
CLINICAL ARTICLE

Surgery for displaced three- and four-part proximal humeral fractures: the rationale for our approach

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Abstract

There are a multitude of different surgical techniques described, practised and reported to have similar outcomes for displaced proximal humeral fractures. This paper reviews the outcomes of these techniques and the reason for using the different options; it also reviews the factors which affect outcomes. It will outline our decision-making process to justify the management of these fractures at the University of Cape Town.

Introduction

Proximal humeral fractures account for 4% to 5% of all fractures and the prevalence has been increasing over the last decades with no clear evidence for this.¹ Older women are twice as likely to sustain these fractures.¹ These patients have a higher incidence of osteoporosis. Thankfully 85% of proximal humeral fractures can be successfully managed by conservative means as seen in several series.²⁻⁵

Locking plate technology has been introduced to deal with this thinned cortical and trabecular bone and is hopefully the answer to the poor results which have occurred in the internally fixed osteoporotic fracture.⁶

The risk of avascular necrosis is the other complication of these fractures which may dictate the management.

Classification

Neer's modification of Codman's classification system for these fractures is well known and widely used with its straightforward description of parts and displacement.⁷ It has been well documented that there is difficulty in implementing this classification for fractures from plain radiographs, and even with the additional information of

computerised tomography (CT) there still is inter- and intra-observer error.⁸ Improvement in reliability and alternative classifications have been proposed by several other authors including Hertel.⁹ But a 3-D CT scan classification by Edelson has been taken further by Emery into an actual physical 3-D reconstruction model which allows a better understanding of the fracture displacement in three dimensions. This may allow improved reduction manoeuvres as they can be practised on the models.¹⁰

The reproducibility of using the classifications impacts on the ability to compare series and outcomes, especially when there is no clear consensus on which fracture type is being treated.

Osteoporosis

As mentioned above fracture fixation in patients with fragility fractures has generally had poor results.

The majority of these fractures occur in those patients at risk for osteoporosis, i.e. elderly females.¹¹ The humeral head loses bone in the central and lateral aspects,¹² with the best bone for screw purchase being in the inferior medial subchondral bone.¹³ Therefore to get good screw purchase the screws have to be as close to the articular surface as possible.



Figure 1: Dorsomedial spike on the humeral head of greater than 8 mm

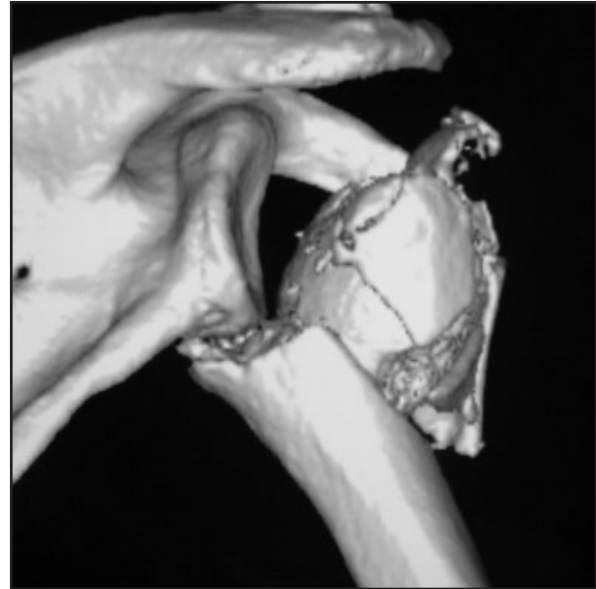


Figure 2: No dorsomedial spike and disrupted medial hinge

Screw cut-out is a real problem and the need to put the screw subchondrally may lead to screw cut-out complications as seen in 23% of patients operated at the Rochester Medical Centre with locked plates.¹⁴

The anatomical aspects of the osteoporotic head also suggest that nails which enter through the lateral superior aspect of the head have less purchase in this area of least bone density.

