

## TRAUMA

# Management of complex proximal humerus fractures in the elderly: what is the role of open reduction and internal fixation?

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### Abstract

The ultimate goal of management of proximal humeral fractures in the elderly patient is to get the patient independently mobile. This article will review the current literature regarding this cohort of patient. Recent Cochrane reviews and a large multicentre randomised study question the role of surgical intervention. Implant design is evolving rapidly, and many elderly patients now behave more like the younger patient. There remains little compelling evidence to guide decision-making for the complex proximal humeral fracture in the elderly, and the decision needs to be made on a case-by-case basis taking into account the patient's comorbidities, the fracture pattern and characteristics, the attending surgeon's skill sets, and the availability of equipment.

**Level of evidence:** 5

**Key words:** proximal humerus fracture, fragility fracture, osteoporosis, implant evolution, internal fixation

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## Introduction

The ultimate goal of management of proximal humeral fractures in the elderly patient is to get the patient independently mobile. This relies on a multidisciplinary team approach in which operative intervention may or may not be indicated.

Elderly patients may not tolerate prolonged immobilisation, and in addition, sling immobilisation affects balance and may increase the risk of falling.

Fixation of osteoporotic bone is different to that of physiologically normal bone. Fracture healing takes a longer time, the implant fixation in the bone is compromised, and fracture patterns may be more complex, with surgery becoming more technically demanding. This combination of factors may lead to progressive failure at the bone implant interface, implant migration and fracture displacement.<sup>1,4</sup>

Indications for surgery vary a great deal from study to study, and are often ill defined. Identification of risk factors for poor outcomes is important, including the identification of poor bone mineral density and the possibility of developing avascular necrosis.

## Incidence

There is an increasing incidence of proximal humerus fracture rates and a decline in hip fractures in patients over 50 years of age.<sup>5</sup>

Proximal humerus fractures are reported to be the third most common osteoporotic fracture excluding spine and the second most common upper extremity fragility fracture. It is reported that 73% occur in females.<sup>6,7</sup>

In a recent prospective study of 5 147 women with osteoporotic fractures, undisplaced proximal humerus fractures comprised 17.5% and were the third most frequent fracture after distal radius and vertebral fractures. Patients over the age of 70 years showed a decrease in the incidence of distal radius and vertebral fractures, but not proximal humerus fractures.<sup>8</sup>

## Osteoporosis

Osteoporosis results in altered microarchitecture and a decreased bone mass which is caused by an imbalance in the bone resorption and formation. In addition, there are intrinsic changes such as altered collagen cross linkage and distribution of mineralisation which contributes to the decreased bone strength and modulus of elasticity. The resultant increased bone fragility increases fracture risk. Stiffness of bone alters by 1–2% per decade, and the strength of bone decreases by 2–5% per decade. The energy required to cause a fracture decreases by up to 10% per decade over the age of 35 years.<sup>9</sup>

Osteoporosis is the most common bone disease in the US.<sup>10</sup> The costs relating to management of osteoporotic fractures is significant, and these fractures are an important cause of morbidity and mortality.

The diagnosis of osteoporosis is largely based around hip and spine bone mineral density, and the diagnostic criteria in relation to proximal humerus fractures is less clear.<sup>11</sup>

A proximal humerus fracture may be the presenting complaint in a patient with osteoporosis, and allow its diagnosis. This opportunity should not be missed.

There is a six-fold increased risk of developing a hip fracture in the first year after a proximal humerus fracture.<sup>7</sup>

Bisphosphonate treatment has been shown to reduce the risk of a fragility fracture by up to 70% in patients with osteoporosis.<sup>12,13</sup> Despite this, the initiation of anti-osteoporosis treatment following upper limb fragility fractures is low.<sup>8,14</sup>

This is in contrast to the reported increased initiation of treatment in patients who suffer vertebral or hip fracture.<sup>15</sup>

This implies that patients with osteoporotic proximal humerus fractures are an important group to identify and manage.

The disease burden of osteoporosis is large both in terms of the impact on the individual, and the cost to society. Managing these patients appropriately may enable a reduction in the risk of subsequent fragility fractures, and improve the individual patients' quality of life.

