Outcomes following arthroplasty for proximal humeral fractures

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ABSTRACT

Fractures of the proximal humerus are very common and increasing in incidence within an ageing population. The majority of undisplaced fractures can be treated conservatively. Displaced fractures in good quality bone or in the young are considered for surgical fixation. However, displaced and comminuted fractures with or without dislocation, especially in the elderly, cannot be reliably treated with fixation. These patients are generally considered for joint arthroplasty. This review article focuses on the outcome following arthroplasty for proximal humeral fractures.

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1. Introduction

Proximal humeral fractures account for almost 10% of all fractures.¹ Their incidence is rising with an aging population, accounting for a third of all fractures in the over 65 years of age with an expected further increase in the next 20 years.² It is three times more common in women, with trauma secondary to low energy falls accounting for 90% of cases.²

The estimated cost to the health service and rehabilitation in a country with a similar population to the United Kingdom, is over £80 million.³ In those over 65 years old, the burden of loss of independence and reliance on others for support has a profound effect on their mental and socioeconomic state. It also has a significant impact on the work life of individuals caring for these patients(3).

Treatment of proximal humeral fractures depends on fracture morphology, patient co-morbidities and expected outcome. The aim is to achieve a healed stable fracture in a pain free functional shoulder. This can be achieved conservatively or surgically. The literature supports conservative management for non-displaced or minimally displaced fractures.⁴ However, surgical management remains controversial when it comes to comminuted fractures. This is more so in the over 65s due to poor quality bone in this patient group.⁵

Currently there is no real consensus to establish superiority of open reduction and internal fixation (ORIF) to prosthetic replacement.¹ The fixed-angle devices implanted in ORIF have substantially evolved over the past two decades to withstand the rotator cuff's biomechanics and resist fracture varus collapse.⁶ However, the literature shows a suboptimal clinical result in the over 65 years age group with a complication rate of 48.8% and revision rate of 13.8% according to two recent systematic reviews.^{6,7}

Consequently, proximal humeral prosthetic replacement in the form of hemiarthroplasty (HA) was implanted for complex or comminuted proximal humeral fractures.^{6,7} It was first designed and used by Neer in the 1950s due to the poor results achieved by other means of management.^{8,9} Neer classified proximal humeral fractures into different parts: greater tuberosity, lesser tuberosity, articular portion of the head and the humeral shaft. To be considered as parts, these structures must be angulated more than 45° or displaced by more than 1 cm. Initial evidence of an intact medial hinge results in a preserved blood supply and fixation should be considered.¹⁰ If lost, the avascular necrosis is reported to be up to 75%. However, this has been refuted by more recent publication. This paper suggests that there is no increase in complication rate in particular avascular necrosis when the medial hinge is involved.

The most complex fractures are the ones likely to need a prosthetic replacement. This includes Neer's 3–4 part fractures, fracture dislocations, head splitting fractures, displaced anatomical neck fractures, or if more than 40% of the joint surface head is involved.^{11,12}

Prosthetic replacement is a technically demanding procedure

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with complex mechanical considerations. Good functional outcome requires restoration of humeral height, implant retroversion, reasonable availability of bone stock, functioning musculature, and in the case of HA, anatomical reconstruction and healing of the tuberosities to restore cuff function.^{12,13} Cuff dysfunction occurs due to displacement of the tuberosities. In the case of an insufficient or non-functioning rotator cuff, shoulder replacement in the form of reverse polarity arthroplasty (hemisphere on the glenoid and socket on the proximal humerus) has gained popularity as an alternative to HA.^{14–16} This form of shoulder arthroplasty does not rely on the tuberosity healing and cuff integrity by recruiting the deltoid to restore functional mobility of the shoulder.^{14–16} The decision however to perform a reverse polarity shoulder replacement rests mainly on fracture configuration, patient age and occasionally on the premise of pre-existing cuff disease. Finally, surgical training, preference and experience have shown to play a major part in achieving satisfactory results in either techniques.^{11,17}

This article review will focus on the outcomes of proximal humeral fracture management with prosthetic replacement.

