Management of proximal humeral fractures

D.J.C. Burton*, A.T. Watters

*Corresponding author. Tel.: +44 1937 574609.
E-mail address: djcb1972@hotmail.com (D.J.C. Burton).

Department of Orthopaedics and Trauma, Bradford Royal Infirmary, Duckworth Lane, Bradford, UK

KEYWORDS
Shoulder fractures; Rehabilitation; Internal fixation

Summary
All aspects of proximal humeral fractures produce much debate. From classification systems to modes of treatment and rehabilitation, the influence of patient age and management of complications all may lead to confusion. Here we aim to give a balanced, contemporary overview of the subject and provide suggestions as to how to approach these injuries.

© 2006 Published by Elsevier Ltd.

Introduction
Proximal humeral fractures are common (approximately 4–5% of all fractures) and increasing in frequency, probably due to their association with osteoporosis in our increasingly aged population. They represent over 70% of humeral fractures occurring over the age 40. Overall this injury tends to follow a bimodal age distribution, though they are less common in younger people in whom they are usually the result of higher-energy trauma. The exception to this is 2 part fractures, which follow a unimodal distribution in the elderly. Fractures of the shaft and distal humerus on the other hand, are more common than proximal humeral fracture in the young population.

Management decisions for the majority of these injuries are straightforward, though some cases lead to vigorous debate regarding classification and treatment decisions can range from the most conservative to the most aggressive operative intervention. The availability of new, specific implants spurs some on toward operative intervention, whilst some texts still recommend treatment techniques of questionable value, making diagnosis and treatment confusing.

In this article we will consider the common classification systems, investigations, relevant anatomy and the more commonly proposed treatment regimes—together with the preferred management options of the senior author (ATW).

Classification
Fracture classification systems are most useful when they allow accurate anatomical description, guide treatment and allow an estimation of prognosis. The first classification that seemed to meet these requirements was the Neer classification of 1970, although this was based on the anatomical observations of Codman as early as 1934. Despite marked intra-and inter-observer error, this remains the most commonly used classification system today.

Codman described the proximal humerus divided into 4 fragments, along the lines of physeal union (Fig. 1). Thus there are head, greater tuberosity, lesser tuberosity and shaft fragments, each with specific soft tissue attachments. Neer developed this scheme by describing the fragments as parts, when they are displaced from the other fragments by
10 mm or 45° of rotation. Hence displaced fractures, or fracture dislocations, may be 2, 3 or 4 parts.

Additionally there are a group of humeral head fractures that are described as impression fractures, usually occurring with a dislocation, in which the articular surface and subchondral bone becomes indented by the glenoid rim. Impression fractures are divided according to the percentage of the articular surface affected, generally less than 20%, 20–45% and greater than 45%. Head splitting fractures are a further development of this mode of injury, as the humeral head is cleaved into at least 2 separate fragments.

Jakob and the AO group developed a classification system that describes the degree of vascular isolation of the articular fragment. Type A fractures are extracapsular, of 2 anatomical (‘Codman’) fragments and lead to no vascular isolation of the humeral head. Type B fractures are intracapsular, of 3 fragments and lead to partial articular vascular isolation. Type C fractures are the most severe, leading to complete vascular isolation and are usually in 4 fragments. Like all AO classifications, each type is subdivided and, although this is useful for research, it leads to a rather unwieldy system less suited for general clinical applications. Siebenrock et al. considered the AO system, like the Neer system, to be of insufficient reproducibility to allow comparison of studies using these classifications.

Despite the reservations expressed, it is still important to use a classification system. Otherwise it becomes impossible to compare different papers on the subject and reach any conclusions regarding the validity, effectiveness and success rates of the various treatment modalities described. The authors prefer to use the Neer system.