As indications for management, including surgery, vary a great deal, a comprehensive classification system is required.

Many clinical studies base their indications on the amount of displacement as defined by Neer in 1970.<sup>16,17</sup>

Other studies have a lower threshold for surgical fixation with indications including 0.5 cm of tuberosity displacement, medial metaphyseal comminution<sup>18</sup> or humeral head angulation of >30°,<sup>19</sup> and although it has been suggested in some studies that operative management is the preferred method of treatment in displaced fractures, with conservative treatment resulting in 'consistently inferior results',<sup>1</sup> there is much evidence against this.

Studies have shown that the surgeon's interpretation of displacement was variable and arbitrary<sup>20</sup> and the benefit of surgery over conservative treatment has been questioned.<sup>20,21</sup>

## Classification

Neer's modification of Codman's classification relies on identification of four potential parts and their displacement (shaft/articular surface/greater tuberosity/lesser tuberosity).

Despite poor intra- and inter-observer reliability, it remains the most commonly utilised classification system.

More comprehensive classification systems have been developed, including the morphological system by Hertel,<sup>22</sup> but their usage in clinical practice remains limited.

## Management options

As mentioned, the management options include non-surgical and surgical modalities, and we ideally need to know if the bone quality is sufficient for internal fixation to support and maintain fracture reduction. Indices utilising the cortical thickness of the proximal humerus on plain radiograph have been validated to predict both local and general decreased bone mineral density.<sup>23,24</sup>

The cortical index<sup>24</sup> is a ratio of medial and lateral cortical thickness to total humeral width measured at 10 cm distal to the tip of the greater tuberosity. The cortical bone thickness average (CBT avg)<sup>23</sup> takes measurements of the combined cortical thickness (medial and lateral cortical thickness) at two levels and averages them. The initial level of measurement is the most proximal point on the humeral shaft where the medial and lateral cortices are parallel and the second level is 20 mm below that. These measurements have been shown to be easily reproducible on simple anteroposterior radiographs of the proximal humeral shaft.

A recent advance is the ability to quantify the bone mineral density using CT scan evaluation of the proximal humerus.<sup>25</sup> It was found that a bone mineral density value of 95 mg/cm<sup>3</sup> was the cut-off, below which implant failure was likely to occur. As many centres use CT scan as part of the pre-operative workup, these recommendations could have useful practical implications.<sup>26</sup> The mode of failure in osteoporotic bone is more likely to be failure of the bone than of the implant itself.

Factors which predispose to internal fixation failure in the proximal humerus include low bone mineral density, varus malreduction, avascular necrosis, poor medial column restoration and non-anatomic reduction.<sup>27</sup>

The options available for the surgical management of the proximal humerus are many and varied, which in itself is an indication of the technical difficulty and variable outcomes of each modality.

Anatomical fixed angle plates, intramedullary nails, minimally invasive screw or wiring constructs and arthroplasty (both hemi and reverse) have all been described. In addition, fixation may be augmented with bone cement, intramedullary fibula strut grafts or cortico-cancellous iliac crest grafts.

### K-wires

The benefit of K-wire fixation after closed reduction is that there is relatively little surgical insult and exposure, and minimal soft tissue damage. This may reduce the risk of avascular necrosis.<sup>19,28</sup> However, the thin cortices may not provide enough purchase for fixation, and loss of reduction may ensue.<sup>28</sup> Resch *et al.* describe a technique utilising the humerus block to provide lateral fixation and angular stability to the K-wires<sup>29</sup> and it is felt the relative stability achieved may in fact be an advantage in osteoporotic bone where rigid implants can cut out, or promote non-union. This technique relies on soft tissue bridging between the fragments, and appears to be more suitable for valgus impaction fractures.

Resch himself reports good results in three-part fractures, but in four-part fractures this is a technically demanding technique and is not widely employed.<sup>19</sup>

### Plates

Since the introduction of locked plate technology (angular stable constructs) the rate of fixation of proximal humeral fractures has increased.

Although the majority (84%) of fractures are managed conservatively there has been a relative increase of 28.5% of fractures that underwent open reduction and internal fixation (ORIF) between 2004 and 2005 when compared to 1999–2000.<sup>30</sup>

It is worth noting that the rate of revision surgery has increased as well.

