# Fractures of the proximal humerus: overview and non-surgical management

Rajiv Gogna
Gev Bhabra
Chetan S Modi

## Abstract

Proximal humeral fractures account for 6% of all adult fractures, usually occurring in elderly patients following a low-energy fall. Fracture patterns occur because of the intricate bony anatomy of the proximal humerus and its rotator cuff attachments, which cause displacement of the tuberosities in a predictable nature. This can lead to long-term functional deficit, not only due to mechanical restrictions but also biological consequences such as impaired vascularity and avascular necrosis. The majority of fractures can be treated non-operatively to give satisfactory restoration of function for the vast majority of patients, with recent literature evidence supporting this method of management.

**Keywords** classification; fracture; non-operative; proximal humerus; rehabilitation; shoulder

## Introduction

Proximal humeral fractures are often managed non-operatively, with recent literature evidence supporting this method of treatment. It involves a period of immobilization followed by gradual exercises and a guided rehabilitation programme to restore shoulder movement and function. Historically the management of these fractures was based on radiographic parameters or classification systems in use, however because of the limited evidence to support operative intervention the decision-making process is often centred on patient characteristics, functional demands and expectations. In this mini-symposium we will discuss epidemiology, anatomy of the proximal humerus and its relevant blood supply, as well as the common fracture patterns and their classification. Finally we will highlight the recent literature evidence relating to operative versus non-operative management of proximal humeral fractures and how non-operative care is usually commenced.

***Rajiv Gogna*** *MBBS FRCS (Tr & Orth), Specialist Registrar ST8, Coventry and Warwickshire Shoulder and Elbow Unit, University Hospitals Coventry and Warwickshire NHS Trust, Coventry, UK. Conflicts of interest: none declared.*

***Gev Bhabra*** *BSc MBChB MD FRCS (Tr & Orth), Consultant Shoulder and Elbow Surgeon, Coventry and Warwickshire Shoulder and Elbow Unit, University Hospitals Coventry and Warwickshire NHS Trust, Coventry, UK. Conflicts of interest: none declared.*

***Chetan S Modi*** *MBChB MSc DipSEM FRCS (Tr&Orth), Consultant Shoulder and Elbow Surgeon, Coventry and Warwickshire Shoulder and Elbow Unit, University Hospitals Coventry and Warwickshire NHS Trust, Coventry, UK. Conflicts of interest: none declared.*

## Epidemiology

The majority of proximal humeral fractures occur in the elderly, osteoporotic population with an overall prevalence of approximately 6% of all adult fractures[1]; an estimated 706,000 occurred worldwide in 2000.[2] Around 85% of fractures occur in patients older than 50, with a female to male ratio of 70:30.[1] As with most osteoporotic fractures the age-specific incidence has been steadily increasing over the past five decades,[3] placing an increased burden on healthcare systems. This poses a significant challenge as these patients are often poorly equipped to cope with the functional debilitation and prolonged rehabilitation involved with non-operative management of these fractures.

## Anatomy

There are many reasons why proximal humeral fractures can result in impaired function, ranging from mechanical factors whereby deformity or soft tissue quality result in impaired movement and excursion, through to biological factors where certain fracture patterns may compromise the blood supply to bony segments resulting in avascular necrosis.

### Glenohumeral joint biomechanics

The major contributor to movement at the shoulder girdle is the glenohumeral joint, which works with the scapulothoracic joint to allow 180° abduction in a 2:1 ratio. Abduction requires external rotation of the shoulder joint to allow the greater tuberosity to clear the acromion and prevent impingement, hence a malunited tuberosity can result in functional restriction. The vast range of motion of the glenohumeral joint is a trade off with stability; provided by static (glenohumeral ligaments, labrum, articular congruity, negative intra-articular pressure) and dynamic restraints (rotator cuff muscles, biceps long head, periscapular muscles).

The large spherical articular surface of the proximal humerus articulates with a relatively small glenoid fossa, providing the rotator cuff with a mechanical advantage as the tendons insert close to the articular surface improving their efficiency. Fracture displacement of the tuberosities can result in earlier contact with the glenoid rim and hence range of motion and tendon excursion will be restricted. Trauma to the shoulder joint can also result in changes to the capsule (either due to scar tissue or possible local and systemic effects akin to the development of a frozen shoulder[4]) causing it to thicken and contract, hence restricting the full range of humeral head rotation. Although restoring or maintaining the bony anatomy of the proximal humerus is important for functional movement, it is also vital to restore soft tissue quality reiterating the importance of rehabilitation.