Vascular anatomy of the humeral head

Critical to the prognosis in proximal humeral fracture is the blood supply to the humeral head articular fragment. This receives its main blood supply from the ascending branch (also known as the anterolateral branch) of the anterior circumflex humeral artery (itself a branch of the third part of the axillary artery). This artery enters the bone at the intertubercular groove and supplies the tuberosities and the humeral head via the intraosseous arcuate artery, which lies within the head. To a lesser extent blood supply also arrives via the soft tissue attachments of the rotator cuff, mainly through the posterior circumflex humeral artery, which supplies a small part of the greater tuberosity and posteros-inferior head. Gerber et al. defined the territories of these arteries in a series of cadaveric radiopaque injection experiments, proving that the vascularisation of the whole humeral head was only possible via the anterolateral branch of the anterior circumflex humeral artery.

Injuries that disrupt the blood supply to the articular fragment tend to be those that detach both the tuberosities and damage the arcuate artery, i.e. Neer 4 part or AO C-type fractures and fracture dislocations. Head splitting fractures also tend to critically disrupt the blood supply to the articular fragment. Impaired vascularity increases the
risk of Avascular Necrosis (AVN) and collapse of the humeral head.

**Diagnosis**

Following standard history taking and examination of the patient with a possible shoulder injury, including neurovascular assessment, full radiological examination is required. The complete shoulder trauma radiological series consists of an anteroposterior view, scapula lateral view and an axillary view (Fig. 2) (a Velpeau view may be required if the shoulder cannot be abducted sufficiently for the axillary view). Without these 3 views the fractured proximal humerus cannot be completely assessed. The axillary view is particularly important to assess head splitting fractures, visualise posterior displacement of the greater tuberosity and to assess the relationship between the articular surfaces. Unfortunately this view is often considered unnecessary by Accident and Emergency and Radiology departments, despite good evidence in the literature to the contrary.\(^8\)

Computed tomography (CT) is useful to further visualise complex fractures and to assess the humeral and glenoid articular surfaces in impression, head splitting and glenoid rim fractures. It is also useful in assessing bone stock in cases of nonunion and anatomy in malunion (Fig. 3).

**Treatment methods**

Treatment methods will be described by fracture pattern. Debate becomes fierce as the complexity and number of parts increase; there is also patient age, physiological state and comorbidities to take into account along with expected demands to be put on the limb.
Undisplaced and minimally displaced fractures

There is general agreement that fractures that are not sufficiently displaced or angulated to represent a part by Neer's description may be treated conservatively. This is done in a broad arm sling under clothes or with a body swathe. The 'Polysling' is an example of a rather more comfortable form of support made of synthetic material and is ideal. The shoulder is immobilised for 10–14 days, although elbow and wrist exercises may commence immediately to prevent stiffness. An interim radiograph is obtained to ensure no deterioration in position. At 10–14 days the patient may start gentle range of movement (ROM) passive exercise with the help of a physiotherapist.

The exception to this situation arises when there is over 5 mm of displacement of the greater tuberosity, which should be treated in the same way as 2 part greater tuberosity fractures. These fractures are best seen on the axillary radiograph. The greater tuberosity fragment usually migrates proximally and posteriorly under the influence of supra- and infraspinatus. In cases of fracture dislocation the closed reduction of the shoulder often leads to perfect reduction of the greater tuberosity, though this must be reimaged at 1 week to rule out late displacement. Any more than 5 mm of displacement may lead to impingement and the fragment should be reduced and fixed when fresh, as later osteotomy for malunion and impingement is fraught with difficulty (Fig. 4).

The approach for fixation of greater tuberosity fragments utilises a deltoid split. With the arm draped free the humeral head may be rotated to visualise the fragment and its bed. If there is a single, large fragment then 3.5 mm cancellous screws may be used, carefully countersunk to avoid impingement. If the fragment is not amenable to screw fixation (due to comminution or poor quality bone), a suture technique is used, using a figure of eight pattern through the rotator cuff tendon and then through a drill hole in the shaft. The fragment is reattached and the surrounding cuff insertion repaired. A No. 2 Ethibond (Ethicon, USA) or Fiberwire (Arthrex, USA) is appropriate in this situation. Neer regime rehabilitation may start 2–3 days post-operatively.
Two part fractures

This is the commonest fracture pattern seen. Two-part fractures of the proximal humerus may be impacted, angulated or displaced. Where there is impaction the fracture will usually unite promptly, but with associated angulation into varus, valgus or posterior bow deformity. Significant functional impairment may result because of impingement or malposition of the articular surface. Displaced or ‘off-ended’ fractures, where the action of opposing muscle groups pull the distal fragment medially and anteriorly, may be slow to unite and in some cases may progress to nonunion.

