JBJS REVIEWS

Treatment of Proximal Humeral Fractures

A Critical Analysis Review

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» There is substantial variability in the treatment of proximal humeral fractures because of classification systems with poor interobserver reliability, rapid advances in technology (e.g., anatomically designed locking plates and reverse shoulder arthroplasty), and limited Level-I and II evidence for best treatments based on fracture patterns and physiological age.

» Almost three-quarters of proximal humeral fractures can be treated nonoperatively with good functional results as nearly 50% are nondisplaced or Neer one-part fractures. Another quarter occur in infirm patients or are characterized by fracture patterns that reliably heal well with minimal complications.

» Displaced fractures in physiologically young patients should preferentially be treated with open reduction and internal fixation (ORIF) as functional outcomes are generally good and anatomical restoration can improve the results of subsequent arthroplasty, if needed.

» Improved results with fixation have been reported in association with the use of bone substitutes, fibular strut allografts, and inferior head-supporting calcar screws to prevent humeral head displacement and screw perforation.

» A number of recent trials have brought into question the advantage of both ORIF and hemiarthroplasty over nonoperative treatment for patients over the age of sixty years who have three and four-part fractures without dislocations.

» Reverse shoulder arthroplasty initially showed varied results for the treatment of irreparable fractures in healthy older patients, but recent Level-I and II studies have shown an advantage over hemiarthroplasty. Medium and long-term data are still needed.

The majority of proximal humeral fractures can be treated nonoperatively with acceptable functional results[1-5]. It has been estimated that almost three-quarters of fractures fit into this category; however, there is still disagreement concerning which fractures should be treated

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TABLE I Recommendations for Care*

Recommendations for Care	Grade
Open reduction and internal fixation is recommended for displaced fractures in physiologically young patients	C
Nonoperative treatment should be considered for displaced three and four-part fractures in patients more than sixty years of age who are physiologically older	B
Reverse shoulder arthroplasty should be considered instead of hemiarthroplasty for unreconstructable three and four-part fractures in patients older than seventy years of age	B
Fibular strut allograft, bone substitutes, and inferior calcar screws should be considered to help prevent displacement of reductions in proximal humeral fixation	B

*Grade A = Good evidence (Level-I studies with consistent findings) for or against recommending intervention. Grade B = Fair evidence (Level-II or III studies with consistent findings) for or against recommending intervention. Grade C = Conflicting or poor-quality evidence (Level-IV or V studies) not allowing a recommendation for or against intervention. Grade I = There is insufficient evidence to make a recommendation[59].

operatively and even more controversy regarding the appropriate surgical intervention[1,5].

This controversy is the result of four factors. First, the main classification systems used for proximal humeral fractures, the Neer[3] and AO classification systems[6,7], are currently unreliable for scientific communication and surgical decision-making, with poor to moderate interobserver reliability[6,7]. Second, the vast majority of proximal humeral fractures occur in patients older than fifty-five years of age, but with a peak between the ages of eighty and eighty-nine years[1]. This population represents a very diverse functional group for which treatment based on fracture pattern or age alone may not lead to optimal functional outcomes. Treatment is commonly based on factors that may be subjective and difficult to quantify. Third, the rapid growth of implant options in the last decade has introduced even greater choice to already confounded indications[8]. Specifically, locking-plate technology and reverse shoulder arthroplasty have dramatically enhanced the ability of the surgeon to address these fractures, but without the corresponding data to aid in decision-making. Last, clinical trials are lacking not only for the newer technologies but also for previous treatment methods. Recently, the results of a number of trials have collectively showed similar outcomes following operative and nonoperative treatment for patients over the age of fifty-five or sixty years[9-12].

For the reasons outlined above, there is substantial variability in the treatment choices for surgeons. In 2011, Bell et al., in their review of a large sample of Medicare data, found a significant increase in the number of both open reduction and internal fixation (ORIF) and hemiarthroplasty procedures, without any corresponding increase in the incidence of fractures ($p < 0.001$)[8]. More striking was the substantial regional variation in the rates of surgery (range, 0% to 68%). This research highlighted what many surgeons already understood: that there is no consensus on the optimal treatment for proximal humeral fractures, leading to substantial variation in management[8,13].

The purposes of the present review are to critically evaluate the current data, to provide a general framework for an approach to treating these fractures, and to highlight the major controversies that need to be resolved in order to determine the optimal treatment of these injuries.

Epidemiology

The incidence of proximal humeral fractures (like those of other osteoporotic fractures) is increasing with the aging population, with proximal humeral fractures representing approximately 5% of all fractures[13]. The incidence is as high as 105 fractures per 100,000 patients and continues to rise[1]. An estimated 70% of all of these fractures occur in patients over the age of sixty years, with the greatest reported incidence among individuals with an age of eighty years or more[1]. Approximately three of four fractures occur in women, with nearly 90% occurring as the result of a low-energy fall. Most importantly, 50% are nondisplaced or minimally displaced[1,14]. Younger patients with injuries sustained during high-energy trauma account for the remaining fractures of this type[15].

Classification

Neer Classification System

Currently, there is no ideal classification system for proximal humeral fractures. In fact, the most widely used system, the Neer system, has only modest intra-observer and interobserver reliability[6,7]. This system is based on judging the displacement (>1 cm) or angulation (>45°) of four anatomical parts of the proximal part of the humerus (the head, the lesser and greater tuberosities, and the shaft) with imaging or intraoperative examination[3,16]. Radiographs, two and three-dimensional (2D and 3D) reconstructions, 3D stereotactical reconstructions, and even models have shown poor to modest interobserver reliability among surgeons[4,6,7,17-19]. Nonetheless, this system does provide a general framework for how to approach these fractures and has provided the foundation for a number of recent trials[9-11,20].