### Structure of the proximal humerus

The proximal humerus consists of the humeral head, the greater and lesser tuberosities and the humeral shaft (Figure 1). The humeral head is spheroidal in shape with a mean radius of curvature of 25 mm[5] and covered by articular cartilage. The humeral head has mean retroversion of 30° from the distal humerus transepicondylar axis (range 5° anteversion to 50° retroversion)[6]

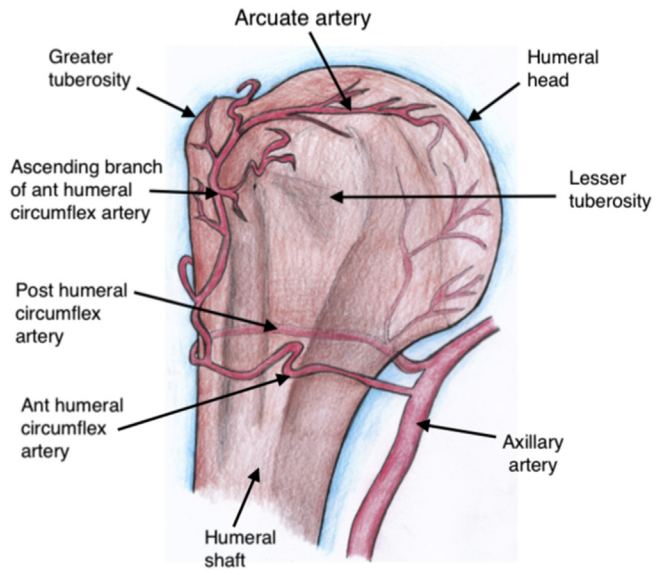


**Figure 1** The four 'parts' of the proximal humerus include the humeral head, shaft, greater tuberosity and lesser tuberosity with a groove for the long head of biceps tendon running between them. Blood supply arises from the axillary artery, which gives off the anterior (ant) and posterior (post) circumflex humeral arteries that anastomose around the surgical neck.

with mean neck-shaft angle of 135°. The junction where the head meets the shaft is defined as the anatomic neck; this represents the old epiphyseal plate. The anatomic neck is the only route of entry for blood vessels supplying the humeral head; hence displaced fractures involving the anatomic neck pose significant risk of avascular necrosis of the head.

Conversely the area immediately inferior to the tuberosities is defined as the surgical neck, an area that is weaker and more frequently involved in fracture patterns. The tuberosities are metaphyseal expansions, which provide attachment for the rotator cuff tendons. The lesser tuberosity lies anteriorly providing attachment for the subscapularis, whereas the greater tuberosity sits postero-laterally and it attaches the remaining rotator cuff tendons. The greater tuberosity is located on average 9 mm distal to the most proximal aspect of the humeral head. This head-to-tuberosity distance is vital to maximizing cuff efficiency, as too short a distance leads to inadequate cuff tension and impingement whereas a very low tuberosity may result in excessive tendon strain and cuff failure.[7]

Between the two tuberosities is the bicipital groove for the long head of biceps which runs superiorly through a fibrous sheath and enters the shoulder joint before attaching to the supraglenoid tubercle. The bone surrounding the bicipital groove is strong cortical bone hence usually remains intact during low-energy fracture patterns, serving as a useful landmark for fracture reduction. This overall arrangement has implications on the fracture patterns observed and they frequently occur in predictable zones due to the integral strength of the segments.

### Blood supply to the proximal humerus

The proximal humerus derives the majority of its blood supply from the anterior (AHCA) and posterior (PHCA) humeral circumflex arteries, which form a ring anastomosis around the surgical neck of the humerus after they arise from the axillary artery (Figure 1). The posterior circumflex humeral artery is the larger of the two, arising from the posterior surface of the axillary artery before accompanying the axillary nerve. It gives off several branches that supply the posterior cuff and pierce the posteromedial aspect of the humeral metaphysis, and terminates by crossing through the quadrilateral space to anastomose anteriorly with the AHCA.