This increase may not be related only to advances in technology, as other factors such as patient and surgeon expectations and the fracture patterns related to active lifestyles may also have contributed to this increasing surgical trend.<sup>28</sup>

Fixed angle anatomic locking plates have become the most commonly utilised implants for fixation of proximal humerus fractures.<sup>20,31</sup>

The mode of failure of locked plates differs from conventional plates which will fail by the loosening of individual screws sequentially whereas locked plates will fail by simultaneous cut-out of multiple screws or by fracture of the bone at the stress riser at the end of the plate.<sup>32</sup>

It has been shown that good restoration of support to the inferomedial calcar is important in maintaining fracture reduction.<sup>33-35</sup>

Early loss of reduction remains a problem and was noted in 22.5% of cases, with a strong correlation to the amount of impaction, female sex, and metaphyseal comminution.

This highlights that surgical technique and implant placement are important. The screws should be placed in such a way so that they gain as much purchase as possible in subchondral bone.

After reduction of the osteoporotic fracture, a residual cavity is often created. Some authors advocate the use of adjuncts to fill this defect. Calcium phosphate and bone graft (cancellous or fibula strut) have been used. Attention to reduction technique may limit the size of the resultant bone defect.<sup>2</sup>

Early good results with locked plates<sup>17</sup> were tempered by studies reporting complication rates as high as 21%,<sup>18</sup> and even as high as 37%,<sup>36</sup> with a 20% re-operation rate.

All the studies seem to report worse outcomes with four-part fractures, and it appears that two-part fractures tend to do well.

The variation in indications for surgery and the type of fractures managed in most of these studies makes comparative interpretation of the reported results challenging.

The proximal humerus plate has gone through a number of evolutionary changes in an attempt to improve the outcomes. The initial clover leaf plates did not have angular stability and have been replaced by fixed angle locking plates with divergent screws, low anatomic profiles, suture holes for the attachment of tension band sutures and rotator cuff sutures, and now variable angle locking screw options, medial calcar support screws and cannulated screws to allow delivery of cement into the fracture site.

New technology continues to be introduced with the latest being investigation into the use of different materials such as PEEK (polyetheretherketone) plates. PEEK has a modulus of elasticity much closer to bone than titanium or stainless steel, and it is postulated that this material will allow the development of a plate with the benefits of angular stability for the screws, but reduced implant stiffness to reduce the stress riser affect and allow biological healing of the fracture.<sup>37</sup>

As an adjunct to fixation with plate or nails, tension band suture fixation of the rotator cuff and tuberosities has been shown to improve outcomes.<sup>38-40</sup>

### Nails

In general, the surgical management of insufficiency fractures is best achieved by an implant that is load sharing. The intramedullary nail is such a load-sharing device. In addition, the more medial position of the implant, shorter lever arm in the humeral head, and better preservation of blood supply, soft tissue and periosteum would infer that this is the better implant to utilise. However, there are problems associated with its use in osteoporotic bone and insufficiency fractures because the fracture configuration is often complex and unstable with comminution of the lateral cortex, which may lead to secondary displacement and failure. Post-fixation shoulder pain related to damage to the rotator cuff insertion and impingement remains an unsolved issue.<sup>9,41-43</sup>

A recent meta-analysis concluded that although satisfactory clinical results can be achieved utilising nails in two- and three-part fractures of the proximal humerus, re-operation rates were 15.8% and complication rates were as high as 42.5%, 28% of which were related to loss of reduction, screw perforation or malunion. In four-part fractures the re-operation rates were as high as 63.2%, and there were 29 complications in 33 patients. They concluded that the use of intramedullary nails 'for four-part fractures cannot be recommended'. In this meta-analysis, there was no study that included a non-operative control group and only 33 of a total of 448 patients had four-part fractures which were managed with intramedullary nails. This probably is a reflection that the general orthopaedic community is in agreement with their conclusions.<sup>44</sup>

Good outcomes have been reported for fracture fixation with intramedullary nails but elderly patients tend to have poorer functional results and increased complications.<sup>45</sup>