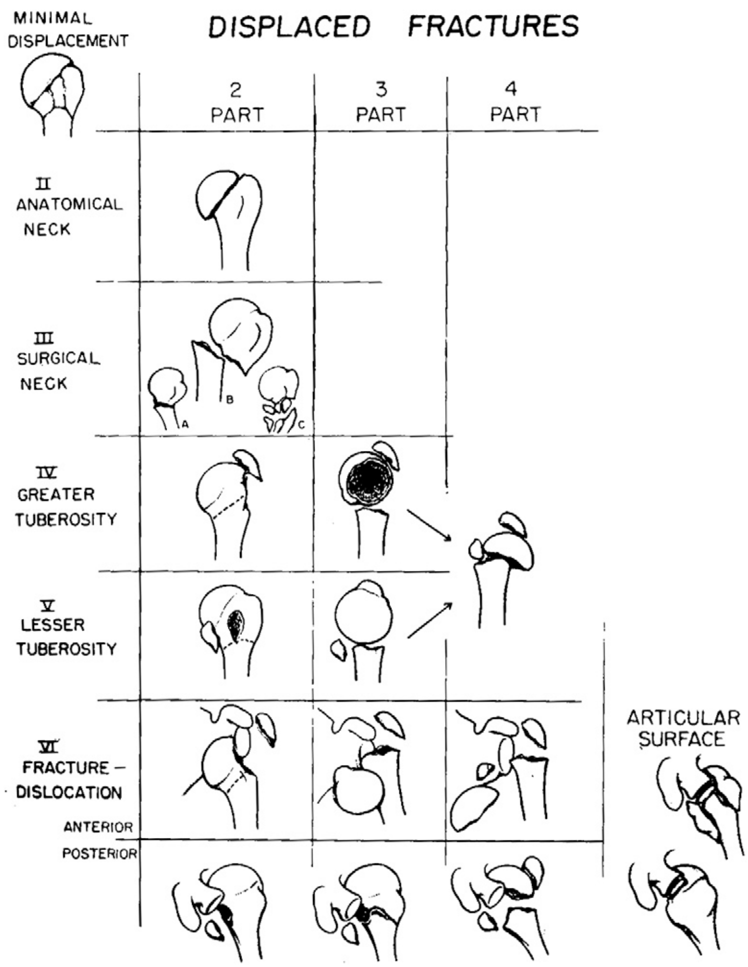

Fig. 1
Illustration depicting the original classification system of proximal humeral fractures described by Neer, in which each part is defined by either >1 cm of displacement or >45° of angulation. (Reproduced from: Neer CS 2nd. Displaced proximal humeral fractures. I. Classification and evaluation. J Bone Joint Surg Am. 1970 Sep;52[6]:1077-89.)

Despite the fundamental failures of the Neer classification system, Court-Brown et al., in the best epidemiological work to date, prospectively classified 1027 fractures and found that 49% were one-part fractures (minimally displaced), 28% were two-part surgical neck fractures, 9% were three-part surgical neck and greater tuberosity fractures, and only 3% represented four-part fractures, including dislocations (Fig. 1)[1]. The most common dislocation was a two-part anterior dislocation with a greater tuberosity fracture. Typically, this injury was associated with a nondisplaced neck fracture.

AO Classification System

In the same study[1], Court-Brown et al. classified these same fractures with the AO system, which is less widely used and less intuitive but more comprehensive. Type-A fractures are unifocal injuries (one fracture area), type-B fractures are bifocal, and type-C fractures are all either intra-articular or anatomical neck fractures. The investigators found that 66% were type-A fractures, whereas only 6% were type-C fractures. More importantly, almost 50% of fractures fell into four subtypes: type B1.1 (valgus impacted) (Fig. 2), type A2.2 (varus impacted) (Fig. 3), type A3.2 (translated surgical neck fractures) (Fig. 4), and type A1.2 (displaced greater tuberosity fractures).

Common Fracture Patterns

Valgus-Impacted Fractures

The valgus-impacted fracture was not included in the original Neer classification system, but it is estimated to represent 20% of proximal humeral fractures[1,4,21-23]. Defined by the valgus angulation of the displaced humeral head, this type of fracture represents a spectrum of injury ranging from minimal angulation to dislocation and includes a separate humeral head piece (Fig. 2). The most common valgus-impacted fracture, representing 15% of all fractures, is the AO B1.1 group, defined by a valgus-impacted head and a displaced greater tuberosity. These fractures generally heal predictably well with little chance of osteonecrosis and acceptable outcomes in older patients[1,4,21-23]. Less-common valgus-impacted fractures are the A2.3, C1.1, C1.2 groups.

Varus-Impacted Fractures

Also not included in the original Neer classification system, the varus-impacted fracture pattern is defined by varus angulation of the head and impaction onto the shaft (AO A2.2) (Fig. 3). This type of fracture represents 13% of proximal humeral fractures[1,24]. There

Fig. 2
Radiograph showing a valgus-impacted fracture (AO type B1.1), a category not included in the original classification system described by Neer. The pattern is a spectrum of injury, with a progressively valgus-angulated impacted head due to a neck fracture and a displaced greater tuberosity fracture.

is controversy regarding the prognosis of these fractures, but there are some data indicating good functional results with nonoperative treatment[25-27].