Tingart has shown that the cortical thickness of the proximal humeral diaphysis predicts bone mineral density of the proximal humerus so as to give the surgeon an idea of the type of bone he/she is dealing with.¹⁵

Avascular necrosis (AVN)

Avascular necrosis is one of the consequences of proximal humeral fractures that influence the outcome and therefore the decision-making in their management. AVN is not the cause of the poor outcome but rather the resultant collapse, if it occurs. The reported incidence of AVN is variable but is between 12% and 34% in Neer type 3 fractures and 4% to 59% in type 4 fractures.

Hertel has given us predictors of humeral head ischaemia. These are a dorsomedial metaphyseal extension of less than 8 mm (accuracy 0.84), integrity of medial hinge (accuracy 0.79), and basic fracture type (accuracy 0.7) with a 98% accuracy if the first two are present. Poor predictors for ischaemia were the number of parts and the displacement of the parts. The presence of a dislocation was also a poor predictor¹⁶ (*Figures 1 and 2*).

The same author reports that the presence of ischaemia does not predict the development of AVN, as they had patients developing AVN with perfused heads, while ischaemic heads did not go on to develop AVN.¹⁷

Patients appear to tolerate AVN well if there is no collapse. However, if they develop collapse the functional outcome is reduced. Once again some of these patients tolerate the collapse better than others and require no further surgery (*Figure 3*). Gerber also found that the results were worse if malunion occurred in the face of AVN. AVN associated with reduced healed fractures had similar functional results to those that had a primary arthroplasty for their fracture.¹⁸

Revision surgery for malunion or non-union has worse outcomes than revision surgery for AVN with collapse.^{19,20}

Neurological injury

Sixty-seven per cent of patients have evidence of neurological injury on EMG. Fifty-eight per cent involve axillary nerve and 48% the suprascapular nerve, with many having combined injuries. Fortunately nearly all recover. These not only occur in displaced fractures but have also been seen in undisplaced fractures.²¹

Osteosynthesis

Percutaneous pinning

The supposed advantage of pinning the humerus percutaneously is less soft tissue stripping and possible preservation of the blood supply. Professor Herbert Resch quotes the German literature which shows closed reduction lowers the AVN rate and his own rate was only 9%. Although they had no iatrogenic neurological injuries, they voice their concerns regarding the possibility of one. Cadaver studies have shown that the axillary nerve is at risk, as well the biceps tendon and cephalic vein.²² Rowles recommends specific landmarks and manoeuvres to reduce the risk.²³



Figure 3: Ischaemic head in four-part fracture at surgery, follow-up X-ray with AVN and clinical result

The surgical results from three different countries (Austria, USA, France) were presented at The 2008 Nice Shoulder Course – Proximal Humeral Fractures and Fracture Sequellae. Resch who presented his series of 153 cases of minimally invasive surgery found acceptable results in 80%. Thirteen per cent lost reduction. The other series were considerably smaller and they reflect the literature with satisfactory results. The complication rates of pin migration, penetration, pin tract sepsis and AVN was reported to be between 2% and 26%.^{24,25}

The concern with the technique is pin migration especially in osteoporotic bone, which is found in the majority of fractures. The pins need to be buried to prevent sepsis. The pins need to be 2.5 mm and terminally threaded to prevent migration and breakage. The patient needs to be compliant so that removal can be performed 3 to 6 weeks later. They also need to comply with the period of immobilisation required.

There is a significantly longer period of exposure to radiation during the reduction and pinning of these fractures. The procedure is not recommended in patients with comminuted tuberosities and osteoporosis for obvious reasons. It does however have the advantage of not having to remove hardware especially if a joint replacement is needed later.

Locked plates fixed or angle stable plates (Figure 5)

This form of fixation was introduced to try and counter the loss of fixation occurring with the use of standard plates in patients with osteopaenia.²⁶ The terminology may cause debate as many surgeons prefer calling the plates fixed angle plates with locking mode, as locking screws are not always necessary.

Three major series were presented at the The Nice 2008 Shoulder Course – Proximal Humeral Fractures and Fracture Sequellae.

Eklund presented the results of a European multicentre study of 158 fractures fixed with a locked plate. All fractures united. Nine per cent had implant-related complications. Thirty-five per cent had non-implant complications. Thirty-five patients had primary or secondary screw penetration. The AVN rate was 8%, five lost reduction with one requiring surgery. Older patients and those with higher fracture types had more complications.

