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CURRENT CONCEPTS REVIEW

Internal fixation of proximal humeral fractures

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We discuss the appropriate assessment and treatment options available for proximal humeral fractures. Important factors to consider are the fracture pattern, the bone quality and any co-morbidities. These are common injuries and are increasing in incidence due to an ageing population. The management of displaced 3- and 4-part fractures remains controversial. The ideal is anatomic reduction and stable internal fixation of the fractures especially the tuberosities to allow early mobilisation. The recent introduction of fixed angle locking plates allows stable fixation even in markedly osteoporotic bone. The early results are encouraging however there are presently no randomised trials comparing these devices to conservative treatment, conventional plating or hemiarthroplasty.

Keywords : vascularity ; displacement ; function.

INTRODUCTION

Proximal humeral fractures are common injuries accounting for 4-5% of all fractures and third most common fracture in patients over 65 years of age (*16*). Studies suggest they are increasing in incidence due to an ageing population (*12*). In older patients they follow low-energy trauma such as a fall on an outstretched hand from a standing height. This can lead to marked comminution due to osteoporosis. In younger patients they are higher-energy injuries and a fracture-dislocation can occur as the capsuloligamentous structures fail before the bone. A cause of a missed fracture of the proximal humerus is an epileptic fit with associated posterior dislocation of the humeral head. A pathological fracture should always be considered with a fracture following a minor injury.

The majority of proximal humeral fractures are managed non-operatively in a collar and cuff relying on gravity to maintain reduction. In displaced fractures there are multiple treatment options with no consensus as to the best method of treatment. The basic principles of open reduction and stable internal fixation allowing early mobilisation remain. The recent introduction of locking plates may allow improved fixation even in osteoporotic bone enabling earlier mobilisation leading to an improved outcome.

ANATOMY

The most important factor when considering the anatomy of displaced proximal humeral fractures is

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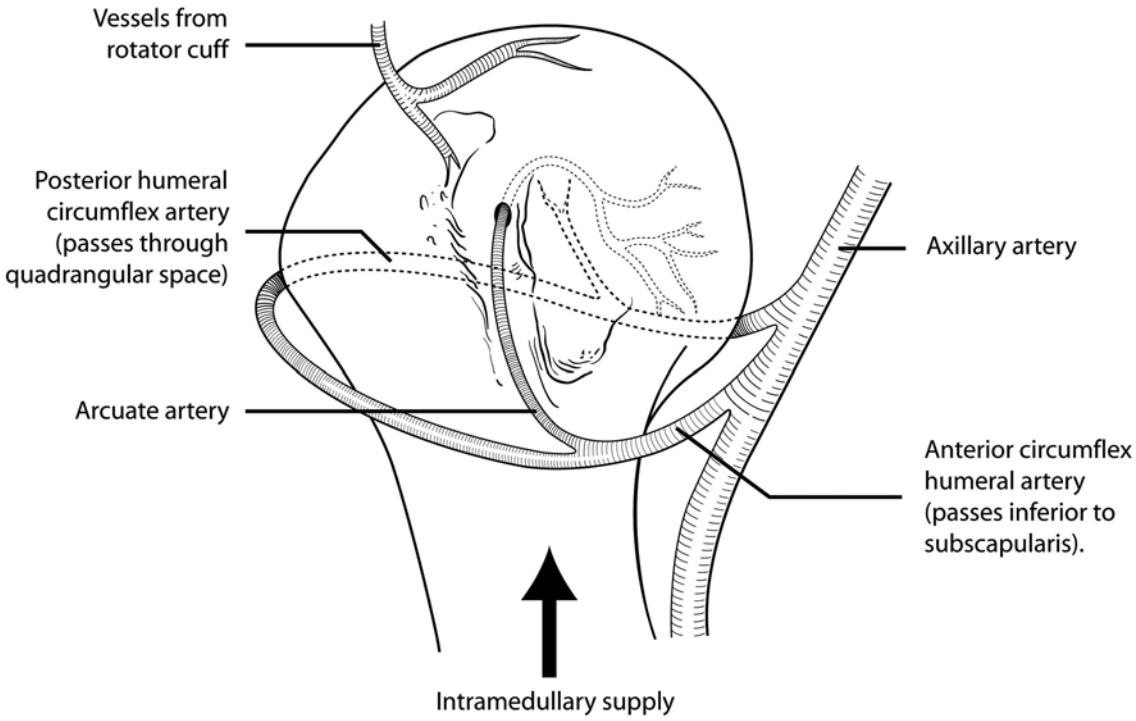

Fig. 1. — Blood supply to the proximal humerus. Note arcuate artery in bicipital groove

the blood supply to the humeral head. The incidence of avascular necrosis of the humeral head after comminuted fractures has been reported to be up to 77% (*29*). The blood supply to the majority of the humeral head is thought to be from the anterior humeral circumflex artery (ACA), a branch of the axillary artery at the inferior border of subscapularis (fig 1). The ACA passes laterally to give the arcuate artery which passes deep to the long head of biceps tendon (*15*). This ascends in the intertubercular groove lateral to the long head of biceps giving branches to the greater and lesser tuberosities. It enters the humeral head where the proximal end of the intertubercular groove meets the greater tuberosity (*7*). It is important to limit dissection near the bicipital groove as the surgical approach may damage an intact supply. However another study has shown perfusion of the humeral head after division of the arcuate artery (*4*). This is from an intact metaphyseal-epiphyseal supply. This would explain the low incidence of avascular necrosis following valgus impacted fractures and this supply is lost with displaced surgical neck fractures. There is a small contribution to the posteroinferior humeral head from branches of the posterior circumflex artery and to the tuberosities from the rotator cuff through tendino-osseous anastomoses.