Translated Surgical Neck Fractures

Surgical neck fractures have been reported to represent approximately one quarter of all fractures, and the AO A3.2 subgroup (translated surgical neck fractures) have been reported to represent 13% of all fractures[1,28]. This fracture typically occurs in low-demand patients who are more than seventy years of age (Fig. 4). Court-Brown et al.[28] reported that the functional outcomes following nonoperative treatment were acceptable. Subjective impressions of outcome following nonoperative treatment were better than objective measures, with only 60% of flexion and 65% of abduction power regained after one year. Despite these findings, >90% of the ninety-seven patients who were included in the study were able to return to dressing themselves independently, >60% were able to return to household chores and shopping, and approximately 80% were able to attend to their personal hygiene independently. In addition, these findings were age-dependent, with significantly higher percentages of return found in the younger age groups ($p < 0.01$). However, these fractures have been associated with a nonunion rate of approximately 5%, although operative treatment does not seem to improve outcomes[29].

Greater Tuberosity Fractures

Displaced greater tuberosity fractures (AO A1.2) represent approximately 10% of all fractures, with almost half being associated with an anterior dislocation[1]. Small fractures retract over time, whereas larger fractures typically do not. There is controversy as to how much displacement constitutes an indication for operative treatment because of the potential for later impingement and rotator cuff dysfunction. Some authors have suggested 5 mm of displacement as the indication for operative treatment, but the best treatment is controversial[30,31]. Importantly, approximately 10% of these fractures are associated with a neck fracture that can displace with reduction of a dislocation[1,13].

Nonoperative Treatment

Nonoperative treatment is appropriate, with little controversy, for nearly 75% of proximal humeral fractures[1,3,5,12,14,16,21,24,28,32], including nondisplaced or one-part fractures (49% of all fractures), fractures in infirm patients, fractures in patients in their late eighties and nineties, and fracture patterns that reliability heal well with nonoperative treatment[1]. There is substantial variation in the treatment of the remaining 25% of fractures[8,24].

Certain fracture patterns in this remaining one-quarter have been shown to have acceptable functional results when treated nonoperatively in older patients, including three and four-part valgus-impacted fractures (AO B1.1) (Fig. 2)[21], two-part varus-impacted fractures (AO A2.2) (Fig. 3)[1,24], and, as previously mentioned, even translated two-part surgical neck fractures (AO A3.2) (Fig. 4)[28].

Historically, however, nonoperative treatment was considered to be inappropriate for these fractures and most three and four-part fractures on the basis of Neer's 1970 sentinel work[3,16]. In that two-part, single-author article, Neer both defined his classification system and recommended that all three-part fractures should be treated with ORIF and that four-part fractures should be treated with a hemiarthroplasty because of the high risk of osteonecrosis[3,16]. By today's standards, the scientific support for these research findings is lacking.

Few studies have reproduced the findings described by Neer, but there have been few reports dedicated to the nonoperative treatment of proximal humeral fractures[9-12]. Most of those studies have shown poor radiographic outcomes following nonoperative treatment but have demonstrated acceptable functional results and patient satisfaction, with little difference from operative treatment. However, failed nonoperative treatment can result in more complicated situations with poorer outcomes after salvage surgical intervention[25,33].

In a number of recent randomized trials[11,12], nonoperative treatment has been compared with ORIF for the treatment of three-part fractures and with hemiarthroplasty for the treatment of four-part fractures. Although there have been some substantial improvements in operative treatment, the clinical importance of these improvements is questionable and the complication rate is

Fig. 3
Radiograph showing a varus-impacted fracture (AO type A2.2). This pattern represents 13% of all proximal humeral fractures.

Fig. 4
Radiograph showing a completely translated surgical neck fracture (AO type A3.2). In general, surgical neck fractures represent 28% of all proximal humeral fractures and generally occur in patients who are more than seventy years old.

high. Overall, the consensus after four recent trials was that functional outcomes were decreased after proximal humeral fractures in patients more than sixty years of age but that the benefits of operative intervention were questionable[9-12]. The impact of these trials is yet to be determined.

Another factor that may change the calculus on early surgical intervention for the treatment of displaced proximal humeral fractures is that the salvage options have evolved. Previously, a nonunion, malunion, or osteonecrosis led to unsatisfactory results following salvage osteotomies and fixation or hemiarthroplasty. Now, with the use of the reverse shoulder arthroplasty[25,33-35], which relies less on rotator cuff function than previous operations did, the outcomes of salvage surgery may be more acceptable and may expand the initial indications for nonoperative treatment.

Reduction and Fixation

Reduction and fixation is generally recommended for displaced fractures in physiologically young and active patients even if they are older than sixty years of age. Defining "young and active" as well as "displaced," however, is subjective and leads to substantial management variation (Table I).

Minimally Invasive Reduction and Fixation

An improving understanding of fracture patterns and more versatile implants such as locking-plate fixation can allow surgeons to achieve good results with minimally invasive techniques[36,37]. Minimally invasive treatment works best for valgus-impacted fractures and translated two-part fractures (if fixation is deemed necessary). However, it does not work well for four-part fractures. The so-called learning curve is steep, and the role and advantages of such treatment compared with traditional open techniques are unclear[4,5,38].