Kempf presented the French experience in 73 patients. Thirteen per cent had screw cut-out or malposition; 8% had loss of reduction; and 16% developed AVN.

The German experience presented by Lill described 14% having primary implant malposition and another 14% late displacement. Twenty per cent developed AVN, infection, non-union and heterotopic bone. The deltopectoral approach was compared to a deltoid split in a prospective study by the same presenter. There were better results in the deltopectoral group at a year follow-up (presented at The Nice Shoulder Course 2008 Hepp P, Lill H *et al.* JSES in press).

A summary of the data presented reveal 60% to 80% have good outcomes. Complications occur in 20% to 50% and are both implant and non-implant related. Revision surgery occurs in 10% to 30%. Outcomes are related to tuberosity reduction and the development of complications.

A literature review by David Ring of published results and complications reflects those at this meeting.²⁷

Kevin from Rochester followed up 53 patients with this plating method for a year. Thirty-six per cent had radiographic signs of a complication; screw cut-out with intra-articular displacement in 23%; varus displacement in 25%; and osteonecrosis in two (4%). These were more likely to occur in patients over the age of 60 years. They could not associate the predictors of humeral head ischaemia with the complications.¹⁴

The concern with screw cut-out is when there is settling of the head or AVN with collapse, the screws are fixed to the plate and they can go nowhere but into the glenoid. Therefore long-term follow-up is needed as AVN collapse can occur many years after the injury.

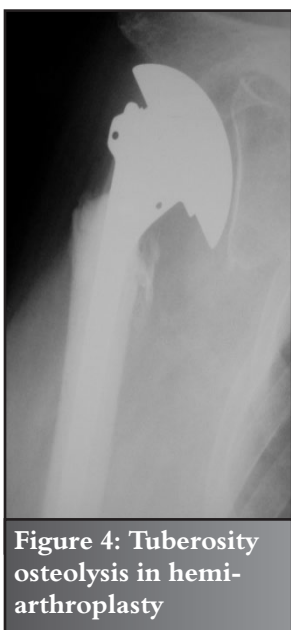


Figure 4: Tuberosity osteolysis in hemiarthroplasty

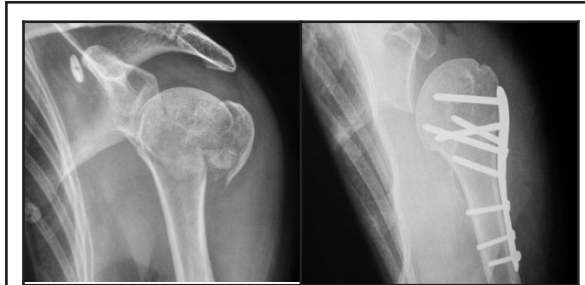


Figure 5: Plating of a three-part valgus impaction fracture

Intramedullary nails

Intramedullary nails have the advantage of combining competitive fixation strength while possibly decreasing the risk of further devascularising the fragments. The technique has the added advantage of addressing associated diaphyseal fracture extension or segmental fractures more elegantly.

The disadvantages are that the rotator cuff is violated and there is a higher risk to the axillary nerve. Most nails have a proximal bend which advocates insertion through the tuberosity which reduces the cuff footprint and therefore rotator cuff strength with residual cuff deficiency. Impingement due to the nail left proud is a well-known complication.

Prince has identified that risks to the axillary nerve are higher in the spiral blade technique and when the angle of the screw is oblique. He also states the nerve should not be injured if the arm is in neutral and the screw is placed less than 5 cm from the acromion.²⁸

There was a high incidence of screw back-out with initial nails, but these are being addressed with the newer nails having locking options in the nail.²⁹

Biomechanically the nails are now being compared to locking plates and other forms of fixation with similar outcomes and complication rates.³⁰

Cuny presented the French experience at the Nice Shoulder Meeting 2008, but he has also published results in 67 patients using the telegraph nail.³¹ There were good outcomes in the two-part neck fractures and valgus impacted fractures. Thirty-one per cent required some form of hardware removal; eight had the nail impinging subacromially and needed removal; 18% of the valgus impacted fractures developed AVN, while 37% of the more severe fractures developed AVN.