The head of the humerus forms part of a sphere. The centre of the head lies just posterior and medial to the centre of the shaft. The angle of the shaft to the head is 130° and the head is retroverted in relation to the shaft at an average of 30°. In osteoporotic patients the head consists of a subchondral plate with poor quality bone deep to this, leading to difficulty of fixation in this patient group (*27*). The bone is strongest at the areas of insertion of the rotator cuff due to reinforcement by Sharpey's fibres and therefore transosseous suture techniques are used to maintain reduction of tuberosity fragments.

The glenohumeral joint has the largest range of movement of any joint. This is due to the shallow glenoid occupying only a quarter to a third of the surface area of the head. The proximal humerus

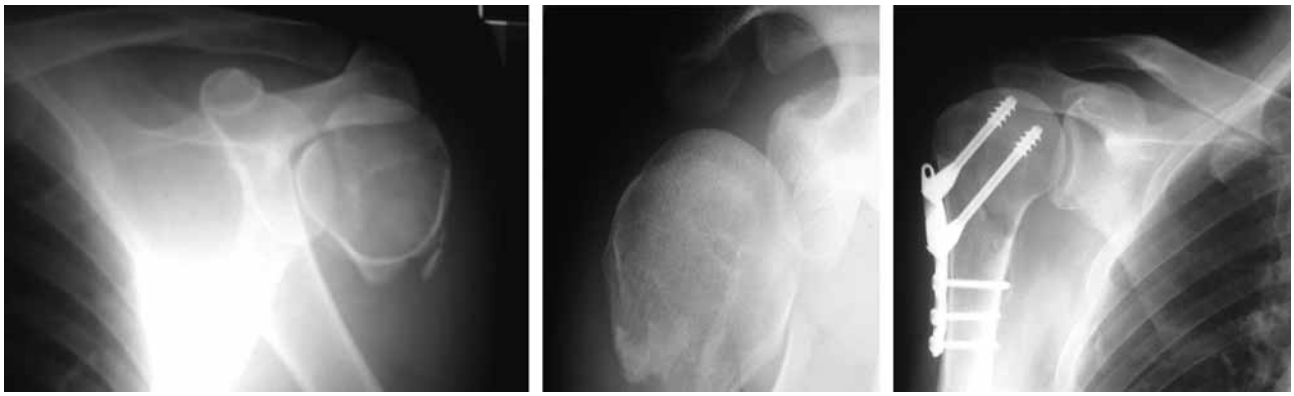

Fig. 2. — 2-part fracture of the surgical neck of humerus. Note shaft pulled medially by pectoralis major. Treated by internal fixation with a PlantTan plate.

consists of the head and articular surface, the shaft and the greater and lesser tuberosities. Anatomical neck fractures occur just below the articular surface. They are rare and have a poor prognosis due to loss of the blood supply to the head fragment. Surgical neck fractures occur between the level of the tuberosities and the insertion of pectoralis major (fig 2). They are extracapsular and the blood supply to the head is preserved.

The greater tuberosity is the attachment for the supraspinatus, infraspinatus and teres minor, and the subscapularis attaches to the lesser tuberosity. The long head of biceps (LHB) passes through the bicipital groove between the tuberosities. The transverse humeral ligament spans the proximal end of the bicipital groove maintaining the LHB tendon reduced. A lesser tuberosity fracture will cause the loss of these restraints, leading to medial dislocation of the LHB tendon.

Eight muscles are attached to the proximal humerus and are normally in balance. However a fracture causes these to produce deforming forces as follows (figs 2, 3 and 5) :

- The head tends to be pulled into abduction and external rotation by supraspinatus and infraspinatus.
- The greater tuberosity is pulled superiorly and posteriorly by supraspinatus, infraspinatus and teres minor.
- The lesser tuberosity is pulled medially by subscapularis .
- The shaft is pulled medially by pectoralis major attachment to the lateral edge of the bicipital groove.

This is important to note in apparently undisplaced greater tuberosity fractures seen on the antero-posterior view ; the axillary view should be carefully inspected as the greater tuberosity may in fact be displaced posteriorly by the pull of infraspinatus and the head internally rotated by the unopposed pull of subscapularis and pectoralis major. The resulting malunion will cause a loss of external rotation and abduction.