The anterior circumflex humeral artery arises from the lateral surface of the axillary artery and runs laterally beneath the conjoint tendon over the anterior surface of the humeral neck to anastomose with the PHCA. Just lateral to the biceps tendon it gives off its main branch, the ascending branch, which runs superiorly parallel to the biceps tendon to provide blood supply to the tuberosities. Hence great care must be taken not to injure this branch when plating proximal humeral fractures. Within 5 mm of the articular surface, the ascending branch penetrates the cortical bone to become the arcuate artery (terminal branch); thought to be the major contributor of vascularity to the humeral head.[8]

As with all long bones, the humerus also has an intramedullary nutrient artery providing endosteal supply. This retrograde flow to the head is usually disrupted following minimally displaced fractures that traverse the humerus below the anatomical neck. The rich network of anastomoses and small branches maintain proximal humeral vascularity, and even with anatomical neck fractures avascular necrosis does not always ensue, especially if the medial hinge remains intact. It is thought that the medial capsular attachment also provides arterial supply to the head, hence why valgus impacted fractures tend to have a better prognosis.[9] The most accurate predictors of humeral head ischaemia are less than 8 mm of calcar length attached to the articular segment, disrupted medial hinge and anatomic neck fracture patterns.[10] Although these factors were found to be independent predictors of intraoperative humeral head ischaemia, a follow-up study from the same authors found this does not correlate with subsequent avascular necrosis.[11] In fact, avascularity of the humeral head (which can be determined by MRI or intraoperative drilling of the humeral head) does not correlate with the rate of fracture union or future avascular necrosis.

### Segments of the proximal humerus

The landmark paper by Codman in 1934 stated that fractures of the proximal humerus tend to occur through predictable lines, which correlate with lines of epiphyseal fusion.[12] The four major 'parts' he described are the humeral head, the greater and lesser tuberosities and the humeral shaft. His work set the foundation for the most commonly used classification systems in modern day trauma.

The humeral head has a dense plate of subchondral bone supporting the articular cartilage. This subchondral plate becomes thinner around the margin of the articular surface where the joint capsule attaches – defining the anatomical neck. Due to the transition of mechanical properties, fracture lines can propagate in this region making the humeral head a potential 'part' in fracture patterns. The capsule is thicker medially and often this is the only remaining attachment to the head fragment and can be a predictor of blood supply to the humeral head as previously stated.

The humeral shaft is a tube of thick cortical bone hence is also structurally strong. It expands proximally in the metaphyseal

region, and this transition in structural properties forms the most common site of fracture — the surgical neck of the humerus. The attachment of the pectoralis major tendon results in the shaft being pulled anteromedially (Figure 2). More proximally the greater tuberosity attaches the supraspinatus superiorly, the infraspinatus posterosuperiorly and the teres minor posteriorly. As a result the greater tuberosity is usually pulled posteromedially following a fracture. Anterior and medial to the bicipital groove lies the lesser tuberosity which attaches the subscapularis. A lesser tuberosity fracture displaces anteriorly. Although the bone of the tuberosities is thin, it is permeated by the Sharpey's fibres of the cuff insertions providing it with extreme integrity.[4]

Isolated tuberosity fractures are usually the result of a tension failure of the fragment due to rotator cuff contraction. In elderly osteoporotic patients, the energy transferred from a fall may result in more complex multifragmentary fractures. Apart from bone quality, the position of the limb and the amount of energy conveyed to the shoulder can influence fracture configuration.

## Classification

It was Neer in 1975[13] who first utilised Codman's original theory to develop a fracture classification that still remains the most commonly used to describe these injuries. He introduced the concept of fracture segments and emphasized that proximal humerus fractures can yield up to four distinct segments in varying configurations. However it is important to clarify that if there is little displacement between fracture segments then there is a much higher chance of union without avascular necrosis. As such, Neer stated that a fracture segment should only be considered a separate 'part' if there was more than 1 cm gap or 45° of rotation at the fracture site.[13] This is fundamental to the Neer classification and often misused — as even if there are fracture lines visible between the head, shaft and tuberosities, it is still considered to be a 'one-part' minimally displaced fracture unless there is displacement exceeding these criteria.

