Arthroplasty for Proximal Humerus Fractures: A Review of Current Management

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Summary: Surgical treatment options for proximal humerus fractures (PHFs) include osteosynthesis and arthroplasty. In general, arthroplasty is reserved for comminuted 3-part and most 4-part fracture in which there is a high risk of tuberosity malunion and humeral head avascular necrosis. Traditionally, hemiarthroplasty has been the preferred arthroplasty option. More recently, however, there has been a trend towards the use of primary reverse total shoulder arthroplasty to treat such fractures. Its use is particularly relevant in cases with increased risk of tuberosity malunion. This paper reviews the anatomy and classifications of PHF, and discusses indications and contraindications for hemiarthroplasty and reverse total shoulder procedures in the setting of PHF.

Key Words: arthroplasty—reverse total shoulder—proximal humerus fracture—hemiarthroplasty.

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Proximal humerus fractures (PHFs) account for 4% to 10% of all fractures in the elderly,[1–4] are the second most common fracture of the upper extremity,[5] and the third most common fracture overall behind hip and distal radius fractures.[2,4] PHFs frequently result from a low-energy mechanism such as a fall from standing, in elderly women, and the incidence is predicted to triple by 2030.[6] The high correlation with osteoporosis[7] may complicate surgical management—especially with respect to osteosynthesis and tuberosity union during hemiarthroplasty.

Fifteen percent of PHFs will ultimately require operative intervention.[8] Surgical outcomes are multifactorial and depend on the magnitude and location of displacement, congruency with the glenohumeral joint, and other risk factors such as osteoporosis. Although the advent of fixed-angle locking plate constructs has improved and enhanced our osteosynthesis capabilities, this technique is not without complication.[9,10] In fact, some of these patients do achieve good range of motion return initially,[11–13] but have complication rates as high as 40% to 60%.[13–15] Most concerning among these complications is avascular necrosis (AVN)[16] resulting in chronic pain, functional loss, and reoperation.[17,18] AVN may necessitate revision surgery for conversion of failed open reduction internal fixation (ORIF) to hemiarthroplasty.[19,20]

Hemiarthroplasty for 4-part PHFs was first described by Neer in 1970.[8] Arthroplasty can provide adequate pain relief in patients with 4-part PHFs with Constant scores ranging from the 60s to 70s.[21–25] The most common reason for subpar outcome are tuberosity nonunion and prosthesis malalignment.[19,26–31] More recently, some authors suggested the use of primary reverse total shoulder arthroplasty (RTSA) for patients at high risk for tuberosity nonunion.[32–35]

CLASSIFICATION SYSTEM

The most widely used classification scheme is the Neer.[36] Fractures of the proximal humerus are described with up to 4 anatomic parts: the less tuberosity, the greater tuberosity, the humeral head, and the humeral shaft. Forty-five degrees of angulation or 1 cm of displacement is required to qualify as a part—with the exception of the greater tuberosity which only requires 0.5 cm of displacement.[36] The Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification focuses more on the fracture pattern and its impact on humeral head vascularity.[37,38] Type A are least likely for vascular compromise and type C are most at risk of AVN.[39] Although comprehensive, it is rarely used clinically, as it is significantly time and labor intensive, as well as findings of low interobserver and intraobserver reliability.[40–44] Without a perfect classification system, Neer's original scheme remains the most frequently used (Fig. 1).

ANATOMY OF HUMERAL HEAD

Deforming Forces

The glenohumeral articulation is stabilized by a complex arrangement of static and dynamic stabilizers, which are particularly important when treating PHFs (Fig. 2). The greater tuberosity is displaced posteromedially by the pull of the rotator cuff muscles, the lesser tuberosity is displaced medially by the subscapularis, and the humeral shaft is displaced medially by the pectoralis major and abducted by the deltoid.[46,47]

Blood Supply

The therapeutic crossroad between ORIF and hemiarthroplasty is most affected by the blood supply of the humeral head (Fig. 3). Three major vessels, the anterior circumflex humeral artery (ACHA), its terminal branch the arcuate artery, and the posterior circumflex humeral artery (PCHA) provide vascularity to the humeral head. Initial studies suggested that the primary humeral head blood supply came from the ACHA and that the posterior portion of the humeral head and the greater tuberosity were supplied by the PCHA.[49,50] Recent work has changed this philosophy by presenting evidence of the PCHA that it is not only anatomically larger than the ACHA, but also provides the greatest perfusion to the

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The authors declare that they have nothing to disclose.