IMAGING

Adequate imaging is required and there are three standard radiograph views of the shoulder. These are :

- Antero-posterior – taken perpendicular to the plane of the scapula.
- Y-scapula – a lateral view taken parallel to the blade of the scapula and useful to show the relation of the humeral head to the glenoid. It can be difficult to interpret.
- Axillary – difficult in the trauma situation due to pain but the most important as it will show congruency of the humeral head on the glenoid and any angulation of the shaft. Therefore a modified axillary view can be taken with the arm in adduction (fig 3b). The plate is positioned

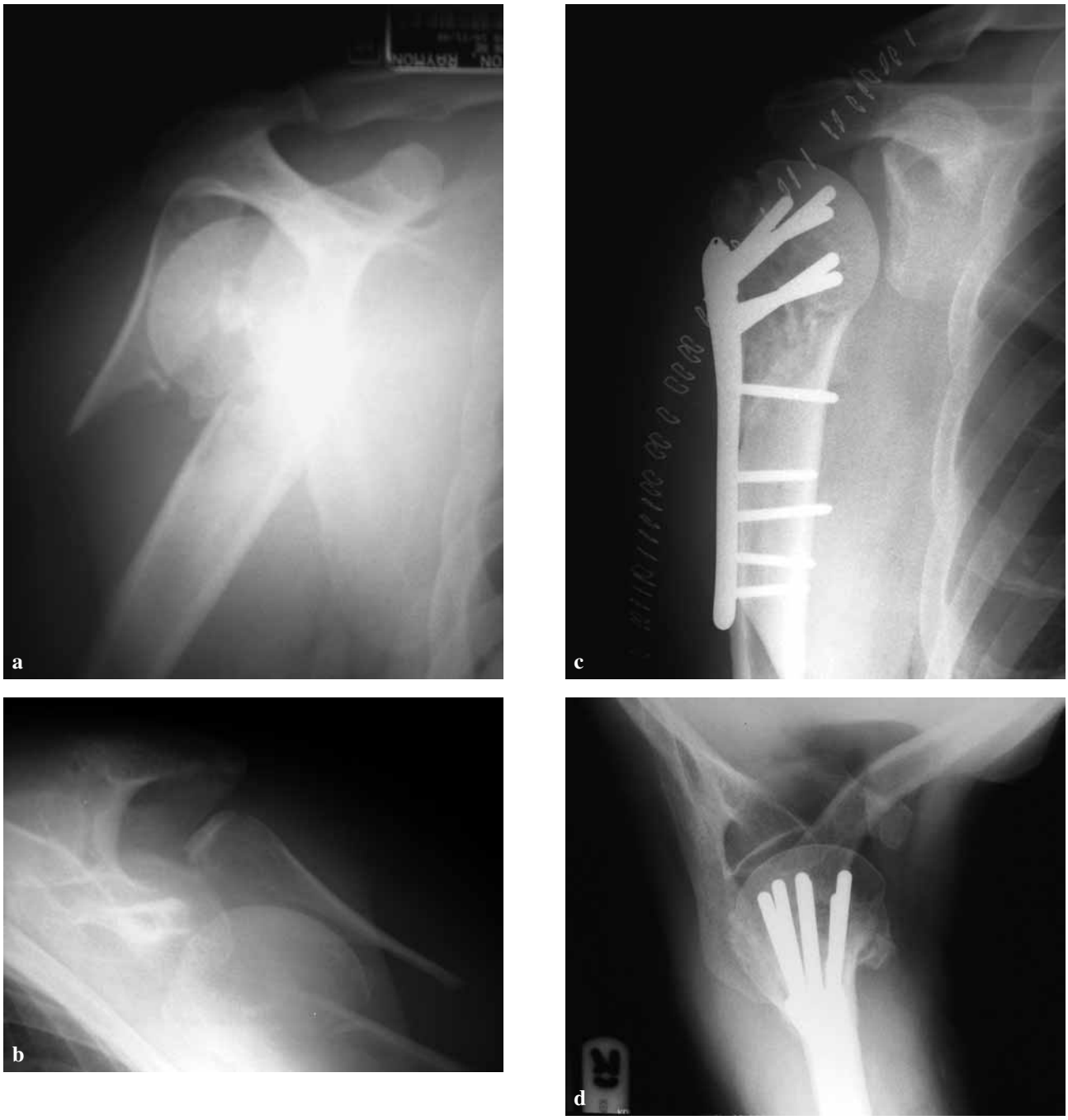

Fig. 3. — 3-part fracture ; a) AP view ; b) Modified axillary view showing marked posterior displacement of large greater tuberosity fragment ; c & d) Internal fixation with a locked plate (S3, Hand Innovations).

posterior and inferior to the shoulder and the x-ray beam directed from anterior and superior obliquely across the shoulder.