Two, three or four-part fractures could also be combined with a glenohumeral joint dislocation or an intra-articular (head-splitting) or impaction fracture[14]; adding further descriptive terminology. The Neer classification remains useful in modern day trauma as it allows orthopaedic surgeons to communicate and describe fracture patterns whilst also providing some indication about the long-term prognosis. Like all classifications it is not without its flaws, and studies have revealed it has a poor to fair inter- and intra-observer reliability[15] that increases with surgeon experience.

The more detailed AO Foundation/Orthopaedic Trauma Association (AO/OTA) classification[16] is based on fracture location and the presence of impaction, angulation, translation, comminution and joint dislocation. Although theoretically this classification system provides a more comprehensive overview of describing fractures, its complexity limits its usefulness. As a result the Neer classification still remains the most commonly used system.

### Two-part fractures

Only one segment is significantly displaced from the rest of the proximal humerus hence they can be distinguished as two-part greater tuberosity, two-part lesser tuberosity, two-part surgical neck and two-part anatomic neck fractures (Figure 3). Isolated greater and lesser tuberosity fractures usually occur following a shoulder dislocation due to tension failure with cuff contraction (Figure 4). They may reduce or remain displaced following shoulder reduction. Although they have the best prognosis with regards to avascular necrosis, displaced greater tuberosity fractures can heal in a malunited position and result in functional restrictions; as a result they are usually treated with open reduction and internal fixation.

Two-part anatomic neck fractures have a very high risk of avascular necrosis due to the compromised blood supply to the articular fragment; Neer suggested due to inevitability of avascular necrosis, these injuries should always be treated by humeral head arthroplasty. The two-part surgical neck fracture is the most common subgroup, with anteromedial displacement of the humeral shaft due to the pull of pectoralis major. Recent literature evidence and randomized controlled trials aimed to

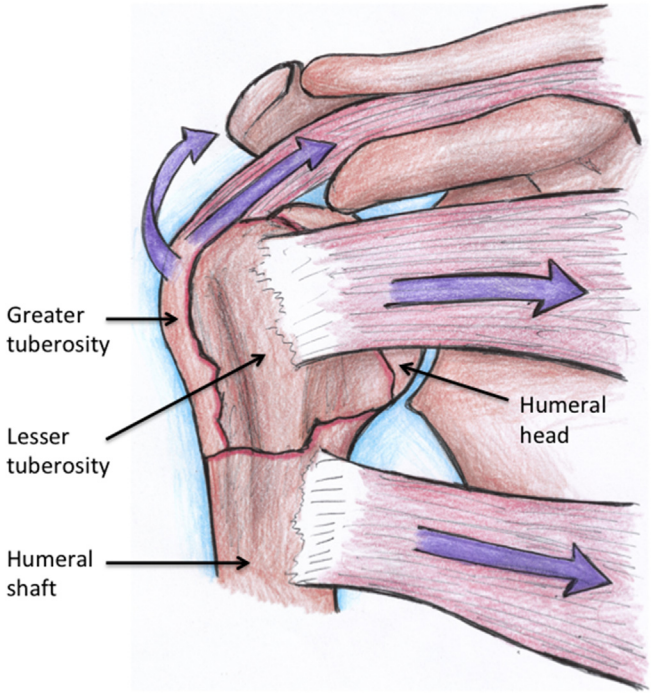


**Figure 2** Rotator cuff attachments result in the greater tuberosity being displaced posteromedially by the effect of the supraspinatus and infraspinatus muscles. The lesser tuberosity is displaced anteriorly by the subscapularis. The humeral shaft is pulled anteromedially by the pectoralis major.

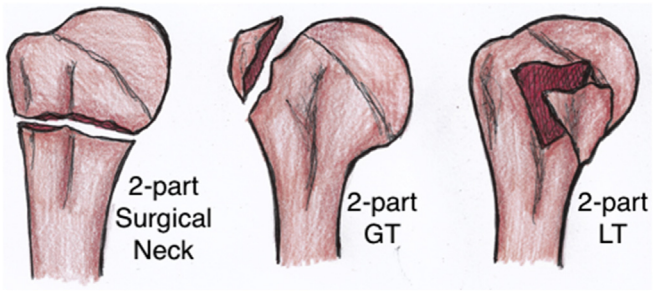


**Figure 3** Two-part fractures of the proximal humerus can involve the surgical neck, the greater tuberosity (GT) or the lesser tuberosity (LT).