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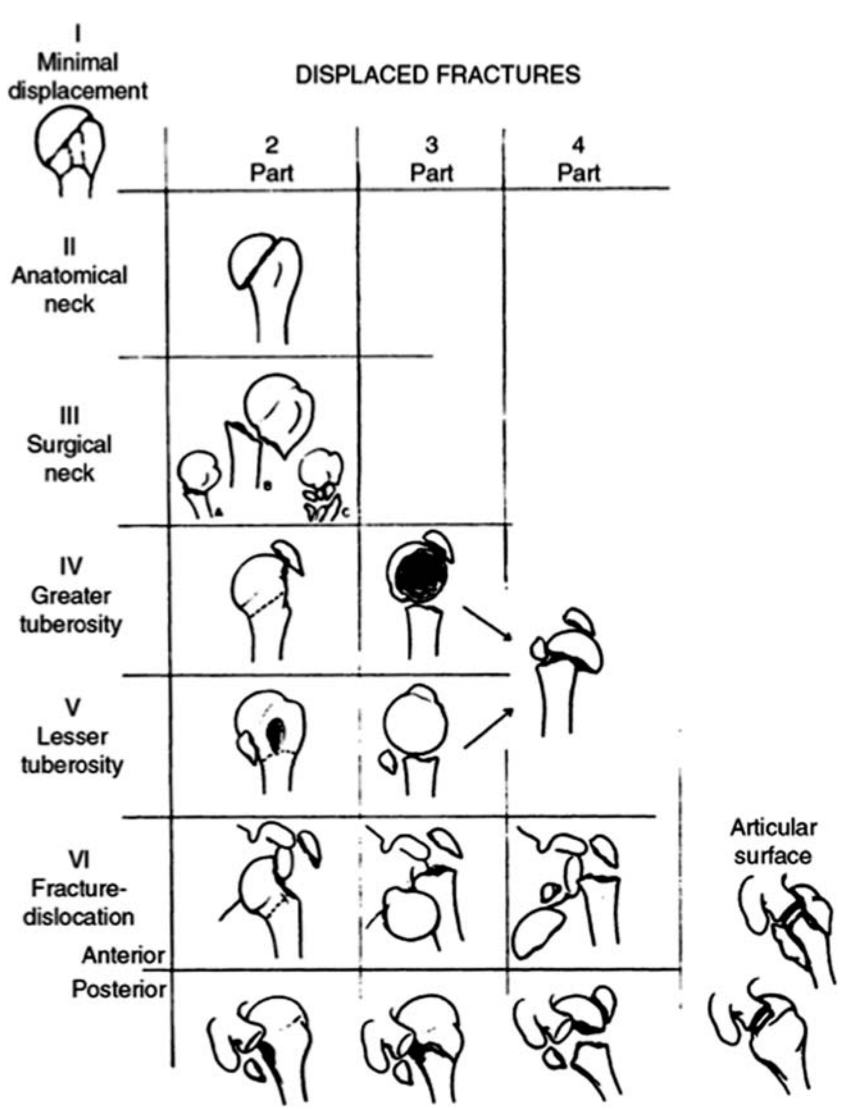

FIGURE 1. This figure describes the original Neer classification for proximal humerus fractures based on number of displaced parts in addition to amount of angulation. Reprinted with permission from Neer.[36] Copyright Neer, Lexington, SC. All permission requests for this image should be made to the copyright holder.

head.[48,51] Hettrich and colleagues quantified the contribution of each vessel to humeral head perfusion using of gadolinium uptake on magnetic resonance imaging in a cadaveric model. Contrary to classic teaching, they discovered that the ACHA supplied only 36% of the arterial blood flow, whereas the PCHA supplied up to 64% of the total vascularity to the humeral head.[48] This finding changed the perspective of PHFs and has given new importance to anatomic dissection during operative fixation.