Further information can be gained from CT scanning to show the degree of comminution and displacement. Excellent 3-D CT reconstructions

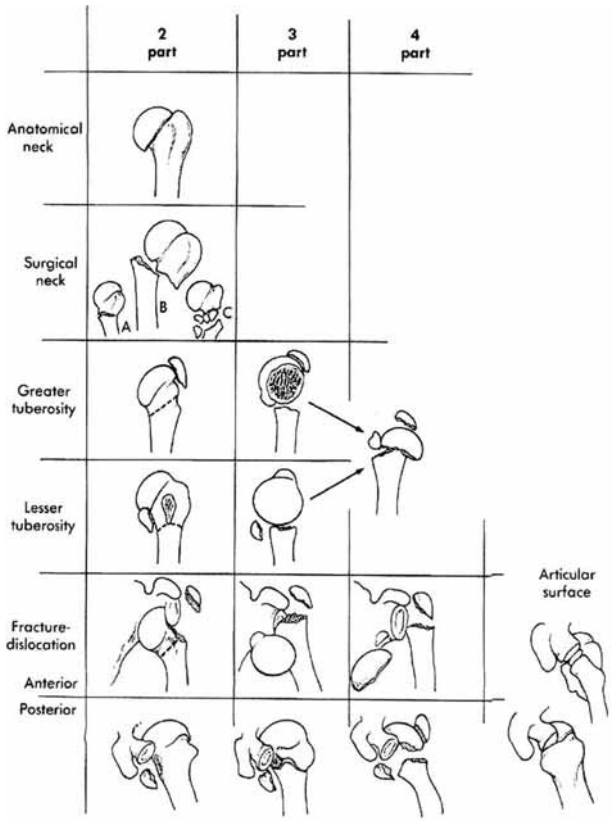

Fig. 4. — Neer classification (reproduced with permission, from C. S. Neer. Displaced proximal humeral fractures : Part I. Classification and evaluation. *J Bone Joint Surg* 1970 ; 52 (6)-A : 1077-1089).

help with visualisation of displaced fragments. MR imaging is useful when a rotator cuff tear is suspected.

CLASSIFICATION

It was noted by Codman in 1934 that proximal humeral fractures occur with 4 main fragments. It was Neer (*21*) who described the displacement of these fragments and noted that the more displaced the fragments are the worse the prognosis is, and he related this to damage to the vascularity of the head (*22*). He divided fractures into 2-, 3- or 4-part fractures and fracture-dislocations, and sub-divided these to give 16 main types. This remains the most commonly used classification. He described displacement of a fragment to be separation of greater than 1 cm or angulation of the head of greater than 45°.

The AO classification divides fractures into 3 groups and relates these to the risk of avascular necrosis (*20*). Each group is further divided giving 27 types. This complexity limits its use in research, besides it does not describe displacement.

	Risk of AVN
• A (extraarticular with 2 main fragments)	Low
• B (partial intraarticular with 2 or 3 fragments)	Medium
• C (intracapsular with 2, 3 or 4 fragments)	High

Both classification systems are complex and have poor intra- and interobserver reproducibility (*14*).

TREATMENT

In clinical practice the important patient factors to consider are age, functional demands and co-morbidity.

The injury factors to consider are :

– displacement
– 2, 3 or 4 part
– fracture-dislocation
– head splitting

In younger patients displaced fractures are treated operatively to achieve anatomic reduction and maximise the chance of a return to normal function. The recent trend with fractures in general has been towards limited internal fixation through minimal access techniques to reduce the risk of avascular necrosis and post-operative scarring. However in the proximal humerus with its poor bone stock in older patients this may be at the cost of stability limiting early movement. In elderly patients the controversy remains as to the best treatment for displaced 3- or 4-part fractures. There is doubt as to the adequacy of fixation of conventional techniques in osteoporotic bone. Studies have shown good results with all forms of treatment including non-operative treatment. There are few randomised trials and none using more modern