Open Reduction and Fixation

The fracture pattern, technical considerations, and the surgical approach may have important implications for the outcome. Certain fractures are associated with higher complication rates. Fractures in varus alignment may have a greater tendency for post-fixation displacement and fixation cut-out. Anterior three and four-part dislocations with the humeral head still engaged on the glenoid still have soft-tissue attachments and can be effectively treated with fixation, whereas those with complete separation of the head are associated with a high rate of osteonecrosis. Similarly, posterior fracture-dislocations with an engaged head and fractures associated with the reverse Hill-Sachs lesion can do well with fixation.

Anatomically contoured locking-plate fixation initially was expected to revolutionize patient care and outcomes. However, numerous studies showed equivocal initial results, with complication rates generally ranging from 20% to 30% and a reoperation rate of approximately 10%[39,40]. As our understanding of fixation and fracture patterns has improved, our techniques and outcomes have also improved. Consideration of the use of allografts[26,27,41] (e.g., a fibular strut allograft), implantation of strategically placed inferior strut screws[42], and ensuring impaction of the humeral head on the shaft without any varus angulation appear to reduce the risk of major complications such as loss of reduction and screw cut-out (Table I and Fig. 5, *A* and *B*). Furthermore, considerable care must still be taken when managing patients who have severely osteoporotic bone. The lack of bone stock within the metaphysis of the proximal aspect of the humerus requires meticulous screw placement into the subchondral bone of the humeral head to further reduce the risk of screw cut-out and loss of reduction[39,43].

In addition, approaches have evolved with a renewed interest in fixation. Although the standard deltopectoral approach is utilized most frequently, the deltoid-splitting approach, through the anterior and middle raphae, has become popular and allows for better visualization of certain types of fractures during fixation[44]. Nonetheless, the exact patient subgroups and the exact fracture patterns that should be fixed are not fully elucidated. Current trials have shown limited improvement of function following fixation as compared with nonoperative treatment for patients over the age of sixty years[9,12]. Trials or prospective cohort studies of younger patients involving the use of more modern fixation techniques are needed.

Intramedullary Nailing

The rationales for intramedullary nailing are to preserve blood supply and to minimize surgically induced soft-tissue injury in patients with simple fractures (specifically, translated two-part fractures)[45,46]. The major limitation of this technique is that the insertion point for the nail is near or through the attachment of the rotator cuff and therefore may affect functional outcomes and motion[47]. However, trials in which nailing has been compared with locked plating for the treatment of two-part fractures have failed to demonstrate any

Fig. 5-A

Fig. 5-B

Fig. 5A Radiograph showing a displaced three-part fracture in a physiologically and chronologically young patient at the age of forty-eight years. **Fig. 5B** Radiograph made after reduction and fixation performed with the use of a fibular strut graft for support and inferior strut screws.

significant benefit of one technique over another. For example, Lekic et al. reported no differences between the two methods in terms of the range of motion at six months, the average neck-shaft angle, or the rate of complications[48]. The results of studies comparing the two methods with respect to three and four-part fractures have been more equivocal, with literature supporting both sides[49-51]. A systematic review conducted through the Cochrane database indicated that impingement following intramedullary nailing was the only difference in outcomes between the two techniques across all fracture types[52]. Despite the lack of discrete evidence supporting one technique exclusively, most surgeons recommend the use of locked plating for the treatment of three and four-part fractures[53].

Arthroplasty

Hemiarthroplasty

The 1970 study by Neer[3,16], which showed a high rate of osteonecrosis of the humeral head and poor functional outcomes, led to the expanded use of hemiarthroplasty for the treatment of three and four-part fractures and dislocations[16]. Unfortunately, the subsequent data showed varied results, with the general findings of minimal pain but limited function[54]. The major limitation to the success of a hemiarthroplasty is the high rate of tuberosity nonunion, pull-off, and resorption, which may be technique-related[55]. After hemiarthroplasty, many shoulders are stiff, even to passive motion, because of soft-tissue scarring. No pain but limited motion may potentially be acceptable to physiologically older patients but not to younger patients. Additionally, for younger patients, there is always the concern of glenoid cartilage erosion and pain over time.

Three recent trials, discussed in more detail below, have brought into question the indications for hemiarthroplasty, showing comparable results when compared with nonoperative treatment and worse outcomes when compared with reverse shoulder arthroplasty (Table I)[10,11,56].

Reverse Shoulder Arthroplasty

Reverse shoulder arthroplasty originally was indicated for patients with rotator cuff arthropathy or glenohumeral arthritis in the setting of a large or irreparable rotator cuff tear. Although the exact biomechanics are still being elucidated, the prosthesis functions by providing a semi-constrained fixed fulcrum and by improving the efficiency of the deltoid muscle by medializing the center of rotation. Subsequently, the prosthesis allows for improved function in the setting of an absent or nonfunctioning rotator cuff[57].

Because the major limitation related to the use of hemiarthroplasty for the treatment of fractures is the risk of tuberosity nonunion, pull-off, or resorption, reverse shoulder arthroplasty may be an ideal alternative as it relies less on tuberosity healing and a functional rotator cuff. Although the early results were inconsistent, the more recent results, after the development of improved technology and advanced implantation techniques, have been very promising[57,58]. The Level-I and II studies discussed below showed improved outcomes when reverse shoulder arthroplasty was compared with hemiarthroplasty. In addition, reverse shoulder arthroplasty allows for greater freedom when managing patients nonoperatively because salvage is now possible following the development of a malunion, nonunion, or osteonecrosis (Fig. 6, *A* and *B*)[56,58].