**Figure 4** Radiograph showing a shoulder dislocation with a displaced greater tuberosity fracture, often requiring fixation if it remains displaced following reduction.

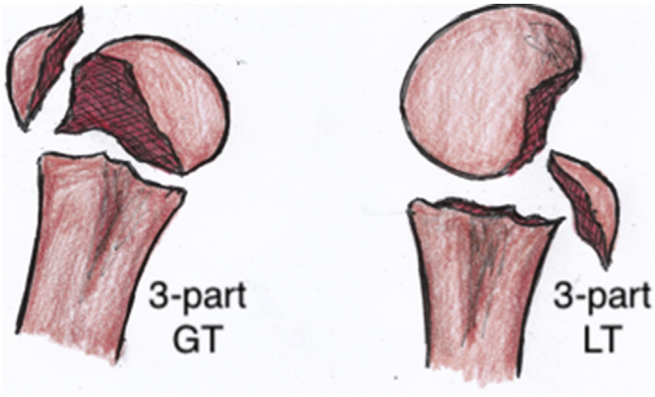


**Figure 5** Three-part fractures usually involve the surgical neck with a fracture of the greater or lesser tuberosity. The remaining cuff attachment dictates the resultant deformity of the head.

evaluate the ideal management of these injuries, which we will evaluate later.

### Three-part fractures

Although there are five possible configurations that could exist, Neer found that they almost invariably included a fracture of the surgical neck along with a fracture of the greater or lesser tuberosity (Figure 5). Depending which tuberosity remained intact; the residual rotator cuff attachment would dictate the rotational pull on the head fragment. In three-part greater tuberosity fractures, the humeral head is internally rotated by the pull of subscapularis. Conversely, in three-part lesser tuberosity fractures the humeral head is abducted and externally rotated by the pull of the supraspinatus and infraspinatus muscles. Although the head retains some blood supply from the residual tuberosity attachment and the medial capsule (as previously mentioned), this can be compromised if a dislocation occurs. Consequently in fracture-dislocations we consider replacement of the humeral head due to precarious blood supply unless patient factors dictate otherwise.

### Four-part fractures

In four-part fractures there is displacement of all segments with separation of the tuberosities and valgus or varus tilt of the humeral head (Figures 6 and 7). Although there is a more significant risk of avascular necrosis, theoretically there may be residual capsular attachment medially bringing blood supply to the humeral head. Apart from in young patients, where we aim to

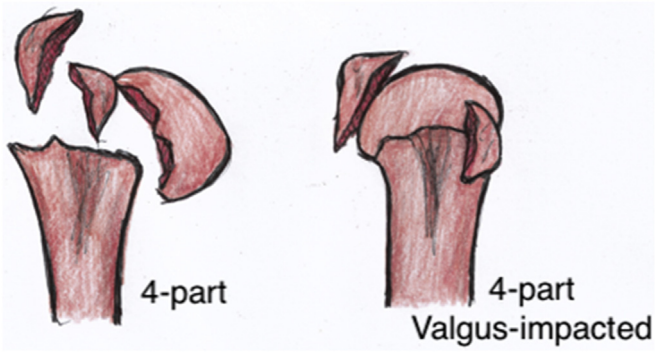


**Figure 6** Four-part fractures involve separation of all four parts, with either varus or valgus tilt of the humeral head.


**Figure 7** Radiograph showing a valgus impacted four-part proximal humerus fracture with displacement of both tuberosities.

fix these fractures to preserve the native humeral head; the majority have been treated historically with arthroplasty. Fixation was notably difficult until the advent of modern angular-stable locking plates, which do not collapse if avascular necrosis of the head does occur. Screw cut-out is a risk of fixation hence vigilant follow-up is required. Even if the head does collapse due to avascular necrosis, it is argued that fixation to restore the normal tuberosity anatomy places the cuff at an adequate tension and length so that future arthroplasty surgery is easier and likely to be functionally more successful.

