>75.0</td>
</tr>
<tr>
<td>Marti, Lim and Jolles (1987)</td>
<td>6/13</td>
<td>46.2</td>
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vascularity of the humeral head. Sevitt and Thompson (1965), in a cadaver study, demonstrated the effect of different fracture patterns of the neck of the femur on the vascularity of the femoral head. We aimed to show the effect of ligation of the anterior humeral circumflex artery, and of various fractures, on the vascularity of the humeral head.

MATERIALS AND METHOD

The permission of our ethical committee was obtained for post-mortem removal of the upper humerus from 16 cadavers aged 60 to 84 years.

Before the perfusion four shoulders were allocated to each of four groups:

Group A. Specimens were used intact, to demonstrate the normal arterial anatomy.

Group B. These control specimens had a deltidoid-splitting approach to expose the anterolateral aspect of the upper humerus.

Group C. In this group the anterior humeral circumflex artery was ligated at the level of its entry into the humeral head through the same deltidoid-splitting approach.

Group D. In these specimens osteotomy was performed by a Desouer power saw of the greater and lesser tuberosities and the surgical neck of the humerus through the same approach, to simulate a four-part fracture.

Perfusion. In all specimens, the first part of the subclavian artery was cannulated via the thoracic cavity with 5.0 mm diameter plastic tubing and ligated in place. One litre of 50% barium sulphate (Micropaque; Nicholas Laboratories, Slough, UK) in 3% gelatin mixture was infused at 40°C using a constant-pressure pump (Lears Ltd, Kingston upon Thames, UK) at 34 kPa (5 psi). A tourniquet at the level of the elbow limited the field of perfusion. Adequate perfusion was assessed by observing the flow of perfusate through a skin incision placed proximal to the tourniquet. The upper limb was cooled to allow the perfusate to set before the upper humerus was removed. The specimens were fixed in 10% formal saline for one week and then decalcified in 5% nitric acid using serial radiographs to determine when this was complete. The arterial anatomy of the complete specimens was demonstrated by microfocal radiographs taken with a microfocal X-ray generator (Hilger and Watts, London, UK) on to Kodak mammography film. Further details of the intraosseous arterial anatomy were obtained by microfocal radiographs of 10 mm sections of the humeral heads cut in the sagittal and coronal planes.

RESULTS

Group A and group B. There was some variation in the degree of filling of the arterial tree in different specimens, but all were suitable for analysis. We found no difference between the specimens of groups A and B and describe them together. In all eight the main arterial supply of the humeral head was by the intraosseous arcuate artery, a continuation of the ascending branch of the anterior humeral circumflex artery (Figs 1a, b and c). The arcuate artery was a single vessel in seven specimens, but in one the anterior humeral circumflex artery gave off two arcuate arteries as it ascended in the bicipital groove. These two vessels merged in the mid-substance of the humeral head. The normal arcuate artery enters the bone at the upper end of the bicipital groove and follows a curving posteromedial path just distal to the line of the old epiphyseal plate. A multiple arcaded pattern of branches radiates out to reach and supply all the subchondral bone beneath the articular surface of the humeral head.

There were anastomoses with the arcuate artery from three sources (Figs 1a, b and c):
1) A group of three to four arteries entered the posteromedial aspect of the proximal 1 cm of the humeral neck.
2) In six of the eight specimens there was a straight artery running from the middle of the humeral metaphysis, passing proximally to the site of the epiphyseal plate to anastomose with the mid-point of the arcuate artery.
3) There were small vessels from the greater and lesser tuberosities.

Group C. In this group the ascending branch of the anterior humeral circumflex artery had been ligated at its entry to the humeral head, but the arcuate artery was filled with perfusate throughout its intraosseous course in all four specimens through the anastomotic links. There was good filling of the arterial arcades of the whole humeral head.

Group D. In three of the four specimens in which a four-part fracture had been produced, there was no perfusion of the humeral head (Fig. 2). Good perfusion of the humerus to the level of the osteotomy showed that there had not been a failure of the technique.

In one specimen there was filling of the medial part of the arcuate artery and of some of its arcades to the subchondral bone (Fig. 3). In this specimen the medial end of the saw cut between the shaft and head had been distal to the junction between the anatomical neck and the articular cartilage and distal to the entry of the posteromedial arteries into the humerus. In the other three specimens the cut was at this junction, disrupting the anastomosis between the arcuate artery and the posteromedial arteries.