Arthroplasty

Neer's original results with these fractures have been hard to reproduce.³² If consistently reproducible results were obtained I think there would be less debate regarding the management of the difficult fractures at risk of AVN. The relief of pain is reproducible but the range of motion is less predictable.

A humeral head replacement is used when the fractured head is not reconstructable. No other surgical option is really available other than excision, arthrodesis, conservative treatment or possibly humeral head allograft, none of which are desirable when the option of a humeral head is available.

The other reason for replacing the head is when the risk of AVN is high enough to predict AVN and secondary collapse requiring a second operation in the future, and the second operation is undesirable as for example in an elderly patient with co-morbidities. Revision surgery outcomes are never as good as first time successful surgery.

As in the plating group malunion is a problem with diminished functional scores. Non-union and osteolysis of the tuberosities are more of a concern than in the plated groups (*Figure 4*). One of the reasons proposed is that many of these are done by non-dedicated shoulder surgeons who may do a small volume of these cases. Better outcomes are seen in series done by dedicated shoulder units.

The relief of pain is reproducible but the range of motion is less predictable

Outcomes are directly affected by tuberosity union and position. Boileau's review of 67 patients treated with hemiarthroplasty reveal 27% with initial malposition of the tuberosities and then a further 23% who had subsequent migration of the tuberosities.

Tuberosity malunion is probably a technical problem with failure of correct positioning of the tuberosities, failure to secure the tuberosities adequately and then failure of the tuberosities to unite.



Figure 6: The ideal case for a reverse prosthesis?

A cadaver study has shown that an eight-fold increase in torque was required to produce external rotation when the tuberosities were malpositioned.³³

Several techniques have now been described to ensure better tuberosity fixation. Different materials and techniques are now used to attach the tuberosities to the prosthesis. The prostheses have been designed with smaller proximal portions with less bulk so that more bone graft can be used to obtain union.

The version and height have also been shown to alter the outcomes and this has resulted in many companies making jigs and devices to aid the surgeon with anatomical reconstruction.³² In addition intra-operative imaging and X-rays are used to confirm the correct anatomical reconstruction of the humerus (*Figure 8*). Computer-assisted surgery is presently being investigated as a tool to improve anatomical reconstruction.

A much slower rehabilitation programme in the first six weeks is now advocated to allow union to occur.

In contrast fracture fixation when compared to hemiarthroplasty seldom goes on to non-union.

Walsh and Boileau's article, Arthroplasty of the Shoulder, is a must-read for a review of this subject.³²

Reverse shoulder arthroplasty

The reverse shoulder replacement designed for rotator cuff tear arthritis is an attractive option because the need for tuberosity healing is not required for function. Unfortunately, this has not been validated in the clinical setting (*Figure 6*).

Serveaux presented the results of 15 cases at The 2008 Nice Shoulder meeting and was unable to demonstrate any benefit over a standard hemiarthroplasty.

Bufquin reviewed 43 patients with a reverse arthroplasty and found the Constant score was only 44. There was tuberosity displacement in 53% and scapular notching in 25%. Patients achieved good abduction but poor internal and external rotation. He concluded that there was no clear benefit yet.³⁴

Cazeneuve followed up 30 patients for 6.5 years. He did not suture the tuberosities. He felt it was a reasonable alternative, but they had poor rotation. They also had a worrisome 50% with scapular notching; in addition 20% had proximal humeral lysis and 15% had been revised (*Figure 7*).

Our approach

We adopted the fixed angle plates in our practice after an internal audit found we had complications of more than 50% which were either implant-related or due to fixation failure. At that stage no early results were really known, but the biomechanical results showed much better pull out strength than the fixations available.

We had encountered a few cases of disappearing tuberosities after we had performed what we felt were secure, anatomic tuberosity fixations which gave us concern.

The surgical technique also changed in that we do no soft tissue stripping except for the distal deltoid insertion to allow exposure. The rotator cuff and interval is not cut and is not released at all. Fracture reduction is done through the fracture using a Cobb and image intensifier to check the reduction.