HEMIARTHROPLASTY FOR PHFS

Indications for Arthroplasty and Risk of AVN

Fracture characteristics and patient-related factors are critical to consider planning operative intervention (Table 1). As previously noted, gauging the risk of progression to humeral head AVN is the most critical consideration when deciding between arthroplasty and ORIF. AVN can be difficult to predict, and improper risk stratification may lead to improper surgical management and ultimately reoperation.[53] Boileau et al[52] characterized the theoretical risk of AVN based on the fracture pattern. The incidence of osteonecrosis is <10% for 2-part fractures and 10% to 25% in 3-part fracture, hence many are managed nonoperatively or with ORIF. Four-part fractures, however, have AVN rates approaching 60%. When a 4-part fracture occurs concomitantly with dislocation, the rate of AVN range from 80% to 100% in the literature.[52] As such, many surgeons prefer to preform hemiarthroplasty in the setting of 4-part PHF. Valgus-impacted 4-part PHF may be an exception as medial soft tissues remain intact which lowers the rate of osteonecrosis to only 25% to 30%.[52] The potential for preserved blood supply enabled reliable results using osteosynthesis.[9,54,55] Focusing on the medial soft-tissue hinge, some authors recommend that 3- and 4-part PHF with >20 degrees of varus angulation be treated with primary hemiarthroplasty and not ORIF.[55] Exact criteria for hemiarthroplasty versus ORIF remain controversial and in some case may depend on the

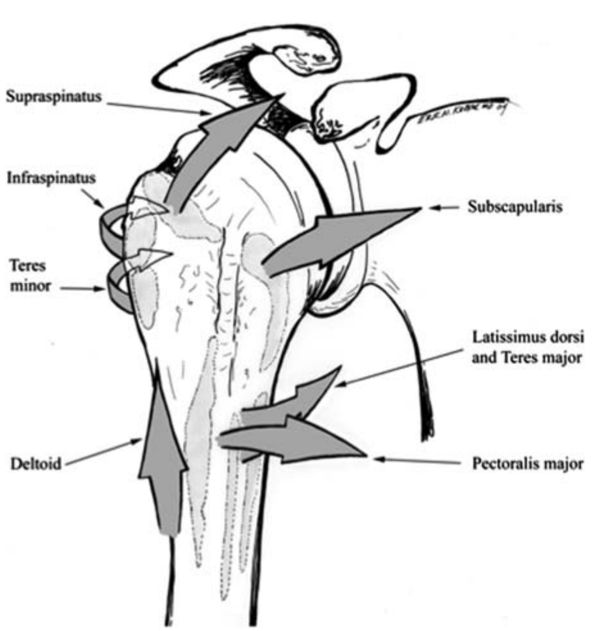

FIGURE 2. This illustration demonstrates the deforming forces that occur after fracture of proximal humerus. The supraspinatus exerts a force posteromedially. The infraspinatus and teres minor pull posteromedially and externally rotate. The subscapularis exerts an anteromedially directed force on the lesser tuberosity. The pectoralis major internally rotates and adducts, whereas the deltoid pulls superiorly on the metadiaphysis of the humerus. Reprinted with permission from Gruson et al.[45] Copyright Gruson, New York, NY. All permission requests for this image should be made to the copyright holder.

surgeon's level of comfort and experience with each surgical procedure.

Patient characteristics are another important factor within the treatment algorithm. Poor bone stock in the setting of osteoporosis, for example, can negatively impact healing and lead to hardware failure during ORIF. Such patients may do better if treated with replacement. An assessment of the patient's rotator cuff is important as well. A functional rotator cuff is crucial to the long-term success of a shoulder hemiarthroplasty.[56] Elderly and female patients tend to have lower functional scores following hemiarthroplasty when compared with younger, male patients.[57]

Hemiarthroplasty Technique

The authors prefer a modified beach chair position with the head of the bed elevated to 45 degrees and the arm draped freely to allow for extension. The cephalic vein is identified and the deltopectoral approach is exploited. Subdeltoid and subacromial adhesions are bluntly released and the bicipital groove is identified. Mason-Allen sutures are placed in the rotator cuff tendons for facilitate tuberosity manipulation. The intertuberosity fracture line can be located slightly posterior to the groove in most fracture patterns. The humeral head is then removed and the proximal humeral shaft exposed with medial and lateral Bennett retractors. The intramedullary canal is prepared with sequential reaming followed by broaching. During this step, the surgeon must determine the correct height for the humeral component using the aforementioned anatomic landmarks.