There are several schools of thought regarding the management of these injuries, ranging from ‘almost always conservative’ to ‘almost always operate’.

Manipulative reduction under anaesthetic on its own has been described in the past but due to the high incidence of redisplacement has been largely discredited. Similarly ‘traction reduction’ using a hanging plaster-of-Paris cast has also been discredited for failure to achieve reduction and for the discomfort that it causes. The authors believe that neither of these treatment options should be offered. Minimal fixation techniques following manipulative reduction are well described. The technique most commonly used is to pass three or four 2.5mm threaded Kirschner wires across the fracture site after reduction. Pin tract infection (particularly when the wires are not buried) and wire migration are common complications. Where the wires pass through the shoulder girdle muscles they also cause pain and interfere with movement and rehabilitation until they are removed. There are also many reported cases of inadequate reduction, possibly due to tendon interposition, or loss of position despite wire fixation. Though there remain some well-known proponents of the closed percutaneous technique, for the reasons outlined above many surgeons find it unsatisfactory.

Open reduction and internal fixation allows visualisation and accurate reduction of the fracture fragments. Many methods of maintaining the reduction have been described, including the use of sutures, sutures with eyeleted nails, tension band wiring, intramedullary nails and various types of plates and screws. More recently custom-designed proximal humeral systems have been introduced, of which the authors have experience of the Plant Tan (Medizentechnic, Germany) and AO Philos (Synthes, Switzerland) systems with fixed angle interlocking screws (Fig. 5).

Court-Brown et al. have reported the results of treatment of a large series of patients, average age 72 years, and concluded that the functional results of operative management in this older group are statistically no better than those treated conservatively. On this basis they advocate conservative management, with its lower complication rate. However, it should be noted that the internal fixation system that they used (Enders nails and sutures), is not ideal for achieving secure fixation in osteoporotic bone and they

![Figure 4](a) Scapular lateral radiograph in anterior dislocation of the shoulder with greater tuberosity fracture and (b) after reduction of the shoulder, significant posterior displacement of the fragment remains.
concede that technical difficulties with achieving and maintaining reduction may contribute to the overall poor results of surgery.

Reports in the literature looking at the PlantTan proximal humeral fixator plate in 2 and 3 part fractures have shown good functional results in the younger age group, though the results in the older age group remain poor.\textsuperscript{13,14} The theoretical advantages of the interlocking, multidirectional screw system in the AO Philos plate (better hold in osteoporotic bone, low profile therefore less likely to cause impingement) has yet to be confirmed in clinical trials, but offers hope for better functional results in the elderly population (Fig. 6).

It is the senior author’s current practice to advocate open reduction and internal fixation using the Philos system\textsuperscript{15} in most displaced-pattern 2 part surgical neck fracture, except in the very elderly and infirm and also in the more deformed (>40°) angulated pattern fractures occurring in younger patients. Initial results are promising, but review and analysis are awaited.

Three part fractures

In this injury one tuberosity usually remains attached to the articular fragment and the rotator cuff then acts as a displacement force on this fragment. In all cases reduction and fixation are advocated, allowing early mobilisation and rehabilitation (Fig. 7).

Resch (Austria) is perhaps the best known exponent of the percutaneous reduction of 3 and 4 part fractures, using elevators introduced through appropriately placed stab holes and subsequent fixation with cannulated screws.\textsuperscript{16} This avoids further damage to the vascularity of the humeral head during dissection. This technique is technically very demanding, particularly in 4 part fractures and is not common practice in the UK. Gerber (Switzerland) has employed similar techniques for reduction and fixation of some 3 part fractures, though the initial approach for other 3 part, and all 4 part fractures, was via a deltopectoral incision using a rasp introduced through the fracture lines for reduction.\textsuperscript{11} The senior author’s preferred method is similar to that for the internal fixation of the 2 part fracture, using the Philos plate and heavy sutures (Fibrewire for example) to reattach the tuberosity fragment either directly or by passing the suture through the rotator cuff tendon. The suture may then be passed through the holes in the plate or through drill holes in the humeral shaft. Care must be taken during dissection to not denude the proximal fragments of their soft tissue attachments as this increases the risk of AVN and nonunion with migration of the fracture fragments.