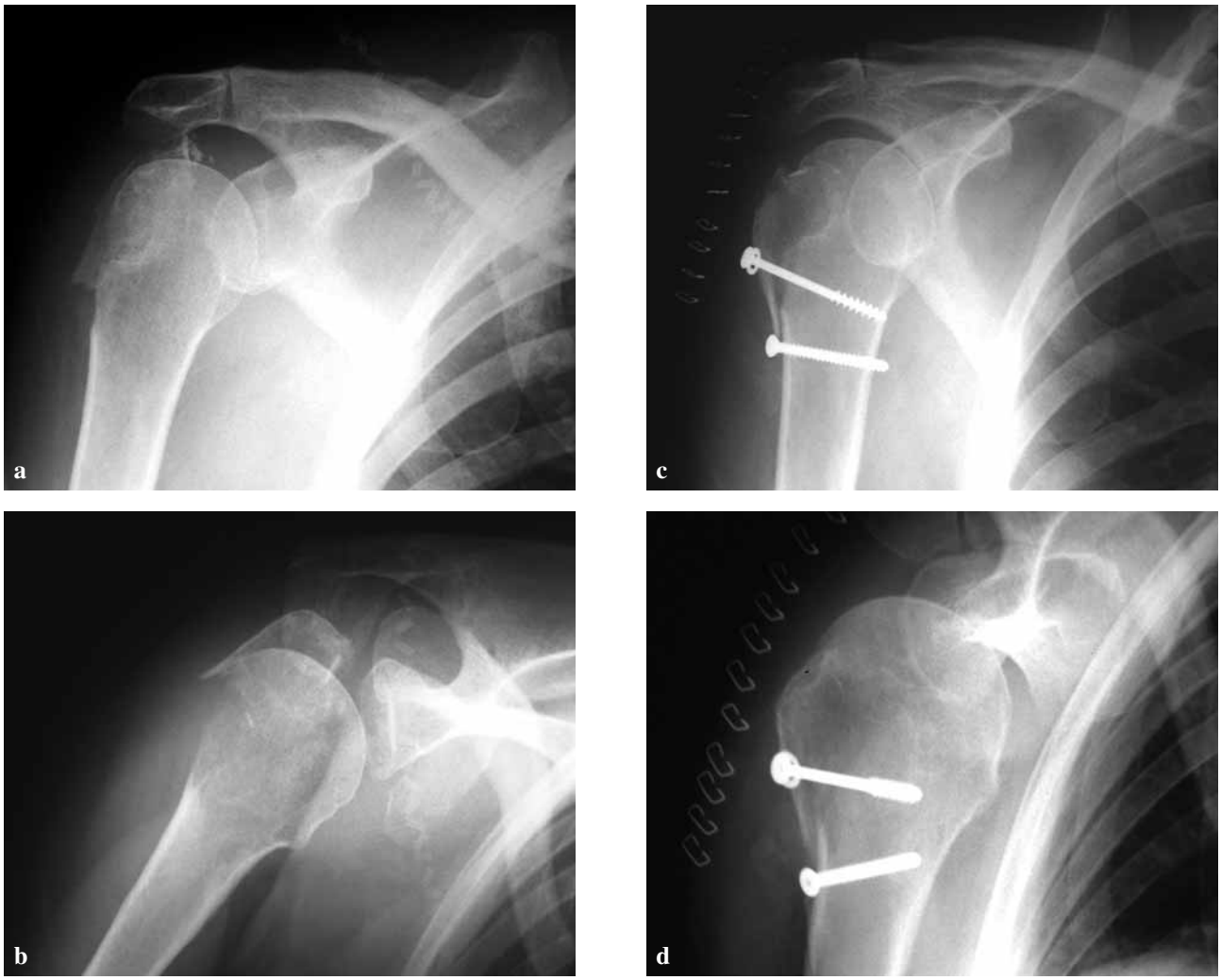

Fig. 5. — Displaced greater tuberosity fracture internally fixed with trans-osseous sutures passed round a capstan screw. Note markedly osteoporotic bone. A lag screw has been placed in the tuberosity fragment and was checked it did not impinge.

fixation techniques. Therefore we present our approach to these varied injuries.

Non-operative management is followed for minimally displaced fractures. These constitute 80% of proximal humeral fractures. In practice this includes most fractures in the elderly as long as there is bone on bone contact between the head and the shaft. For greater tuberosity fractures up to 5 mm superior or 10 mm posterior displacement is acceptable (*17*). The rehabilitation involves initial immobilisation for 2-4 weeks in a collar and cuff. It is important to begin elbow range of movement exercises immediately. As soon as pain allows, passive circumduction of the arm is commenced. Active assisted exercises begin at 4-6 weeks with abduction beyond 90° and external rotation at 6-8 weeks. Active range of motion and isometric exercises are then commenced and continue for 3-6 months.

Non-operative treatment has been advocated in elderly patients with 3- or 4-part displaced fractures (*32*). This randomised study compared non-operative treatment to internal fixation in a group of 40 patients and suggested similar function at

3 years follow-up, with all complications occurring in the surgical group. However it should be noted that tension band wiring was used for internal fixation in this study which probably affords sub-optimal fixation compared with more modern techniques.

Manipulation under anaesthetic and K-wiring has a greater role in the management of children's fractures where rapid healing occurs and in adults if there is good bone quality. 'Mini-open' reductions cause minimal morbidity where indirect reduction fails. It is probably not suitable in elderly patients due to poor fixation in osteoporotic bone and a greater degree of comminution seen with these patients. A cause for greater concern is reports of K-wire migration in osteoporotic bone (*19*). However good results have been reported even in the elderly in 3- and 4-part fractures (*23*).

Greater tuberosity fractures displaced by more than 1cm require internal fixation. This is performed through a deltoid split. An oblique incision is made over the antero-lateral corner of the acromion. A 3-4 cm split is made in the proximal deltoid and a stay suture placed at the distal end of the split to prevent propagation, to avoid injury to the axillary nerve. The greater tuberosity is reduced and held temporarily with a K-wire. Trans-osseous sutures are passed to incorporate the tendon and the sutures are passed round a 'capstan' screw placed lower on the humeral shaft (fig 5).

A subgroup is valgus impacted fractures which are known to have excellent healing potential (*11*). This is thought to be due to an intact medial capsular supply to the head. If reduction is felt to be necessary, minimally invasive internal fixation has been developed to disturb soft tissues attachments as little as possible (*10*) (fig 6). Severely valgus impacted fractures in younger patients produce poor functional results and require more extensive surgery with elevation of the head fragment, bone grafting and internal fixation (*26*).