2. Evolving design

The first shoulder arthroplasty was implanted in 1893 by a French surgeon named Pean.¹⁸ Neer in 1955 implanted the first modern HA prosthesis and used it primarily for proximal humeral fractures that could not be treated by other traditional methods.⁹ However, it was not until the early 1970s that his work was noted by the shoulder orthopaedic community, when he published the results of his case series showing 90% satisfactory outcome.⁹ He later modified his implant to treat osteoarthritis and designed a polyethylene glenoid component.^{9,19}

In the late 1970s and early 1980s, other designs came into the market which were predominantly modified successful hip arthroplasty systems. Despite different biomechanics to the hip joint, these systems employed similar concepts to the hip arthroplasty leading to early implant loosening, poor clinical outcomes and high complication rates.^{7,18} Later in the 1980s, Neer modified his unconstrained design in the form of HA monoblock prosthesis, which showed excellent results in patients with no cuff abnormalities.¹⁹ Subsequently, modular implants appeared giving more options and sizes to match patient fracture configuration and bone stock.¹⁸

In the 1990s, computerised measurements of fracture configuration allowing more accurate anatomic reconstruction revolutionised the prosthetic development and implantation which were more specific to patient anatomy. These were referred to as the third generation implants.²⁰ The ability to dial in implant inclination, offset and head size allowed more accurate centre of rotation which results in better shoulder function.^{18,20}

Total anatomical shoulder replacement, where the proximal humerus as well as the glenoid are replaced, is not a viable option in 3–4 part proximal humeral fractures.^{7,12} This is due to the high risk of rapid glenoid component loosening, polyethylene wear as well as the glenoid cartilage being generally healthy.¹² However, the decision-making process is significantly different if the rotator cuff is injured or severely deficient. Unconstrained designs such as HA or anatomical shoulder replacement produced poor shoulder functional outcomes as their biomechanics rely on sound rotator cuff function.^{12,18} Hence, constrained designs were preferred in these patients.

Initial constrained designs in the 1970–80s were discarded due to high failure rate secondary to loosening.¹⁸ In the late 1980s, a French group developed an implant that reversed the polarity of the joint with the hemisphere in place of a glenoid and the socket in the proximal humerus.^{18,21} This modified joint geometry allows

recruitment of the deltoid muscle for elevation of the arm to re-establish shoulder function. It is therefore a semi-constrained system as it relies on deltoid tension.⁵ The system moves the centre of rotation medially and inferiorly toward the scapula. The medial shift reduces the forces applied to the glenoid and therefore, the risk of glenoid loosening.⁵ The inferior shift increases the lever arm of the deltoid and reduces reliance on a deficient or injured rotator cuff.²² A second design is now used - it positions the centre of rotation more laterally in the glenoid component.⁵ This reduces the work of the deltoid and increases stability, and may reduce wear.

With this increased popularity, the RSA indications further expanded to include other complex conditions such as glenoid or proximal humeral lesions needing graft reconstruction and proximal humeral fractures.¹⁶

3. Literature review

3.1. Hemiarthroplasty

Previously, when ORIF is contraindicated or not possible, HA is considered the gold standard.^{19,23} This procedure has now been superseded as it is technically demanding and requires adequate restoration of normal anatomy.^{5,18,23} Besides trauma, HA is used in the treatment of degenerative and inflammatory glenohumeral conditions with intact rotator cuffs.^{11,18,23} Figs. 1a and 1b are examples of pre and post operative radiographs of HA in proximal humeral fracture.

The first HA series in the literature reported 90% success rate in 43 patients with a mean age of 55.3 years and follow up between 1 and 16 years.⁹

The greatest influence on the success of HA is repair and healing

Fig. 1. a and b: Pre and post-operative radiographs of implantation of HA for a proximal humeral fracture.

of the lesser and greater tuberosities.^{11,13} This can be optimised by restoration of humeral stem height and retroversion.^{11,13} Humeral lengthening of more than 1 cm or shortening of more than 1.5 cm or 40° or more retroversion is likely to produce low Constant scores, i.e., poor functional outcomes.¹³

In 2003, an observational cohort study of 163 consecutive patients treated with primary HA showed good Constant scores with overall good functional outcomes in terms of pain, range of movement and survival of the implant; especially in young patients.¹² Furthermore, a multicentre retrospective study of 167 patients with 3–4 part fractures in 12 Austrian hospitals published in 2004, with follow up of more than a year, showed good Constant scores and excellent pain relief.¹¹ This study also showed greater tuberosity healing significantly influences the outcome of surgery.

However, a systematic review published in 2008 combining 810 patients from 16 studies with a mean age of 67.7 years and mean follow up of 3.7 years, showed a combined Constant score function of only 57 out of 100.²⁴ This was derived from pain relief, range of movement, and strength.