Nail design may impact on outcomes as straight nails have been shown to have better outcomes in terms of range of motion than curved nails, and the more medial insertion addresses the lateral cortex comminution better.<sup>46</sup> There is, however, no statistical difference in the outcomes in a recent randomised controlled clinical trial comparing curved to straight nails.<sup>47</sup>

The use of threaded bushings to minimise screw back-out and provide more angular stability in osteoporotic bone has been proposed.<sup>43</sup>

One of the most important goals of proximal humerus fracture fixation is to restore the medial calcar to prevent varus collapse. New generation nails are starting to incorporate more distal locking screws or a blade to support the medial calcar to prevent this mode of failure.<sup>1</sup> The distal screw constructs may, however, put the axillary nerve at risk.<sup>48</sup>

The design of intramedullary proximal humeral nails has advanced a great deal recently in recent years. Modifications have included:

- straighter nails
- nylon bushings and end caps to confer angular stability
- more distal screws and blades angled superiorly
- suture anchor points on the screw or blade heads
- varied and divergent proximal screw placement.<sup>41</sup>

Comparative studies of plate versus nail fixation have been performed. A recent study testing the biomechanics in sawbones shows higher stiffness and load to failure in nails over plates,<sup>43</sup> but this does not take the soft tissue repair into account. Clinical studies including large meta-analysis and Cochrane reviews have found little to support one over the other, and both appear to be viable options in the two- and three-part fractures, although four-part fractures may require a different approach.<sup>49</sup>

## Augmentation

Many different augments have been used in an effort to optimise the fracture stability, fill defects and promote anatomic healing. This is largely driven by the complications of implant failure and loss of reduction seen in all the surgical options. The most common augments utilised currently are fibula strut grafts, calcium phosphate and PMMA (polymethyl methacrylate) cement.

Implants have been adapted and designed to accommodate these augments, such as the perforated cannulated screws and blades to allow for the delivery of cement to the screw tips and humeral head defects.

Anteromedial and anteroinferior screws have been shown to have the lowest breakaway torque and provide the greatest resistance to displacement when two of these screws are used for augmentation.<sup>50,51</sup>

Biomechanical studies have shown that a corticocancellous bone block contributes to the stability of two-part fractures with a medial fracture gap by increasing the stiffness and load to failure.<sup>52</sup>

In-vitro studies have shown that filling the fracture void with calcium triphosphate cement using PMMA augmentation with plates and nails decreases the risk of screw pull-out and loss of reduction.<sup>53-55</sup>

Fibula struts show promise, although clinical studies in the current literature are of a small sample size.<sup>56,57</sup>

Femoral head allograft augmentation has shown similar results in a group of ten patients, with an average post-op constant score of 72 at 28 months, and one non-union (10%).<sup>58</sup>

Although clinical results are promising, these techniques are not without complications,<sup>59</sup> and there are no studies with a control group to allow for comparison. This makes the interpretation of results difficult.

Concerns regarding late removal of implants following the use of augments such as bone cement appear unfounded.<sup>60</sup>

Bone morphogenic proteins and biomaterials may become useful adjuncts as BMPs are thought to be involved in the development of osteoporosis, but at this stage the literature is limited to preclinical trials.<sup>61</sup>

It seems that current opinion will concur that it does not matter what technique of fixation is employed, or which augmentation method utilised. Good outcomes will still rely on anatomic reduction of the tuberosities and the humeral head.

No amount of augmentation or implant evolution will compensate for poor surgical technique.

The recommendation of the recent reviews is that medial support screws should be used in all cases as they seem to confer improved biomechanical stability by supporting the medial calcar and do not add to the surgical insult.

With regard to augmentation, there is insufficient evidence to support their use, although they do appear to have a stabilising effect.<sup>62</sup>

## Soft tissue

Attention to the status of the soft tissue, and meticulous closure and dressing care in the elderly patient with thin skin is important, and the decision and timing of surgery must take this into account.

## Arthroplasty

A full discussion on the use of arthroplasty in the treatment of proximal humerus fractures is beyond the scope of the title of this article, but as this is a developing option a few points must be mentioned.

There is a documented increase in the use of primary arthroplasty to manage the complex proximal humerus fracture and as with plate and nail fixation, good results have been shown to rely on healing of the tuberosities in an anatomical position. This is particularly relevant when it comes to the use of hemiarthroplasty.