This is done in the hope of minimising the risk of AVN (*Figure 8*).

Our philosophy is to try and fix all fractures that meet the surgical displacement criteria of Neer, and that are reconstructable. Occasionally there is too much comminution with osteopaenic bone and the impression that these fractures do not allow an adequate reduction. Therefore when there is any doubt not only must the fixation plate be in theatre, but a joint replacement set must also be available.

In younger patients we may reduce our surgical threshold to 30° of angulation and 5 mm of displacement (especially if the tuberosity is displaced superiorly).

The reason is that the best head is the native head. The next factor is that it is easier to get union of the tuberosities when the native head is retained. The fundamental issue is to obtain well reduced, well secured tuberosities as they are the cornerstone of a good outcome.

The risk of AVN is weighed up with the patient's comorbidities as a single surgical insult may be the only chance for the patient and so if they have Hertel's criteria for ischaemia, are elderly with osteoporosis and have significant co-morbidities they may be better off with a hemiarthroplasty.

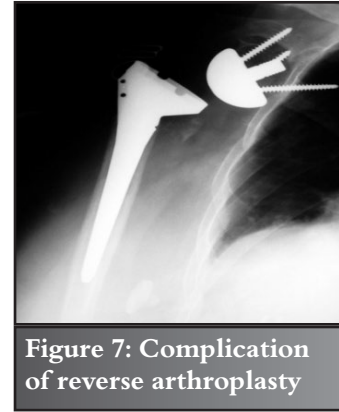


Figure 7: Complication of reverse arthroplasty

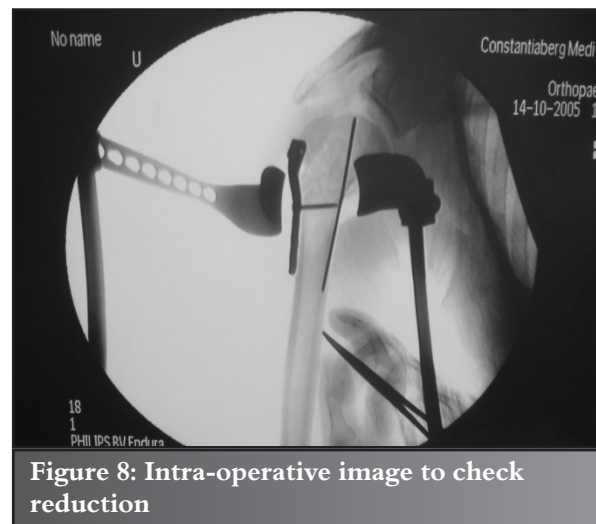


Figure 8: Intra-operative image to check reduction

Our concern for the vascularity is not as intense as it used to be because of the reassurance from the literature that not all avascular heads develop AVN, not all AVN develops collapse and not all those who develop collapse need surgery. In addition, those that do have head collapse and need revision surgery have an equivalent outcome to those who had a primary arthroplasty, as long as the tuberosities are united in the correct position.

The attention is directed to the tuberosities whether doing plate fixation or joint replacement as this is where most of the failures occur.

We reserve percutaneous pin fixation for young patients with two-part neck fractures with good bone. We tend to avoid intramedullary nails except for two-part fractures of the neck with distal extension. We feel they do not address the tuberosities as well as the plates, with additional non-absorbable sutures to the rotator cuff. In addition we prefer not to violate the cuff any more than we have to.

Unfortunately all methods of treating the fractures have a high incidence of complications including the reverse prosthesis, which should conceptually have an advantage over the hemiarthroplasty.

We reserve the reverse prosthesis for patients over the age of 70 years with marked osteoporosis of the tuberosities and an unreconstructable humeral head, or for patients with pre-existing arthritis.

Summary

Three- and four-part proximal humeral fractures are difficult to treat, with all forms of surgical management having a significant number of complications. Each has their own peculiar risks, but all of them have to address the tuberosities. If the tuberosities do not unite or unite in a poor position, a poor outcome can be expected.

Humeral head ischaemia does not necessarily equate to a poor outcome or collapse of the head.

Attempts at preserving the humeral head are almost always made first, before going to an arthroplasty.

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