### Head-splitting and other fracture patterns

The Neer classification includes the subtype of head-splitting and head impaction fractures. A head-splitting fracture is one where the articular surface of the head is split into two or more parts with displacement. Neer believed this subgroup would require humeral head replacement due to avascularity of at least one of the articular fragments. However in younger, active patients we might consider fixation as discussed earlier.

An impaction fracture describes an injury where the articular surface and underlying subchondral bone is crushed against the glenoid rim resulting in a depressed area. They may also warrant humeral head arthroplasty depending on their size and location. A Hill Sachs lesion is an example of an impaction fracture, but due to its posterior location they can usually be managed non-operatively unless large enough to cause recurrent instability. A reverse Hill Sachs lesion occurs anteriorly, due to impaction of the humeral head against the posterior glenoid rim during posterior dislocations of the shoulder joint. Depending on their size and symptoms of instability, they can be managed by fixing the subscapularis into the defect (remplissage) or osteotomizing the lesser tuberosity itself and fixing this into the defect (McLoughlin's procedure).[4]

### Hertel classification

So far we have discussed the Neer classification in depth, but Hertel developed an important classification system based on the 'parts' and fracture planes described by Neer and Codman. The importance of Hertel's binary or lego description system relates to the subsequent risk of humeral head ischaemia as mentioned earlier. Their work states that there are 12 potential fracture patterns; six resulting in two-part fractures, five resulting in three-part fractures and one single four-part fracture pattern (Figure 8). The most accurate predictors of humeral head ischaemia are less than 8 mm of calcar length attached to the articular segment, disrupted medial hinge and anatomic neck fracture patterns[10] where the head segment has no associated bony attachment (Figure 8; numbers 2, 9, 10, 11, 12).

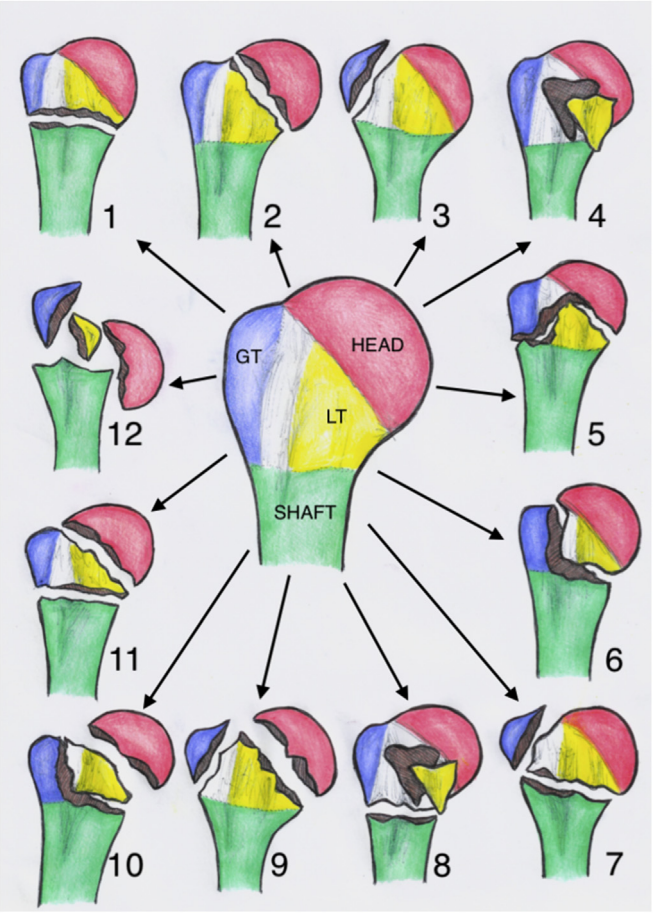


**Figure 8** Modified description of Hertel's binary or Lego description system for proximal humeral fractures, showing the 12 possible fracture patterns. GT, greater tuberosity; LT, lesser tuberosity.