There has been a steadily increasing use of the reverse shoulder replacement in an attempt to bypass the requirements of tuberosity healing in fractures treated with hemiarthroplasty.<sup>30,63</sup>

As with the other treatment modalities the latest Cochrane review does not find enough evidence to recommend the use of one modality over the other, nor is there enough evidence to advise arthroplasty over conservative treatment.

Our opinion and anecdotal findings are that patients often experience good early pain relief and mobility following reverse shoulder replacement, obviating the need for sling immobilisation and the complications associated with this in the elderly.

The reverse shoulder replacement is also a useful salvage option in cases of failed fixation or hemiarthroplasty.<sup>64</sup>

There is little evidence to guide the timing of reverse shoulder arthroplasty, but one small retrospective study found that the use of the reverse shoulder arthroplasty as a primary procedure (rather than as revision for hemiarthroplasty or internal fixation) yielded better results. There was no significant difference in the outcomes if the reverse shoulder replacement was done for the acute fracture or for the treatment of a symptomatic malunion.<sup>65</sup>

## Conservative treatment

This review would be incomplete if we did not report on the results of conservative treatment.

A recent Cochrane review concluded that 'there is high or moderate quality evidence that, compared with non-surgical treatment, surgery does not result in a better outcome at one and two years after injury for people with displaced proximal humeral fractures'. It is however 'likely to result in greater need for subsequent surgery'!

This finding was based on eight studies comparing outcomes between surgical and non-surgical groups but was dominated by the ProFHER study.

These findings excluded fractures as a result of high energy trauma, two-part fractures involving the tuberosities, fracture dislocations and head splitting fractures. It also found insufficient randomised control trials to support a particular choice between different non-surgical or, when indicated, surgical interventions.<sup>21</sup>

The ProFHER study is a multicentre randomised clinical trial to assess the difference in outcomes between patients with proximal humerus fractures managed non-operatively and those managed surgically. Patients included were those with proximal humerus fractures involving the surgical neck where the attending surgeon would have considered surgery. As mentioned, exclusions included, among others, fractures isolated to the tuberosities, head splitting fractures, fracture dislocations, and open fractures or fractures with severe soft tissue injury which would preclude operative treatment. Patients with significant medical comorbidities who could not tolerate anaesthesia were also excluded.<sup>20</sup>

The results showed no difference in outcomes at six, 12 or 24 months between the surgical and non-surgical groups, and in contrast to the Cochrane review of 2012, there was also no difference in the complication rate and the number of patients requiring later surgical intervention or revision.

There were relatively small numbers of four-part fractures in either group, which will make recommendations in this subgroup of patients difficult.<sup>20</sup>

Will this change our treatment strategy?

With the large variation in fracture types in this study there might well be subgroups that do clearly benefit from surgery, but these remain unidentified.<sup>66</sup>

## Conclusion

There appears to be a growing body of evidence that these fractures can and often should be managed conservatively. Two recent Cochrane reviews and the ProFHER randomised study found that surgical management did not confer better outcomes over conservative treatment. While this does not mean that surgery is contraindicated, it does make the patient selection for surgical intervention more difficult.

To complicate matters further, there is little evidence to support one surgical modality over the other.

This, combined with the number of new implants being developed and the industry-(market) driven pressures to use these implants (sometimes with little adequate clinical proof), makes decision making for the orthopaedic surgeon even more complex.

There remains little compelling evidence to guide decision making for the complex proximal humeral fracture in the elderly, and the decision needs to be made on a case-by-case basis taking into account the patient's comorbidities, the fracture pattern and characteristics, the attending surgeon's skill sets, and the availability of equipment.

It remains our opinion that too many of these fractures are undergoing surgical fixation unnecessarily.

That said, many elderly patients will not tolerate conservative treatment and sling immobilisation, and many are presenting with fracture patterns resembling 'young, high energy injuries' due to increased activity and longevity.

The decision to operate should then be made after discussing the pros and cons with the patient and their family.

## Ethics statement

This article does not contain any studies with human or animal subjects performed by any of the authors.

## Declaration

The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies.

## Author contributions

It was a combined project, with each author providing literature review and equal input.

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