Possibly the greatest recent advance for the internal fixation of proximal humeral fractures has been the development of locked fixed angle screw plates. The angular stability between the plate and proximal screws/pegs transfers the forces directly from the bone to the plate. Conventional plating relies on 'purchase' of the screw threads in bone to compress the head against the plate. In osteoporotic patients with poor quality bone pull out of the head screws and loss of fixation is commonly seen. Bone cement has even been added to the construct to improve the fixation of screws. The designs of fixed angle screw plates have either multiple, multidirectional, divergent proximal locking screws (Philos, Synthes, UK) or 2 larger screws and both lying in the same plane (PlantTan, GmbH, Germany). The force transmitted to each screw is possibly less with multiple screw designs. This could explain the high incidence of failure reported due to screw cut out when the PlantTan plate is used in elderly patients, possibly due to a large force on each screw (*18, 27*). The tuberosity fragments are reduced and held by transosseous sutures (no. 5 non-absorbable material) through holes on the plate. This improved fixation should allow earlier movement and improved functional outcome.

A biomechanical study has shown improved torsional rigidity with locked plates compared to a fixed angle blade plate (*31*). Early results with the Philos plate suggest good functional outcome in patients younger or older than 65 years (*2, 13*). However there are as yet no randomised trials showing improved results for locked plates over conventional implants.

We have the patient supine in the deckchair position and positioned towards the middle of the table to allow x-ray screening. We use a deltopectoral approach. The bicipital groove is used to guide correct rotational alignment. The deltoid insertion has to be partially elevated to allow correct seating of the plate which is aligned with its anterior border at the lateral edge of the bicipital groove. This can be repaired at the end by suturing to the pectoralis major insertion. Alternatively a deltoid splitting approach can be used to allow visualisation of the tuberosities to allow accurate reduction and fixation, to give the best chance of a good functional result. After the deltoid is split, the axillary nerve is dissected to prevent injury and the plate is slid carefully under the nerve (*25*). By moving the nerve, the screws for the fixation of the plate to the shaft can then be inserted. Post-operatively active assisted movements are commenced immediately, avoiding