In very osteoporotic bone and in cases of fracture dislocation in the elderly, with complete loss of soft tissue attachments, a primary shoulder hemiarthroplasty allows early mobilisation and produces a comfortable shoulder.\textsuperscript{17} When done immediately, this is far less technically demanding and yields more satisfactory results than at an interval...
Figure 6  (a–c) Completely displaced 2 part fracture, treated by ORIF using the Philos system.
Following failed conservative or operative management (Fig. 8), four part fractures are not amenable to closed reduction. There is also a high failure rate with open reduction and internal fixation due to avascular necrosis and nonunion. Four part fracture dislocation is associated with an even higher risk, the head fragment is usually found to be completely free and devoid of soft tissue at operation (Fig. 9).

In the series from Austria alluded to above, the 11% AVN rate using percutaneous reduction and cannulated screw fixation with an average Constant score of 87% for 4 part fractures. This was in a relatively young population (average age 54 years), using a technique not widely practiced in the UK.

The treatment of choice in the elderly population is generally accepted to be primary hemiarthroplasty. Although hemiarthroplasty had been attempted before the 1950s, it was Charles Neer who revolutionised the procedure for the treatment of proximal humeral fractures. Arthroplasty performed after an interval is made more difficult by softening of the bone, malunion of the tuberosities, contracture and intrarticular adhesions. The treatment of middle-aged patients remains something of a grey area and decisions must be made on an individual basis after discussion with the patient.

The treatment of choice in the elderly population is generally accepted to be primary hemiarthroplasty. Although hemiarthroplasty had been attempted before the 1950s, it was Charles Neer who revolutionised the procedure for the treatment of proximal humeral fractures. Arthroplasty performed after an interval is made more difficult by softening of the bone, malunion of the tuberosities, contracture and intrarticular adhesions. The treatment of middle-aged patients remains something of a grey area and decisions must be made on an individual basis after discussion with the patient.

The decision to perform hemiarthroplasty in young, active patients is very difficult as it will almost inevitably lead, with the passage of time, to a requirement for revision surgery. The levels of discomfort and function from a nonweight-bearing joint makes the sequelae of AVN of the humeral head and femoral head noncomparable, making a trial of fixation of the 4 part fracture in young people a viable option in the first instance. Satisfactory levels of function and comfort have recently been reported in young patients sustaining complex proximal humeral fractures complicated by AVN, having had restoration of anatomy using a deltopectoral approach and a combination of plate, screw and transosseous suture.

If humeral head replacement is performed the deltopectoral approach is preferred. The key to the deranged anatomy is identification of the bicipital groove and the...
long head of biceps tendon, lying between the two
tuberosities. It is usually unnecessary to divide the
subscapularis tendon as the split that commonly occurs
between the two tuberosities allows entry into the shoulder
joint and retrieval of the humeral head fragment. Care must
be taken when retrieving the humeral head in cases of
fracture dislocation, particularly if there has been delay
between injury and presentation, as it may lie very close to
the brachial plexus and axillary sheath.

A number of humeral head replacements are available
and are broadly grouped into modular or monobloc. The
original Neer implant of the 1950s was modified in the 1970s
and has remained in its monobloc form ever since. The
senior author currently uses the Bigliani-Flatow (Zimmer,
USA) modular implant, which comes with interchangeable
head sizes (both diameter and depth) and a range of lengths
and diameters. Other implants have increased modularity
(separate neck for example) and all vary in the number and
distribution of holes in fins for reattachment of soft tissues.

With increasing modularity comes increasing risk of dis-
sociation and theoretically increased risk of fret corrosion
between the components.