Importantly, these procedures were performed by surgeons with substantial expertise with reverse shoulder arthroplasty as this procedure has a steep learning curve and is associated with a high early complication rate.

Level-I and II Investigations

Nonoperative Treatment Versus ORIF

Two recent trials compared the outcomes of nonoperative treatment with

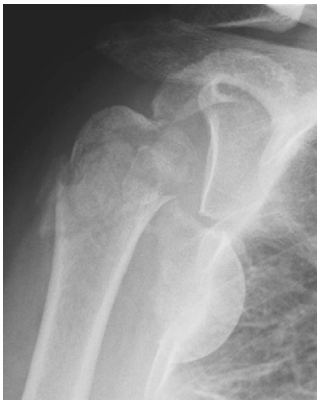

Fig. 6-A

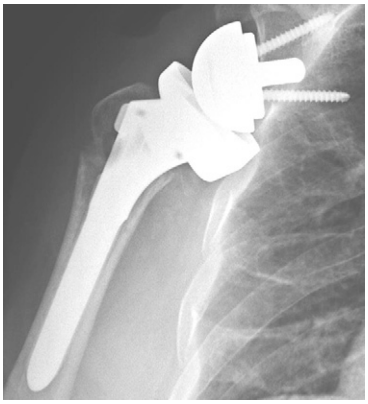

Fig. 6-B

Fig. 6A Radiograph showing an anterior fracture-dislocation, with no soft-tissue attachments to the head, in a physiologically-fit sixty-eight-year-old man. **Fig. 6B** Radiograph made after reverse shoulder arthroplasty.

those of ORIF. In the first trial, published in 2011, Olerud et al. reported the two-year outcomes for sixty patients with three-part fractures that were treated either nonoperatively with use of sling immobilization and early physical therapy or operatively with use of ORIF with a locking plate[9]. The inclusion criteria were an age of greater than fifty-five years and no cognitive impairment or medical contraindications to surgery. Fracture patterns were determined with standard radiographs and conventional computed tomography (CT) scans. Valgus-impacted fractures were excluded because of well-reported good outcomes following nonoperative treatment. Fractures with complete displacement of the head and shaft were excluded because of the perception that such fractures are associated with poor outcomes, although the data in support of this conclusion are limited. Although the trial was underpowered, the investigators found no statistically significant differences and inconsequential clinical differences between the locking-plate group and the nonoperative treatment group in terms of forward flexion (120° compared with 111°; $p = 0.36$) and abduction (114° compared with 106°; $p = 0.28$). The Constant score and the Disabilities of the Arm, Shoulder and Hand (DASH) score were not statistically different, but ORIF was associated with an advantage in terms of Health Related Quality-of-Life (HRQoL) as measured with the EuroQol EQ-5D score. The complication rate was high, with a reoperation rate of 30% (including a 13% rate of minor reoperations and a 17% rate of major reoperations).

In the second trial, Fjalestad et al.[12] examined the one-year results for fifty patients with an age of sixty years or older who were managed either nonoperatively or with ORIF with locking plates for the treatment of three and four-part fractures without dislocation. Similar to the first trial, fractures with displacement of >50% of the head from the shaft were excluded because of the perception of poor outcomes; however, valgus-impacted fractures were not excluded. At one year, there were no statistical or clinical differences between the two groups in terms of the Constant score or the American Shoulder and Elbow Surgeons (ASES) score.

Nonoperative Treatment Versus Hemiarthroplasty

Two trials compared nonoperative treatment with hemiarthroplasty for the treatment of four-part fractures. The first trial was conducted by Olerud et al.[10], the same Swedish group that conducted the first trial comparing nonoperative treatment with locking-plate fixation for the treatment of three-part fractures[9]. As a corollary to the first study, the authors randomized patients with four-part fractures to either nonoperative treatment or hemiarthroplasty. The inclusion criteria were identical to those in their earlier trial, with the inclusion of all patients fifty-five years and older without cognitive impairment. Similarly, valgus-impacted fractures and completely translated fractures were excluded. The findings at two years were similar as well: Constant and DASH scores as well as range of motion were not statistically different, although the study was underpowered. There was a trend toward better scores in the hemiarthroplasty group, with the HRQoL as measured with the EQ-5D being statistically significant and clinically different in favor of the hemiarthroplasty group ($p = 0.02$).

In the second trial, by Boons et al., fifty patients with an age of sixty-five years or older who had four-part fractures were randomized to nonoperative treatment or hemiarthroplasty[11]. No specific fracture patterns were excluded except for dislocations. Patients were excluded if they were cognitively impaired or were medically unfit to undergo an operation. The outcomes at one year showed no difference in Constant and Simple Shoulder Test (SST) scores or visual analog scores for pain.

Hemiarthroplasty Versus Reverse Shoulder Arthroplasty

Two Level-II studies compared the results of hemiarthroplasty with those of reverse shoulder arthroplasty for the treatment of three and four-part fractures in the elderly[56,58]. In the first investigation, Cuff and Pupello studied fifty-three consecutive patients with an age of seventy years or older who had a four-part fracture, head-split fracture, or a three-part fracture with severe comminution of the greater tuberosity[58]. There was no randomization in that study, but the first twenty-six consecutive patients were managed with hemiarthroplasty and the next twenty-six were managed with reverse shoulder arthroplasty; there were no significant differences between the cohorts. At two years of follow-up, the investigators found clinically relevant and statistically significant differences in terms of the ASES (p = 0.0001) and SST (p = 0.0062) scores in favor of reverse shoulder arthroplasty. Forward flexion was 139° in the reverse shoulder arthroplasty group and 100° in the hemiarthroplasty group, but there was no difference between the groups in terms of external and internal rotation. Three patients in the hemiarthroplasty group elected to undergo conversion to reverse shoulder arthroplasty, but the overall complication rates in the two groups were similar.