Few published studies are available on the literature to compare the outcomes following HA to non-operative management or ORIF. In 1984, a prospective study comparing Neer HA monoblock to non-operative management reported a better outcome in the HA group with respect to function, pain and muscle strength.²⁵ Another study comparing HA with ORIF in 32 participants following 4-part fractures reported marginally better Disability of the Arm Shoulder and Hand (DASH) and Constant scores in the HA group following 24 months follow-up.²⁶

In 2011, a randomised-controlled trial (RCT) of HA versus non-operative management in 4-part comminuted fractures in 55 patients, with a mean age of 77 years, reported a significant advantage of quality of life and pain control in favour of HA but no difference in range of movement at 24 months follow up.²⁷ However, a year later, another similar RCT of 50 patients showed no clear benefits in treating patients over the age of 65 years with either HA or non-operative management in 4-part proximal humeral fractures.²⁸ Furthermore, more recent studies showed average functional outcomes following HA especially in those over 65 years. The increased level of dissatisfaction led the authors to question its efficacy.^{13,24}

There are also several complications associated with HA reported in the literature.²⁴ Intraoperative complications include malpositioning, axillary nerve injury and iatrogenic fractures.^{12,24} Early postoperative complications include tuberosity repair pull-off (23%), instability (15%), joint stiffness (5%) and infection (5%). Late complications include glenoid erosion (35%), heterotrophic ossification (30%), rotator cuff dysfunction (23%), implant loosening (3%) and periprosthetic fractures (2%).^{11,12,27,28}

Despite advances in the HA procedure, tuberosity non-union remains the main complication reported in the literature, with a rate of at least 20%.¹³ Moreover, the questionable quality of the rotator cuff, especially in the over 65 year olds, and motivation to strict rehabilitation protocol to allow healing of the tuberosities, showed worse outcomes in this patient group.^{18,23} This led to the increased popularity of implants which do not rely on the healing of the greater tuberosity or integrity of the rotator cuff tendons.

3.2. Reverse shoulder arthroplasty

RSA use has dramatically increased in the last two decades.^{14,16,23} Initially, the semi-constrained design sought to address the shortfall in other replacement types to treat osteoarthritis in patients with pre-existing rotator cuff deficiency or injury.^{18,23} The RSA does not rely on tuberosity healing, an essential component of HA success.^{14,15} It was initially considered as salvage operation for failed HAs or the last resort when other approaches

failed.^{21,29}

In the United States, a cohort study looking at the surgical management of proximal humeral fractures of 38729 over 65 year-old patients between 2011 and 2013 found the rate of RSA increased by 1.8 fold from 14% to 24% from all operated cases ($p < 0.001$).³⁰ In fracture management, RSA accounted for 53.3% of all arthroplasties in 2013 as opposed to 32.2% in 2011. The same findings were echoed by a similar cohort study published in 2015.³¹ Furthermore, a retrospective case-control study from the New Zealand Joint Registry identified 313 HAs and 57 RSA for proximal humeral fractures.³² The RSA group showed a significantly better Oxford Shoulder Score over a 5-year follow up ($p < 0.022$) but no difference in revision rates. Figs. 2a and 2b are examples of pre and post operative radiographs in RSA in proximal humeral fracture.

With higher efficacy and success rates, their popularity has increased dramatically and their use as primary implant for 3–4 part comminuted proximal humeral fractures has increased.³¹ A case series published in 2007 of 43 patients treated with RSA with mean follow up of 22 months demonstrated satisfactory shoulder mobility and mean Constant score of 66%.³³ Subsequently, more case series are continuing to be published regularly in the literature showing promising results with good functional outcomes when RSA is used.^{34–37}

In comparison to HA, RSA has generally better functional outcomes and patient satisfaction with many published articles supporting its use, especially in those over the age of 65. Since 2013, RSA has replaced HA as the most commonly implanted prosthesis in type 3–4 proximal humeral fractures in patients over 65 years of age.³⁰

Fig. 2. a & b: Pre and post-operative radiographs of implantation of RSA for a proximal humeral fracture.

A systematic review published in 2013 reported that RSA has improved forward flexion. It also reported better functional outcome scores and no difference in complication rates when compared to HA.³⁸ The review included 15 studies of whom 9 were case series. However, another systematic review of mainly case series of similar demographics reported findings of improvement in function, pain control and range of movement in both the RSA and the HA groups with slightly higher complication rates in the RSA group.²³ The authors concluded that patients and surgeons should consider the benefit of surgery before choosing the correct implant.

In 2014 a therapeutic prospective non-randomised trial compared the functional outcomes between 12 and 20 patients treated with HA and RSA, respectively.³⁹ The mean Constant score was significantly better in both groups compared to non-operative management. The RSA group showed a higher improvement of Constant score with less reported complications. However, the improvement in Constant score failed to reach statistical significance ($p=0.06$). Another more recent blinded RCT from Spain compared the functional outcomes of 62 patients over the age of 70 equally divided between HA and RSA with a mean follow-up of 28.5 months.⁴⁰ The study showed that the reverse shoulder group had better function, pain control and reduced revision rates ($p < 0.001$).