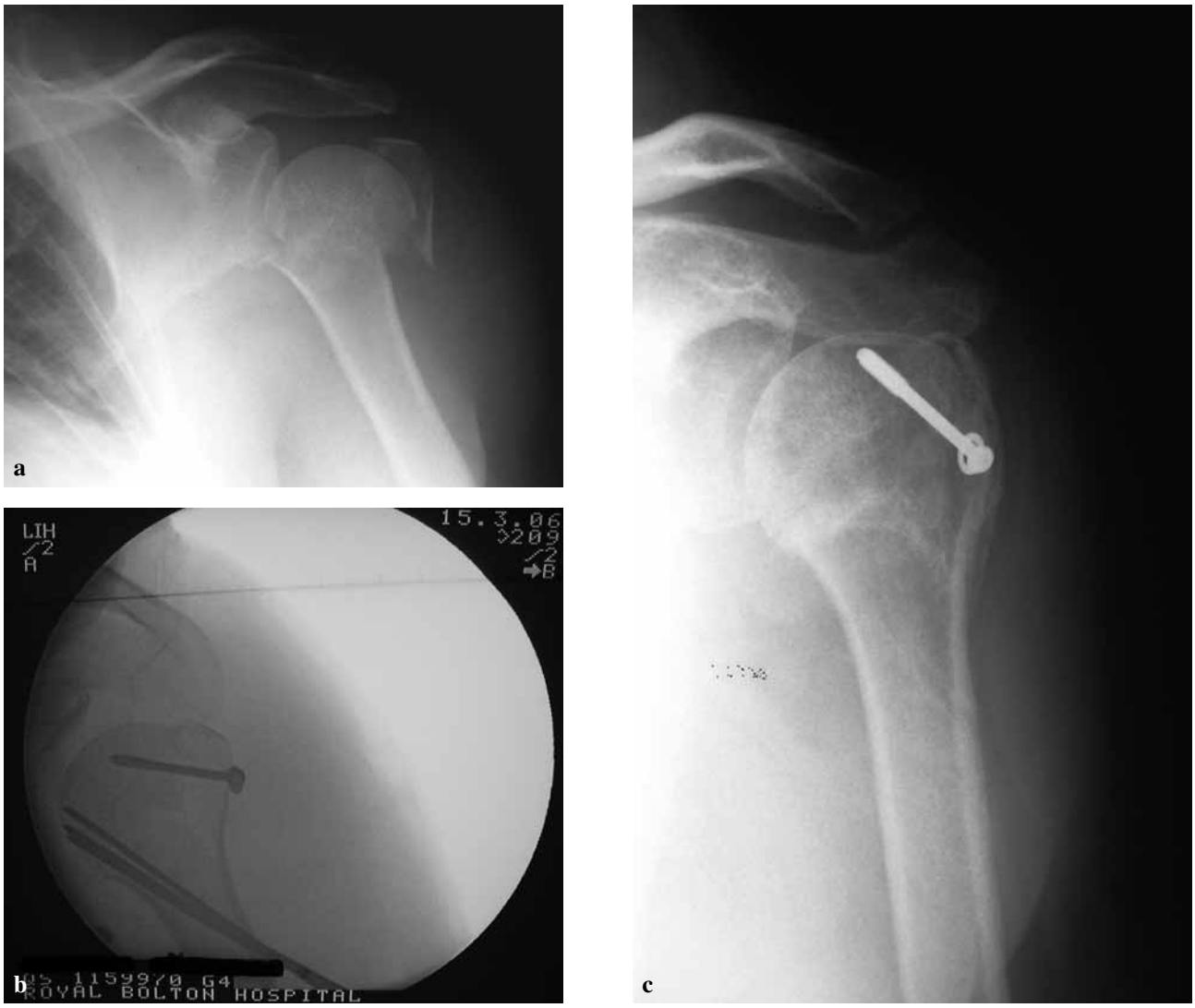

Fig. 6. — Valgus impacted fracture in an elderly patient. Percutaneous fixation technique used with reduction achieved using a bone lever to elevate the head fragment before K-wiring. The tuberosity is held with a lag screw.

abduction beyond 90° and external rotation until the sling is removed at 4-6 weeks.

There have been intramedullary nails developed with proximal locking options to hold any displaced fragments (Polarus, Acumed). The potential advantages are limited soft tissue trauma from percutaneous insertion, and the implant is buried in the bone. The disadvantages are damage to the rotator cuff on insertion, if acceptable reduction cannot be achieved by indirect means then the fracture will have to be openly reduced, and there are limited options on screw placement in the proximal fragments. The few studies available have suggested good results in young patients and 2-part fractures (*24*) and generally poor results in the elderly (*1*).

Primary hemiarthroplasty is indicated for a 4-part fracture with a dislocated head fragment, a head splitting fracture or where internal fixation is not felt possible due to poor bone stock (fig 7). Presently there are no randomised studies showing improved results for hemiarthroplasty over non-