In the second investigation, Sebastiá-Forcada et al. studied sixty-two patients with an age of more than seventy years who were randomized to hemiarthroplasty or reverse shoulder arthroplasty for the treatment of four-part fractures, nonreconstructable three-part fractures (including dislocations), and head-split fractures[56]. At two years of follow-up, the reverse shoulder arthroplasty group had significantly and clinically relevant advantages in terms of the Constant, University of California at Los Angeles (UCLA), and DASH scores (p = 0.001). The average forward elevation was 120° in the reverse shoulder arthroplasty group, compared with 80° in the hemiarthroplasty group. There were more complications in the hemiarthroplasty group, including six conversions of hemiarthroplasty to reverse shoulder arthroplasty.

Summary

There is substantial variability in the treatment of proximal humeral fractures because of a general lack of consensus with regard to the optimal treatment for the most complex fractures. Advancing technology, such as proximal humeral locking plates and reverse total shoulder arthroplasty, combined with a growing number of well-done trials, has the potential to lead to better consensus in the near future. Currently, the general recommendation is to treat almost all fractures (excluding dislocations) nonoperatively for physiologically older patients, with ORIF for physiologically younger and active patients, and with reverse shoulder arthroplasty when reconstruction is not possible. Attention to key technical aspects of the procedures is critical to avoid complications (Table I).

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References

1. Court-Brown CM, Garg A, McQueen MM. The epidemiology of proximal humeral fractures. Acta Orthop Scand. 2001 Aug;72(4):365-71.

2. Koval KJ, Gallagher MA, Marsicano JG, Cuomo F, McShinawy A, Zuckerman JD. Functional outcome after minimally displaced fractures of the proximal part of the humerus. J Bone Joint Surg Am. 1997 Feb;79(2):203-7.

3. Neer CS 2nd. Displaced proximal humeral fractures. I. Classification and evaluation. J Bone Joint Surg Am. 1970 Sep;52(6):1077-89.

4. Robinson CM, Amin AK, Godley KC, Murray IR, White TO. Modern perspectives of open reduction and plate fixation of proximal humerus fractures. J Orthop Trauma. 2011 Oct; 25(10):618-29.

5. Murray IR, Amin AK, White TO, Robinson CM. Proximal humeral fractures: current concepts in classification, treatment and outcomes. J Bone Joint Surg Br. 2011 Jan;93(1):1-11.

6. Sidor ML, Zuckerman JD, Lyon T, Koval K, Cuomo F, Schoenberg N. The Neer classification system for proximal humeral fractures. An assessment of interobserver reliability and intraobserver reproducibility. J Bone Joint Surg Am. 1993 Dec;75(12):1745-50.

7. Bernstein J, Adler LM, Blank JE, Dalsey RM, Williams GR, Iannotti JP. Evaluation of the Neer system of classification of proximal humeral fractures with computerized tomographic scans and plain radiographs. J Bone Joint Surg Am. 1996 Sep;78(9):1371-5.

8. Bell JE, Leung BC, Spratt KF, Koval KJ, Weinstein JD, Goodman DC, Tosteson AN. Trends and variation in incidence, surgical treatment, and repeat surgery of proximal humeral fractures in the elderly. J Bone Joint Surg Am. 2011 Jan 19;93(2):121-31.

9. Olerud P, Ahrengart L, Ponzer S, Saving J, Tidermark J. Internal fixation versus nonoperative treatment of displaced 3-part proximal humeral fractures in elderly patients: a randomized controlled trial. J Shoulder Elbow Surg. 2011 Jul;20(5):747-55. Epub 2011 Mar 24.

10. Olerud P, Ahrengart L, Ponzer S, Saving J, Tidermark J. Hemiarthroplasty versus nonoperative treatment of displaced 4-part proximal humeral fractures in elderly patients: a randomized controlled trial. J Shoulder Elbow Surg. 2011 Oct;20(7):1025-33. Epub 2011 Jul 23.

11. Boons HW, Goosen JH, van Grinsven S, van Susante JL, van Loon CJ. Hemiarthroplasty for humeral four-part fractures for patients 65 years and older: a randomized controlled trial. Clin Orthop Relat Res. 2012 Dec;470(12): 3483-91. Epub 2012 Aug 16.

12. Fjalestad T, Hole MO, Hovden IAH, Blücher J, Strømsøe K. Surgical treatment with an angular stable plate for complex displaced proximal humeral fractures in elderly patients: a randomized controlled trial. J Orthop Trauma. 2012 Feb;26(2):98-106.

13. Court-Brown CM, Caesar B. Epidemiology of adult fractures: A review. Injury. 2006 Aug;37(8): 691-7. Epub 2006 Jun 30.

14. Lind T, Krøner K, Jensen J. The epidemiology of fractures of the proximal humerus. Arch Orthop Trauma Surg. 1989;108(5):285-7.

15. Rothberg D, Higgins T. Fractures of the proximal humerus. Orthop Clin North Am. 2013 Jan;44(1):9-19.

16. Neer CS 2nd. Displaced proximal humeral fractures. II. Treatment of three-part and four-part displacement. J Bone Joint Surg Am. 1970 Sep;52(6):1090-103.