A number of complications have been reported in the literature. Scapular notching remains the most frequent complication associated with RSA leading to polyethylene wear, synovitis, and glenoid component loosening due to bone loss.³³ A survey of 77 patients concluded a 44% prevalence of scapular notching in patients treated for RSA.⁴¹ Other acute complications include neurovascular injury (11.6%), iatrogenic fractures (2.3%), acromial spine fractures (2.3%), dislocation (2.3%) and complex regional pain syndrome (7%).³³ Acromial insufficiency fractures following RSA resulted in inferior outcomes.⁴² Avoidance of arm lengthening plays a part in reducing brachial plexus strain and transient neurologic deficit, which has been reported to affect up to 22% of patients.⁴³

Boileau et al. introduced a radiographic classification that

predict prognosis following prosthetic implantation based on fracture sequelae of multi-fragmented proximal humeral fractures.⁴⁴ This classification specifically looks at whether tuberosities mobilisation is necessary when prosthesis is used (Fig. 3). The authors recommended unconstrained implant (HA) for type 1 and 2 fractures as mobilisation of the tuberosities is not needed provided that the cuff is not injured. However, type 3 and 4 fractures would need mobilisation of tuberosities and hence, RSA is recommended.⁴⁵ Tuberosity osteotomy and mobilisation has a high risk of osteonecrosis leading to high rate of rotator cuff failure and dysfunction.⁴⁵

4. Discussion

Over the past 70 years, proximal humeral fracture prevalence has increased due to an ageing population. The increased demands on healthcare and the resultant socioeconomical burden as well as advances in surgery continue to drive change in how we manage proximal humeral fractures. The vast majority of them are minimally displaced fractures and successfully treated non-operatively.

However, surgical management remains controversial in comminuted 3–4 part fractures in particular in the subset of patients with osteoporotic bone in the patients over the age of 65 years old. Despite advances in open reduction and fracture fixation, patients' functional outcomes and satisfaction remains stagnated. In 2015, the United Kingdom Proximal Fracture of the Humerus Evaluation by Randomisation (PROFHER) multicentre RCT of 231 patients reported no difference in patient functional outcomes and quality of life whether treated surgically (fixation or HA replacement) or not.⁴ The finding of this trial sent shockwaves in the Trauma and Orthopaedic community and questioned the current approach to proximal humeral fracture management.

However, despite fulfilling the inclusion criteria, 100 patients were excluded due to associated dislocation and further 87 patients were excluded by the participating 66 surgeons who felt the patient would do better with surgery. Only 4.4% of the included patients

Fig. 3. Radiographic classification to predict need for mobilisation of tuberosities in arthroplasty.

had part-4 type fractures which is much lower than what is observed in the population (20–30%).⁴⁶ The excluded patients fundamentally are those recommended for fixation or replacement.

A recent meta-analysis of seven RCTs (3 sling vs ORIF, 3 sling vs HA and one HA vs RSA) published in 2017 specifically looking at the management of 3–4 part proximal humeral fractures concluded that RSA results in a improved clinical outcomes and reduced complication rates, with ORIF performing the worst.⁴⁷ This again swings the consensus toward intervention, in particular, RSA.

Currently, there are three ongoing multicentre RCTs looking into the management of proximal humeral fractures. The Norway-based multicentre RCT looking at Displaced Proximal Humeral Fractures treatment with Delta RSA Prosthesis versus Philos plate ORIF in the elderly (DELPHI-trial) is due to report in 2019.⁴⁸ Another ongoing RCT from Australia currently investigating Reverse Shoulder Arthroplasty for the Treatment of Proximal Humeral Fractures in the Elderly versus non-operative treatment (ReSHAPE-trial) is due to report in the coming two years.⁴⁹ Finally, the PROFHER-2 trial is in the recruiting phase with authors specifically aiming to address the shortfalls of the first trial and expected to report in 2024.⁵⁰ PROFHER-2 is specifically looking at the management of the 3–4 part comminuted fractures in the over the 65-year olds with 3 arms in the study: conservative management, HA or RSA.

5. Conclusion

Management of proximal humeral fractures continues to be a challenging task. There is a lack of consensus on the surgical management of complex or comminuted fractures especially in the elderly. There is good evidence to restrict the use of HA to non-reconstructable comminuted fractures in young patients with good rotator cuff function, and in older patients that are not suitable for conservative management but could not tolerate more complex operations. RSA has shown promising results in the elderly, but there is no long-term functional outcome data to support its use in the wider public. Recent doubts have been cast on the surgical management in general, though more robust level I evidence studies are due to report in the coming few years.

Conflict of interest

None.

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