Two holes are drilled 1.5 cm distal to the fracture site for transosseous sutures. Two sutures are passed through the distal humeral holes. The first suture is passed from the outside into

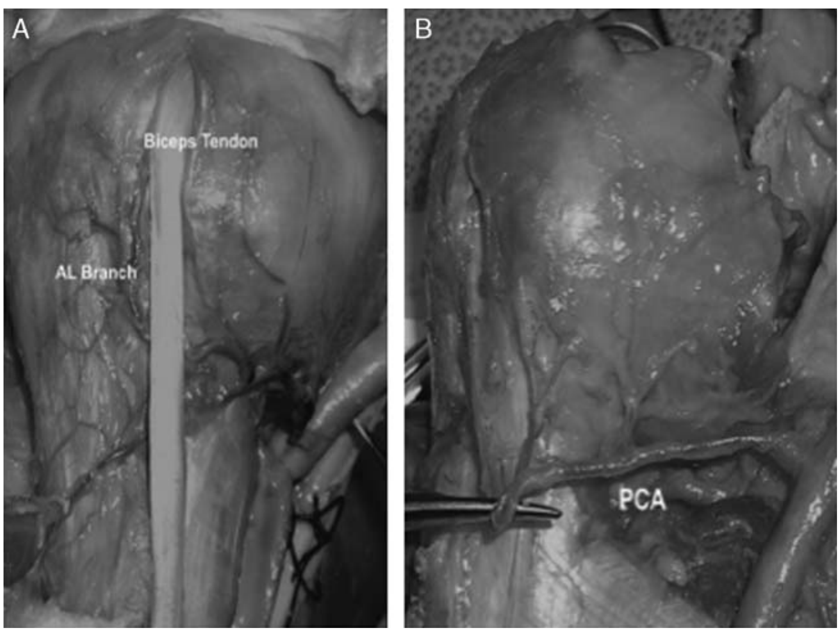

FIGURE 3. B, The posterior circumflex artery is less adherent to the proximal humerus making it less likely to be severed during a fracture, whereas (A) the anterior humeral circumflex is more adherent increasing vulnerability to during trauma. Reprinted with permission from Hettrich et al.[48] Copyright Hettrich, Lexington, SC. All permission requests for this image should be made to the copyright holder.

TABLE 1. Approximate Risk, Based on Current Literature, of Humeral Head ON After PHF

Type of Proximal Humerus Fracture	Theoretical Risk of Humeral Head Osteonecrosis (%)
2-part displaced	< 10
3-part displaced	10-25
4-part valgus impacted	25-30
4-part displaced	40-60
4-part dislocated	80-100

ON indicates osteonecrosis; PHF, proximal humerus fracture.

Estimated percent risk of avascular necrosis of the humeral head after proximal humerus fracture based on number of parts and angulation of the fracture. Reprinted with permission from Boileau et al.[52] Copyright Boileau, New York, NY. All permission requests for this image should be made to the copyright holder.

the canal in the distal to proximal direction, which will be used to secure the greater tuberosity to the fracture stem. Then next suture is placed anterior to posterior to be used as a figure-of-eight suture to pass through both tuberosities after they are fixed to the stem and each other. Cemented versus noncemented implant use is patient specific and determined by bone quality and extent of fracture. Whenever possible, we prefer a noncemented stem. A trial reduction should be performed before final implants to ensure sizing and stability in the anterior inferior and posterior directions. Once satisfied with stability, a final prosthetic head is placed.

After the prosthesis is secured and reduced, attention is turned to systematically tying the tuberosity sutures to the prosthesis and each other. First, the middle suture in the greater tuberosity (GT) fragment is passed around the implant through the implant fins. Then, the longitudinal suture placed in the distal drill hole in the shaft is brought around the GT. Next, the top and bottom sutures of the GT fragment are brought inside-out through the lesser tuberosity. Then the greater tuberosity is brought to the anterior fin of the implant and fixed 5 mm distal to the top of the humeral head. The middle sutures through the GT and the posterolateral distal hole sutures are securely tied. Following this the top and buttom sutures through the lesser tuberosity (LT) are tied, reducing LT to GT. The suture placed distal to proximal in the shaft is brought over top of the tuberosities in a figure-of-eight manner.

After securing the tuberosities in this systematic manner, the stability of the repair is checked with the range of motion. The senior authors accept a minimum of 150 degrees of forward elevation. Then the prosthesis and tuberosity reduction is checked with a portable radiograph.