DISCUSSION

The probability of avascular necrosis after a fracture depends on the pattern of the injury in relation to the arterial anatomy of the humeral head. Laing (1956) used cadaver perfusion studies to show that the main arterial supply to the humeral head was from a branch of the anterior humeral circumflex artery. This artery arises from the lateral side of the axillary artery at the lower
Perfusion angiograms of consecutive coronal 10 mm sections of the humeral head showing: the arcuate artery (A); the metaphyseal anastomosis (M); the posteromedial anastomosis (P); and the greater tuberosity anastomosis (G).

Perfusion angiogram of a sagittal 10 mm section of the humeral head. The arcuate artery is arrowed.
border of subscapularis, and follows a horizontal course behind coracobrahalis to the bicipital groove. One branch ascends on the lateral border of the groove and enters the bone at the level of the greater tuberosity. Laing demonstrated that its intraosseous continuation was along a curved posteromedial path, distal to the position of the old epiphyseal plate, and he named the vessel the arcuate artery. He also noted contributions from posteromedial arteries and, inconsistently, from both the lesser and greater tuberosities.

Gerber et al (1990), using selective cadaver arterial perfusions, demonstrated a rich extraosseous anastomosis between the anterior humeral circumflex, posterior humeral circumflex, thoracoacromial and suprascapular arteries, concluding that the anterior circumflex artery was the final common pathway for the supply to the humeral head, and that almost the entire articular surface of the humeral head was exclusively supplied by its intraosseous continuation, the arcuate artery. They found that the postero medial vessels arising from the posterior humeral circumflex artery supplied only a small inferior articular area adjacent to their site of entry.

Our findings agree with these previous studies. The pattern of the arterial arcades supplying the humeral head is remarkably similar to that of the vessels arising from the superior epiphyseal artery of the femoral head (Trueta and Harrison 1953).

In contrast to the conclusion from selective arterial perfusions (Gerber et al 1990), however, our study shows that the humeral head can be completely perfused after ligation of the anterior humeral artery at its site of entry into the humeral head. This abolished all extraosseous anastomoses with the arcuate artery and highlights the importance of the abundant intraosseous anastomoses from metaphyseal and posteromedial vessels and those of the greater and lesser tuberosities.

The large metaphyseal anastomosis that we found in six of the eight normal and control specimens is of considerable interest. In long bones with an open growth plate, the epiphyseal and metaphyseal circulations have been described as essentially independent (Brookes 1971). Small arteriolar communications are known to develop at the time of fusion of the growth plate, but our study has shown the presence of a large metaphyseal artery.

Fig. 2
A simulated four-part fracture which resulted in failure of perfusion of the humeral head.

Fig. 3
A simulated four-part fracture of the humeral head, with filling of the arcuate artery (arrow) and some of its arcades via the posteromedial anastomosis.
which passes through the central area of the fused growth plate to anastomose with the epiphyseal arcuate artery. We have also shown in the Wistar rat, in which the growth plate does not fuse in maturity, that there is a similar arterial communication passing through the growth plate. This suggests that in the upper humerus at least, the circulations of the epiphysis and metaphysis are not independent.

As regards the management of four-part fractures, our perfusion studies have highlighted the importance of the posteromedial arteries in maintaining the vascularity of the humeral head. These vessels pass beneath the humeral capsular attachment, which at this site extends for 1 cm on to the surgical neck, and run towards the humeral head before entering the bone just below the articular margin. After a four-part fracture, when the blood supply from the anterior humeral circumflex artery, the greater tuberosity, the lesser tuberosity and any metaphyseal arterial anastomoses have all been lost, perfusion of the humeral head via the arcuate artery may continue if the head fragment includes part of the medial aspect of the upper part of the neck.

This would explain the findings of Jakob et al (1991) who reported a low incidence of avascular necrosis of the humeral head in four-part fractures in which the humeral head was impacted and in valgus. In this type of fracture the medial aspect of the humeral head is little displaced, and may thus retain its vascularity from the posteromedial vessels. When the medial fracture line is at the junction between the articular surface and the neck this anastomosis will be lost and the head will be avascular.

A clear appreciation of the plane and level of all fracture lines is essential in assessing the remaining blood supply to the humeral head. CT scanning of the upper humerus with 3-D reconstruction has been shown to improve this evaluation in most cases (Castagno et al 1987). At open reduction and internal fixation it is important to preserve the ascending branch of the anterior humeral circumflex artery, where this is possible.

If this vessel is disrupted, then the preservation of soft-tissue attachments, especially those containing the posteromedial vessels, may help to ensure an arterial supply to the head of the humerus.

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REFERENCES


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