The key to a successful hemiarthroplasty for trauma is the
avoidance of injury to the deltoid muscle, correct retro-
version of the prosthesis (usually about 30°) and secure
reattachment of the tuberosities to each other, the humeral
shaft and the prosthesis itself to ensure healing in the
correct position. Correct soft tissue tension is vital and the
height of the prosthesis must therefore replicate the height
of the native humeral head closely, as there is a tendency
amongst inexperienced surgeons to shorten the humerus.
Finally, the tuberosities should lie below the level of the
humeral head to ensure correct cuff tension and prevent
impingement.

The long head of biceps tendon should be replaced in the
bicipital groove at the end of the procedure or tenodesed to
the floor of the bicipital groove if it has become detached
from the glenoid.

The functional results of hemiarthroplasty are variable
and the patient must be counselled that some stiffness and
loss of range of movement are inevitable, although a
comfortable shoulder is the primary goal. Functional result
is influenced by age of the patient, correct positioning of the
implant and the anatomical reduction of the tuberosities.

Impression and head splitting fractures

Impression fractures are sustained following dislocation of
the shoulder. In general terms articular defects of <20% may
be treated conservatively in a shoulder immobiliser or sling
after joint reduction. Fractures involving 20–40% of the
articular surface may require a bone grafting procedure,
either by transfer of a tuberosity into the defect (the
McLaughlin procedure for posterior dislocation21), or by iliac
crest grafting. Fractures of more than 40% of the head
surface require hemiarthroplasty as they tend to be grossly
unstable as the defect fails to engage the glenoid with any
congruency.

Head splitting fractures cleave the head into at least two
avascular fragments. Primary hemiarthroplasty is the pro-
cedure of choice, however this is a difficult decision to make
in the young patient. In this case an attempt at anatomical
reduction and fixation may be made after forewarning the
patient of the risks and benefits of each option.

Pathological fractures

Pathological fractures involving the proximal humerus may
be treated by intramedullary fixation if the prognosis for the
malignant disease warrants stabilisation. The Polarus nail
(AcuMed, USA) range allows numerous possibilities for
locking in the proximal fragment and may be augmented
with PMMA cement for greater stability. Where there is
extensive replacement of the humeral head by tumour then
a long stem humeral hemiarthroplasty with proximal and
distal locking options may be used. In many cases non-
operative treatment is most appropriate (Fig. 10).

Rehabilitation

The rehabilitation of proximal humeral fractures is critical
to optimise outcome. The sooner that rehabilitation can
commence, the better. This is usually more successful under
the supervision of a physiotherapist. The classical Neer
regime involves 3 phases.22

Phase 1: Passive-assisted exercises, including initial
pendulums in both side-to-side and small circle movements,
with the patient bending over slightly to allow the limb to
swing. This progresses to assisted forward elevation and
assisted external rotation in the supine position. Pulleys
attached to the ceiling may be used, with the opposite hand

Figure 9 Four part fracture dislocation in an elderly patient.
as the motor to provide the assistance. The use of a ceiling pulley is not recommended in the presence of tuberosity fractures until they have healed, at approximately 6 weeks, as their use may lead to displacement.

Exercises are repeated 4 times per day after initial warm-up using a warm pack on the shoulder. These exercises are ideally commenced immediately after stable fixation of fractures, though they may be deferred 2–3 weeks if there is concern regarding the strength of fixation or in the case of potentially unstable fractures that are to be treated conservatively (greater tuberosity fractures for example).

Phase 2: Involves active, resisted and stretching exercises, usually between 6 and 12 weeks post injury. Active exercises involve forward elevation against gravity and the use of rubber ‘TheraBands’ to resist internal and external rotation, one end held in the affected hand and the other attached to a fixed point. Stretching may be done in a doorway, using the door jamb and top of door frame as fixed points against which to stretch. The unaffected limb is also useful to aid in stretching exercises, especially in internal rotation and by clasping the affected hand to move it above and behind the head, leading to abduction and external rotation of the shoulder.

Phase 3: Increases resistance with the use of weights, starting at 1 lb and progressing up to a maximum of 5 lb. If the patient develops pain then the weight should be reduced. Phase 3 starts at about 3 months post-injury and continues until functional gain reaches a plateau or preinjury levels. Stretching is continued throughout phase 3.