Hemiarthroplasty Outcomes and Complications

Reported functional outcomes following hemiarthroplasties are variable. It is important to consider that the surgical technique heavily impacts outcomes. Furthermore, the majority of hemiarthroplasty are performed by surgeons who average only 3 hemiarthroplasty cases per year.[58] In a meta-analysis of hemiarthroplasty (HA) studies, results of the surgery were considered unsatisfactory to over 40% of patients.[58]

One randomized-control trial (RCT) compared hemiarthroplasty to nonoperative management in 55 patients with acute 4-part PHFs.[59] The results statistically favored the HA group in terms of health-related quality-of-life scores. Although the disabilities of the arm, shoulder and hand score and pain assessments were improved in the hemiarthroplasty group, the results were not statistically significant and there was no significant difference between the 2 groups for range of motion.[59] A larger, multicenter RCT is currently underway comparing HA to nonoperative management,[60] whereas a separate multicenter RCT is collecting data to compare HA to osteosynthesis in 3- and 4-part PHFs.[61] These 2 studies promise to add to the body of literature that surgeon's can draw from when deciding how to manage these difficult 3- and 4-part PHFs.

The current literature consistently demonstrates that prosthesis positioning and tuberosity union are crucial to functional outcome following hemiarthroplasty. Although individual techniques vary, tuberosity management is most successfully performed with traction sutures through the rotator cuff tendons and not the bone to avoid additional comminution. These sutures are then passed circumferentially such that fixation is achieved to one another and the prosthesis itself. The most common reason for failure of a hemiarthroplasty is tuberosity nonunion.[62]

In the coronal plane, the greater tuberosity position is defined by the head-to-tuberosity distance, which is between 3 and 20 mm in cadaver specimens.[63] In a review of 23 patients, Loebenberg et al[64] reported better forward elevation of the arm with a head-to-tuberosity distance of 10 to 16 mm. This number was greater than the 5 to 10 mm classically described by Boileau and colleagues.[65] In addition to the height of the GT, the extent of greater tuberosity lateralization is essential in restoring the rotator cuff lever arm.[66] The success of HA relies on a functional rotator cuff, whereas reverse total arthroplasty does not. As a consequence, there is a stronger relationship between tuberosity positioning and outcome for HA as compared with RTSA.[66]

Despite this relationship, tuberosity placement remains one of the more challenging and unpredictable parts of a HA. This is evidenced by 1 study that reported that 50% of HA had malpositioned GT and LT, a finding that is highly associated with poor outcomes.[30] In a retrospective review, Boileau reported on 60 patients treated with hemiarthroplasty. He noted significantly higher functional outcomes, Constant score of 69 versus 54, when the GT was positioned anatomically.[30,67] A recent study by the same author reported higher rates of tuberosity healing, 87%, when a fracture stem prosthesis was used as opposed to 45% in the standard stem group, which the authors related to improved GT lateralization with the ability to use bone graft in the fracture stem.[67]

Humeral height is another important intraoperative factor that impacts the long-term success of shoulder hemiarthroplasty. Shortening humeral height lessens deltoid strength by shortening its lever arm. The most reliable method of determining appropriate humeral prosthesis height is to use the superior border of the pectoralis major tendon as a guide.[69,70] Murachovsky et al[68] reported that the height of the humeral head should correspond to 5.6 cm proximal to the superior border of the pectoralis tendon.[68]

Rotation of the prosthetic stem determines the amount of retroversion of the prosthetic head, which is also critical for surgical outcome. The normal anatomic retroversion of the humeral head is 20 degrees with respect to the trans-epicondylar line, and most surgeons attempt to restore this amount when placing the stem. Boileau and colleagues found higher rates of tuberosity migration when the stem was positioned in over 40 degrees of anteversion.[30]

Aseptic loosening is uncommon, but was reported in 2 of 37 hemiarthroplasties.[72] Similarly, the incidence of proximal humerus component migration reported by meta-analysis of

810 cases of hemiarthroplasty was 6.8%.[58] The same study reported infection rates of 1.6% with superficial infection and 0.6% deep.[58] Other reported complications in addition to loosening of the prosthesis, tuberosity nonunion, or migration and infection include heterotopic ossification and glenohumeral dislocation or subluxation.[67]

REVERSE TOTAL SHOULDER ARTHROPLASTY FOR PHFS

Complications of hemiarthroplasty such as positioning of the prosthesis, rotator cuff tear, and tuberosity nonunion can considerably change outcomes. Although initially designed as an option for patients with cuff tear arthroplasty, some surgeons now advocate the use of primary RTSA in the setting of PHF to limit the unpredictable nature of hemiarthroplasty outcomes. This specific design improves the deltoid's moment arm by both medialization of the center of rotation of the shoulder and moving the insertion site distally improving elevation and abduction of the humerus.[69]