17. Sjödén GO, Movin T, Aspelin P, Güntner P, Shalabi A. 3D-radiographic analysis does not improve the Neer and AO classifications of proximal humeral fractures. Acta Orthop Scand. 1999 Aug;70(4):325-8.

18. Sjödén GO, Movin T, Güntner P, Aspelin P, Ahrengart L, Ersmark H, Sperber A. Poor reproducibility of classification of proximal humeral fractures. Additional CT of minor value. Acta Orthop Scand. 1997 Jun;68(3):239-42.

19. Brunner A, Honigmann P, Treumann T, Babst R. The impact of stereo-visualisation of three-dimensional CT datasets on the inter- and intraobserver reliability of the AO/OTA and Neer classifications in the assessment of fractures of the proximal humerus. J Bone Joint Surg Br. 2009 Jun;91(6):766-71.

20. Olerud P, Ahrengart L, Söderqvist A, Saving J, Tidermark J. Quality of life and functional outcome after a 2-part proximal humeral fracture: a prospective cohort study on 50 patients treated with a locking plate. J Shoulder Elbow Surg. 2010 Sep;19(6):814-22. Epub 2010 Mar 19.

21. Court-Brown CM, Cattermole H, McQueen MM. Impacted valgus fractures (B1.1) of the proximal humerus. The results of non-operative treatment. J Bone Joint Surg Br. 2002 May;84(4): 504-8.

22. Robinson CM, Page RS. Severely impacted valgus proximal humeral fractures. Results of operative treatment. J Bone Joint Surg Am. 2003 Sep;85(9):1647-55.

23. Robinson CM, Page RS. Severely impacted valgus proximal humeral fractures. J Bone Joint Surg Am. 2004 Sep;86(Pt 2)(Suppl 1):143-55.

24. Court-Brown CM, McQueen MM. The impacted varus (A2.2) proximal humeral fracture: prediction of outcome and results of nonoperative treatment in 99 patients. Acta Orthop Scand. 2004 Dec;75(6):736-40.

25. Boileau P, Chuinard C, Le Huec JC, Walch G, Trojani C. Proximal humerus fracture sequelae: impact of a new radiographic classification on arthroplasty. Clin Orthop Relat Res. 2006 Jan; 442(442):121-30.

26. Owsley KC, Gorczyca JT. Fracture displacement and screw cutout after open reduction and locked plate fixation of proximal humeral fractures [corrected]. J Bone Joint Surg Am. 2008 Feb;90(2):233-40.

27. Solberg BD, Moon CN, Franco DP, Paiement GD. Locked plating of 3- and 4-part proximal humerus fractures in older patients: the effect of initial fracture pattern on outcome. J Orthop Trauma. 2009 Feb;23(2):113-9.

28. Court-Brown CM, Garg A, McQueen MM. The translated two-part fracture of the proximal humerus. Epidemiology and outcome in the older patient. J Bone Joint Surg Br. 2001 Aug;83(6):799-804.

29. Court-Brown CM, McQueen MM. Nonunions of the proximal humerus: their prevalence and functional outcome. J Trauma. 2008 Jun;64(6):1517-21.

30. Bono CM, Renard R, Levine RG, Levy AS. Effect of displacement of fractures of the greater tuberosity on the mechanics of the shoulder. J Bone Joint Surg Br. 2001 Sep;83(7):1056-62.

31. Platzer P, Kutscha-Lissberg F, Lehr S, Vecsei V, Gaebler C. The influence of displacement on shoulder function in patients with minimally displaced fractures of the greater tuberosity. Injury. 2005 Oct;36(10):1185-9. Epub 2005 Jun 16.

32. Gaebler C, McQueen MM, Court-Brown CM. Minimally displaced proximal humeral fractures: epidemiology and outcome in 507 cases. Acta Orthop Scand. 2003 Oct;74(5):580-5.

33. Boileau P, Trojani C, Walch G, Krishnan SG, Romeo A, Sinnerton R. Shoulder arthroplasty for the treatment of the sequelae of fractures of the proximal humerus. J Shoulder Elbow Surg. 2001 Jul-Aug;10(4):299-308.

34. Antuña SA, Sperling JW, Sánchez-Sotelo J, Cofield RH. Shoulder arthroplasty for proximal humeral malunions: long-term results. J Shoulder Elbow Surg. 2002 Mar-Apr;11(2):122-9.

35. Antuña SA, Sperling JW, Sánchez-Sotelo J, Cofield RH. Shoulder arthroplasty for proximal humeral nonunions. J Shoulder Elbow Surg. 2002 Mar-Apr;11(2):114-21.

36. Röderer G, Erhardt J, Graf M, Kinzl L, Gebhard F. Clinical results for minimally invasive locked plating of proximal humerus fractures. J Orthop Trauma. 2010 Jul;24(7):400-6.

37. Brunner A, Weller K, Thormann S, Jöckel JA, Babst R. Closed reduction and minimally invasive percutaneous fixation of proximal humerus fractures using the Humerusblock. J Orthop Trauma. 2010 Jul;24(7):407-13.

38. Laflamme GY, Rouleau DM, Berry GK, Beaumont PH, Reindl R, Harvey EJ. Percutaneous humeral plating of fractures of the proximal humerus: results of a prospective multicenter clinical trial. J Orthop Trauma. 2008 Mar;22(3):153-8.