## Clinical evaluation

Assessment of a patient suspected to have a proximal humeral fracture should begin with a thorough history and examination with special attention to nutritional status, osteoporosis, alcohol consumption, smoking and diabetes, which may be important for decision-making and long-term follow-up. As previously stated these injuries typically occur in the elderly following a low-energy fall. Assessing the patient's pre-injury functional status as well as occupation, hobbies and likely compliance with rehabilitation can help to guide subsequent management. Physical examination includes assessment of soft tissues for open fractures (particularly in the axilla) or skin tenting, concomitant upper limb fractures and evaluation of the neurovascular status of the limb paying particular attention to the axillary nerve. Although rare, injuries to the brachial plexus and vascular injuries should be ruled out. Fracture displacement, age over 50 years and brachial plexus injury are risk factors for a vascular injury.[17]

## Non-operative treatment

The majority of proximal humerus fractures are undisplaced or minimally displaced, low-energy injuries. Approximately 50% to 65% are minimally displaced fractures involving the greater tuberosity or surgical neck,[1] and as a result can be managed non-operatively with a low risk of future displacement, non-union and avascular necrosis.

For displaced fractures and more complex patterns, the decision-making process becomes more difficult. In the past, management decisions were based on radiographic parameters and fracture classifications. We have learnt however that the classification systems in use have moderate inter- and intra-observer reliability, as well as poor correlation with long-term

clinical outcomes.[15] Consequently decision-making in modern practice is usually dependent on patient characteristics, medical co-morbidities, functional demands and expectations. For an elderly patient with low functional demand, a reduced range of movement may not have a significant impact on their lifestyle. Hence it is important for orthopaedic surgeons to weigh up the options with the patient before initiating treatment. Younger patients with higher baseline shoulder function and expectations are the most common group where surgical intervention may be beneficial for displaced fractures.

A recent Cochrane review[18] of the management of proximal humerus fractures looked at 23 small randomized controlled trials, concluding that there was insufficient evidence to inform management of these injuries. They stated surgery, even for specific fracture types, did not definitively improve long-term outcomes but were associated with a higher rate of surgery-related complications and re-operations. However it is important to note that the Cochrane review does not cover the treatment of two-part tuberosity fractures, fractures in the young, high-energy trauma or rarer fracture patterns such as head-splitting and fracture dislocations.

Until recently, there was very weak evidence in the literature to guide management of displaced proximal humerus fractures. Studies often had no control group with relatively small patient samples, often containing predominantly simple (two-part) fractures with a potential selection bias effect. The aim of the PROFHER (Proximal Fracture of the Humerus Evaluation by Randomisation) trial was to conduct a pragmatic, multicentre, randomized controlled trial to evaluate the effectiveness of surgical versus non-surgical treatment for displaced proximal humerus fractures involving the surgical neck.[19] At 5-year follow-up, they found no statistically or clinically significant difference between operative and non-operative treatment of displaced two-, three- or four-part fractures. This study, however, included only a relatively small number of four-part fractures and reverse arthroplasty was not used in any of the patients randomized to surgery. Nonetheless, being a randomized, multicentre trial with an initial patient population of 250, it provides strong evidence towards non-operative treatment for most of these fractures, in light of the recent increasing trend towards surgical intervention. It remains to be seen whether the results of the PROFHER trial will have an impact on the frequency of operative interventions for this common group of fractures.

## Principles of non-operative management

The non-operative management of proximal humeral fractures begins with a period of immobilization. Several immobilization techniques have been described, which include a collar and cuff, a broad arm sling or polysling, or even a protective plaster 'U slab' in the acute setting where pain is a major factor. In theory a collar and cuff allows the natural weight of the arm to apply gravitational traction at the fracture site and maintain alignment, helping to reduce pain. It is argued that a broad arm sling or polysling, if overtightened, can actually displace the fracture by pushing the humerus proximally. However some patients find these slings more comfortable and supportive hence it is not uncommon to see them in use. Patients often struggle to lie flat due to the fracture pattern, so lying semi-reclined or in a chair can be suggested for the first few weeks until the pain subsides. Certain types of fractures tend to be less painful, such as minimally displaced and valgus-impacted patterns. As these fractures have greater inherent stability, often patients can commence early mobilization and speed up their rehabilitation protocol.