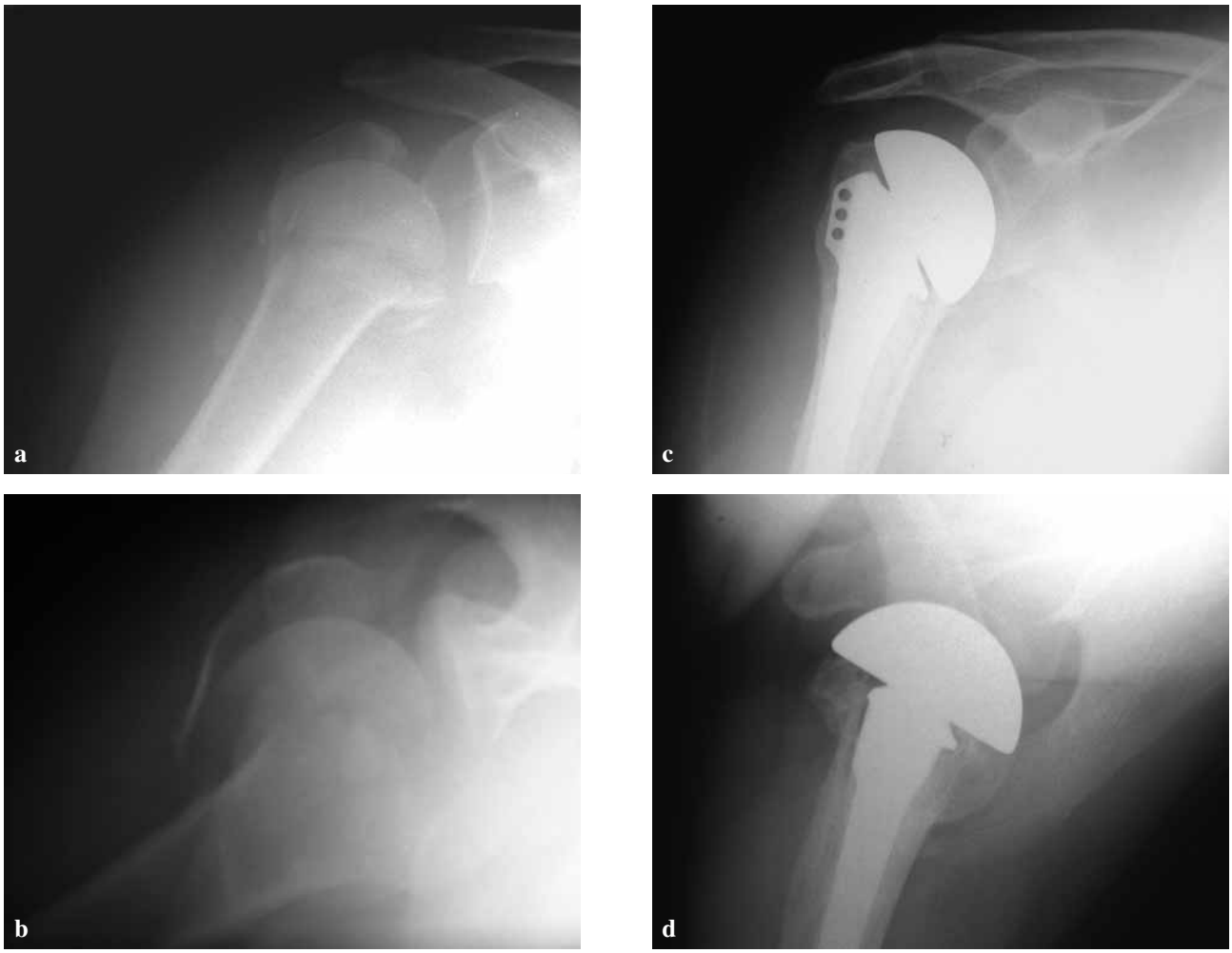

Fig. 7. — 4-part fracture in a 55-year-old man. Internal fixation was planned but at surgery the head fragment was found to be avascular and a hemiarthroplasty was performed. Note excellent healing of tuberosities ; at 4 years the patient has full elevation and rotation.

operative treatment. Poor functional results have generally been reported for hemiarthroplasty but they produce reliable post-operative pain relief *(8, 33)*. Ten year survival has been reported in up to 94%, and important factors include patient age, degree of comminution and accurate reattachment and positioning of the greater tuberosity *(25)*.

We use a deltopectoral approach. The rotational alignment of the prosthesis is guided by the bicipital groove with the stem 1-1.5 cm posterior to this. The prosthesis is always cemented due to poor bone quality. The tuberosities are repaired to each other and to the shaft through drilled holes, by a tension band suture technique. Rehabilitation begins immediately with passive shoulder circumduction and elevation in the plane of the scapula. At 6-8 weeks active elevation and external rotation is begun if radiographs show evidence of tuberosity healing.

The reverse polarity shoulder replacement has become an accepted treatment for patients with a severe fracture and cuff arthropathy or an irreparable rotator cuff tear *(30)*. The prosthesis aims both to medialise the centre of rotation of the glenohumeral joint and increase the lever arm for deltoid to improve deltoid function. Studies have mainly

been in patients with cuff arthropathy and have shown excellent short term functional results with arm elevation above 90°. However there has been a relatively high rate of complications reported with a worrying incidence of glenoid loosening in the longer term (*3*). A study by Guery *et al* of 80 reverse shoulder prostheses at follow-up of 10 years showed a survivorship for revision of 91% and for glenoid loosening of 84% (*9*). Until further studies report on the long-term survival of these implants the present recommendations are that the prosthesis should only be used in the elderly with good glenoid bone stock.

COMPLICATIONS

Potential complications include neurovascular injury, stiffness, pain, adhesive capsulitis, AVN, non-union, malunion and osteoarthritis.

The brachial plexus and axillary artery lie close to the proximal humerus and are at risk of injury. The axillary nerve is most commonly affected as it passes inferior to the subscapularis and around the surgical neck. The axillary and musculocutaneous nerves should be protected at surgery.

The incidence of AVN is related to the degree of comminution of the fracture. Rates of up to 25% have been reported with 3-part fractures (*13*) and 77% with 4-part fractures (*28*). Patients with radiological changes consistent with AVN do not always go on to collapse and they may have excellent function. It has been suggested the functional outcome in patients with AVN is related to the degree of displacement of fragments at the time of healing (*6*). A low incidence has so far been reported with the use of fixed angle devices (*2*).

Non-union of the surgical neck is not common, probably occurring in less than 1% of proximal humeral fractures. In elderly patients with a 2-part fracture it occurs in 4.6% (*5*). The patient is likely to have little pain but poor function with limited abduction and flexion. If the patient is fit for surgery, internal fixation with a stable implant and bone grafting is required. If there is extensive bone loss, prostheses have been used.

Due to the large range of movement at the glenohumeral joint, quite marked angular and rotatory malunion between the shaft and head fragments can be accepted without causing functional loss. This is less so with fractures involving the tuberosities where accurate reduction is essential for good function.

CONCLUSION

Proximal humeral fractures are an increasing problem due to an aging population. The majority of patients will have a good functional result with possibly some restriction of movement. Displaced 3- and 4-part fractures remain a difficult problem especially in osteoporotic patients. The aim is to preserve the head with anatomical reduction and stable fixation allowing early mobilisation to prevent stiffness. The use of proximal locking plates has increased the number of fractures amenable to internal fixation, and may lead to improved results for internal fixation. The trend is towards more limited deltoid splitting approaches to allow accurate reduction of the tuberosities. Hemiarthroplasty is indicated as a salvage procedure in displaced 3- or 4-part fractures with a displaced head fragment or for complications such as AVN. Presently there are no studies comparing fixed angle devices to non-operative treatment or hemiarthroplasty.

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