39. Südkamp N, Bayer J, Hepp P, Voigt C, Oestern H, Kääb M, Luo C, Plecko M, Wendt K, Köstler W, Konrad G. Open reduction and internal fixation of proximal humeral fractures with use of the locking proximal humerus plate. Results of a prospective, multicenter, observational study. J Bone Joint Surg Am. 2009 Jun;91(6):1320-8.

40. Thanasas C, Kontakis G, Angoules A, Limb D, Giannoudis P. Treatment of proximal humerus fractures with locking plates: a systematic review. J Shoulder Elbow Surg. 2009 Nov-Dec;18(6):837-44. Epub 2009 Sep 12.

41. Gardner MJ, Boraiah S, Helfet DL, Lorich DG. Indirect medial reduction and strut support of proximal humerus fractures using an endosteal implant. J Orthop Trauma. 2008 Mar;22(3):195-200.

42. Bai L, Fu Z, An S, Zhang P, Zhang D, Jiang B. Effect of Calcar Screw Use in Surgical Neck Fractures of the Proximal Humerus With Unstable Medial Support: A Biomechanical Study. J Orthop Trauma. 2014 Aug;28(8):452-7.

43. Bae JH, Oh JK, Chon CS, Oh CW, Hwang JH, Yoon YC. The biomechanical performance of locking plate fixation with intramedullary fibular strut graft augmentation in the treatment of unstable fractures of the proximal humerus. J Bone Joint Surg Br. 2011 Jul;93(7):937-41.

44. Gardner MJ, Boraiah S, Helfet DL, Lorich DG. The anterolateral acromial approach for fractures of the proximal humerus. J Orthop Trauma. 2008 Feb;22(2):132-7.

45. Bernard J, Charalambides C, Aderinto J, Mok D. Early failure of intramedullary nailing for proximal humeral fractures. Injury. 2000 Dec;31(10):789-92.

46. Rajasekhar C, Ray PS, Bhamra MS. Fixation of proximal humeral fractures with the Polarus nail. J Shoulder Elbow Surg. 2001 Jan-Feb;10(1):7-10.

47. Knierim AE, Bollinger AJ, Wirth MA, Fehringer EV. Short, locked humeral nailing via Neviaser portal: an anatomic study. J Orthop Trauma. 2013 Feb;27(2):63-7.

48. Lekic N, Montero NM, Takemoto RC, Davidovitch RI, Egol KA. Treatment of two-part proximal humerus fractures: intramedullary nail compared to locked plating. HSS J. 2012 Jul;8(2):86-91. Epub 2012 May 12.

49. Konrad G, Audigé L, Lambert S, Hertel R, Südkamp NP. Similar outcomes for nail versus plate fixation of three-part proximal humeral fractures. Clin Orthop Relat Res. 2012 Feb;470(2):602-9. Epub 2011 Aug 31.

50. Nolan BM, Kippe MA, Wiater JM, Nowinski GP. Surgical treatment of displaced proximal humerus fractures with a short intramedullary nail. J Shoulder Elbow Surg. 2011 Dec;20(8):1241-7. Epub 2011 Mar 21.

51. Adedapo AO, Ikpeme JO. The results of internal fixation of three- and four-part proximal humeral fractures with the Polarus nail. Injury. 2001 Mar;32(2):115-21.

52. Handoll HHG, Ollivere BJ, Rollins KE. Interventions for treating proximal humeral fractures in adults. Cochrane Database Syst Rev. 2012;12:CD000434. Epub 2012 Dec 12.

53. Boudard G, Pomares G, Milin L, Lemonnier I, Coudane H, Mainard D, Delagoutte JP. Locking plate fixation versus antegrade nailing of 3- and 4-part proximal humerus fractures in patients without osteoporosis. Comparative retrospective study of 63 cases. Orthop Traumatol Surg Res. 2014 Dec;100(8):917-24. Epub 2014 Nov 13.

54. Kontakis G, Koutras C, Tosounidis T, Giannoudis P. Early management of proximal humeral fractures with hemiarthroplasty: a systematic review. J Bone Joint Surg Br. 2008 Nov;90(11):1407-13.

55. Antuña SA, Sperling JW, Cofield RH. Shoulder hemiarthroplasty for acute fractures of the proximal humerus: a minimum five-year follow-up. J Shoulder Elbow Surg. 2008 Mar-Apr;17(2):202-9. Epub 2008 Jan 11.

56. Sebastiá-Forcada E, Cebrián-Gómez R, Lizaur-Utrilla A, Gil-Guillén V. Reverse shoulder arthroplasty versus hemiarthroplasty for acute proximal humeral fractures. A blinded, randomized, controlled, prospective study. J Shoulder Elbow Surg. 2014 Oct;23(10):1419-26. Epub 2014 Jul 30.

57. Cuff D, Clark R, Pupello D, Frankle M. Reverse shoulder arthroplasty for the treatment of rotator cuff deficiency: a concise follow-up, at a minimum of five years, of a previous report. J Bone Joint Surg Am. 2012 Nov 7;94(21):1996-2000.

58. Cuff DJ, Pupello DR. Comparison of hemiarthroplasty and reverse shoulder arthroplasty for the treatment of proximal humeral fractures in elderly patients. J Bone Joint Surg Am. 2013 Nov 20;95(22):2050-5.

59. Wright JG, Einhorn TA, Heckman JD. Grades of recommendation. J Bone Joint Surg Am. 2005 Sep;87(9):1909-10.