Irrespective of the type of immobilization used, it is vital to ensure close follow-up for these fractures with weekly radiographs to assess for signs of secondary displacement. This is particularly important for elderly patients, those with significant initial displacement and surgical neck fractures where instability can result in displacement and subsequent non-union. If there are no signs of union by 3 months, further imaging may be required.

It is essential that the period of immobilization be kept to a minimum; if excessive this will ultimately lead to shoulder stiffness. To some extent, there will always be an element of stiffness following a traumatic injury, but this can be minimized with early, directed physiotherapy. Hodgson[20] showed that 'immediate' (1 week) physiotherapy resulted in less pain and greater function in patients with undisplaced or stable fractures compared to immobilization for the first 3 weeks. Their population included 86 patients with two-part fractures treated with a collar and cuff. Constant scores were significantly better after 8 and 16 weeks, although there was no statistically significant difference in functional outcomes by 1 year.

Mobilization is usually commenced with active range of motion of the hand, wrist and elbow from the beginning, as well as simple pendulum exercises for the shoulder as pain settles down (Figure 9). They are performed by asking the patient to lean forward and hang the upper extremity freely, allowing gravity to assist shoulder movements. This can allow as much as 90° of forward elevation. As rehabilitation progresses, patients can commence active-assisted exercises under physiotherapy supervision or self-assisted (such as clasping hands or holding a stick with both hands, allowing the unaffected upper extremity to

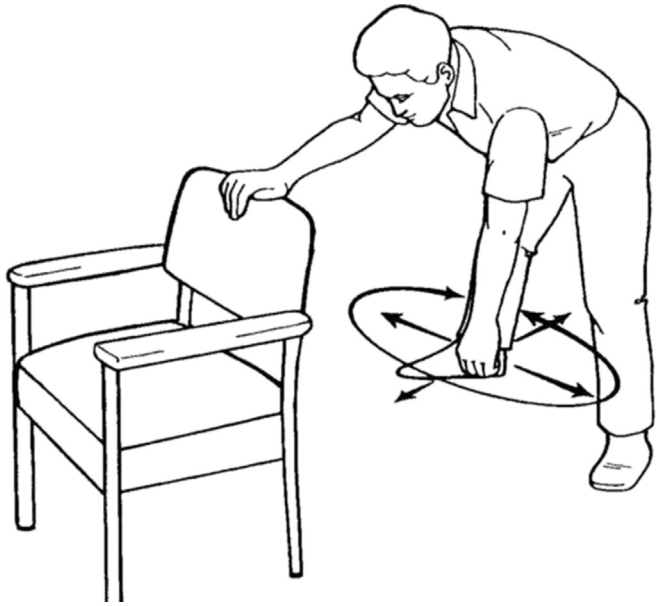

**Figure 9** Pendulum exercises can be commenced early during rehabilitation to mobilize the glenohumeral joint without causing excessive displacement of the fragments.

assist the injured side). There is evidence indicating little difference in outcomes between instructed home-exercise protocols versus supervised physiotherapy,[18] but an initial therapy session can be a useful aid for patients by instructing them how to perform these exercises.

As the fracture begins to heal and radiographs show signs of callus, mobilization can be increased to active movements and by 6 weeks patients can usually commence strengthening exercises. This may include elastic band resistance and light weights, guided by the patient's clinical progress. Fracture healing can be assessed by rotating the distal humerus at the elbow and feeling for the proximal humerus to rotate 'as one' fragment. Once radiographic union is confirmed, patients can be pushed further to try and regain as much movement as possible. However they should be advised that final range will often not be attained until 12–18 months following the initial injury, although this can be attaheived earlier with good rehabilitation and patient compliance.

## Conclusion

Proximal humeral fractures are one of the most common types of fracture seen by orthopaedic surgeons, usually occurring in elderly, osteoporotic patients following a fall from standing height. There was historically limited high-quality evidence in the literature to guide the management of these injuries until more recent randomized controlled trials have shown no statistically or clinically significant difference in medium to long-term outcomes between surgical and non-surgical management, even in more complex fracture patterns. Non-operative management usually involves a period of immobilization and once comfortable, early rehabilitation is commenced starting with pendular exercises and gradually building up to active range of movement and strengthening by 6 weeks. ◆

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