Complications

Neurovascular injury

The neurovascular injury rate has been reported to be as high as 4–6% in some series of displaced proximal humeral fractures.23 Damage to the axillary artery is a recognised, though uncommon, complication of proximal humeral fracture. It typically occurs in elderly, atherosclerotic vessels and after high-energy trauma. An expanding haematoma around the shoulder, with a pale, pulseless, paraesthetic forearm, raises suspicion of vascular injury and indicates angiography. The consequences of vascular injury are necrosis of the limb distally, distal embolisation and permanent damage to the brachial plexus secondary to compression by the haematoma.

Any part of the brachial plexus may be injured. More commonly an axillary nerve palsy is seen following anterior fracture dislocation, due to the position of the nerve on the anterior capsule. After careful documentation of the deficit, progress may be monitored with electromyography. Discussion with a centre managing brachial plexus injury is advised at an early stage, as some surgeons prefer early exploration of the brachial plexus rather than an expectant policy.

Chest injury

Pneumothorax and haemothorax are both possible association with proximal humeral fracture, usually in high-energy
trauma. Intrathoracic dislocation of the humeral head fragment is an interesting though rare complication.

Frozen shoulder

Post-traumatic frozen shoulder is largely preventable with adequate rehabilitation and physiotherapy starting as early as possible post injury. Failure to progress with range of movement (including passive range), with the cardinal loss of external rotation, suggests frozen shoulder. Impingement of fracture fragments and metalwork causing a mechanical block to movement must be ruled out before embarking upon arthroscopic or open capsular release, in the event of failed physiotherapy and stretches for this condition. Closed manipulation is hazardous and may lead to refracture.

Avascular necrosis

Avascular necrosis may occur very occasionally in 2 part fractures of the proximal humerus, however it is following closed treatment (3–14%) of 3 part fractures and open treatment of 3 and 4 part fractures (13–34%) that it is more common. A combination of primary traumatic insult to the vascularity of the humeral head followed by the secondary insult of manipulation and/or surgical dissection leads to necrosis. If the fracture was reduced anatomically with a congruent joint and well positioned tuberosities then a satisfactory functional result may be achieved despite the avascular necrosis. However, a more common picture is that of periarticular soft tissue contracture, degenerative change, metalwork migration and a stiff, painful joint. Treatment is by hemiarthroplasty of the shoulder. A procedure that is more demanding in the chronic situation due to contracture, abnormal anatomy and soft bone (Fig. 11).

Fracture nonunion

This is an uncommon complication caused by excessive movement at the fracture site (over aggressive physiotherapy for example), extensive periosteal stripping in high-energy trauma, wide separation of fragments and soft tissue interposition. The humeral shaft fragment may form a pseudarthrosis with the undersurface of the head fragment, complete with synovial membrane formation, as a result of excessive movement of the fracture site that is bathed in synovial fluid from the shoulder joint above.

Where possible, treatment is with open debridement, reduction and fixation with bone grafting. This is only possible when the humeral head fragment has sufficient bone stock to allow fixation and the articular surface is in good condition. A CT scan may be useful in planning. Humeral head replacement is the procedure of choice where the criteria above are not met, although painless pseudarthrosis may be very satisfactory in some elderly patients with no functional demands.

Fracture malunion

Greater tuberosity migration into a superior position produces subacromial impingement, whilst posterior migration produces impingement with the glenoid. Where there is gross malunion an osteotomy may be performed, through a superior approach. This also allows correction of the position of the rotator cuff, although this may have become shortened with time, making reduction difficult. This procedure is often associated with unrewarding results and is best prevented by early recognition of greater tuberosity migration and managed in the acute situation. This can only be achieved with correct trauma series radiographs to identify the lesion.
Angular malunion of the surgical neck may be associated with a surprisingly good range of movement, providing there is no frozen shoulder and tuberosity impingement. It may be better to perform capsular release and institute intensive physiotherapy before embarking on an angular osteotomy of the proximal humerus. There are some deformities that warrant corrective osteotomy, these are usually gross and are more commonly due to anterior angulation at the fracture site leading to reduced forward flexion.

Acknowledgement

The authors’ thanks go to Jessica Henning, radiographer at Bradford Royal Infirmary, for the line drawings.

References