Indications for RTSA

The indications have expanded for RTSA outside of rotator cuff deficiency, with increasing familiarity of with the procedure and further literature demonstrating poor outcomes after tuberosity malunion in hemiarthroplasty. Despite these new indications, the key in any surgery is correct patient selection. The predictability of tuberosity union is effected by patient-associated comorbidities including comminution, osteoporosis, female sex, in addition to smoking, diabetes, and peripheral vascular disease.[65,70–72] After evaluation of risk factors, an essential part of the assessment involves the patient's preinjury shoulder function, if previous glenohumeral arthritis is found, RTSA should be strongly considered.[73] Even with proper risk stratification, placement of the correct tuberosity position can be difficult as noted by Boileau et al,[30] where up to 50% of patient treated with hemiarthroplasty for PHFs had malpositioning. This frequent complication is a strong argument to preform RTSA, in which tuberosity positioning, union, and functional outcomes have less correlation with outcome. Overall RTSA in acute PHFs and as a salvage procedure after failed hemiarthroplasty continue to expand. As a result, all of these factors should be taken into consideration when the surgeon decides on appropriate management.

Reverse Total Shoulder (Author's Technique)

The senior authors' technique is similar to those applied for rotator cuff arthropathy; however, there is significant focus on tuberosity reconstruction (Fig. 4). The patient is placed in the Semi-Fowlers position, with the arm draped free and lateralized enough to allow full extension in adduction throughout the case. The approach used is a standard deltopectoral approach and once adequate exposure is obtained, each tuberosity is tagged at the bone tendon interface with heavy nonabsorbable sutures. The humeral head fragments are removed, and the humeral shaft is reamed by hand to prevent iatrogenic fracture or fracture propagation.

Following humeral preparation, retractors are placed to facilitate exposure of the entire glenoid. The glenoid is reamed, and the implant-specific baseplate is impacted into place and secured with screw fixation. A trial glenosphere is subsequently inserted, and attention is again directed to the humeral shaft, which is finally prepared for insertion of the humeral stem component. Before placement of the stem, 2 drill holes are created posterolaterally and posteromedially to the bicipital groove to insert 2 heavy nonabsorbable sutures to aid in fixation of the tuberosities.

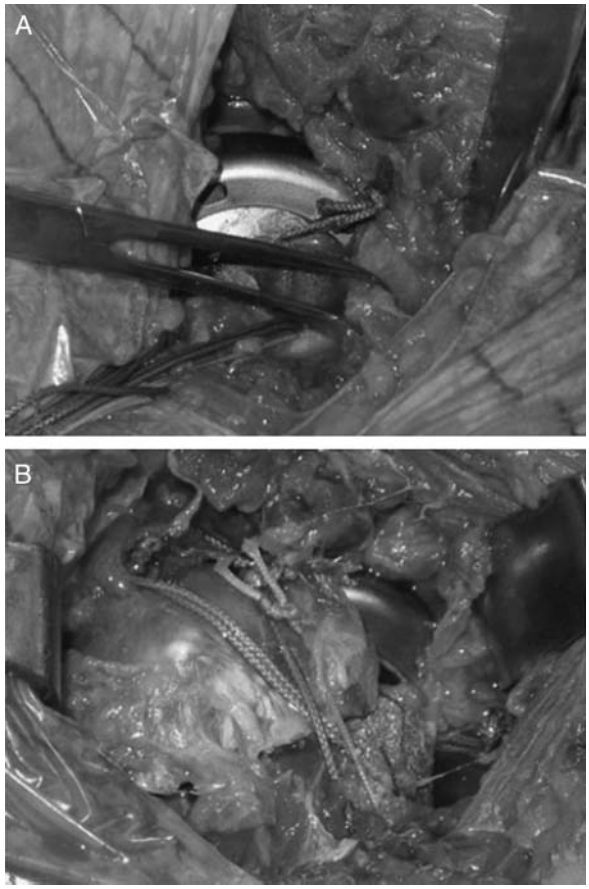

FIGURE 4. The author's intraoperative photos of a tuberosity repair after reverse total shoulder arthroplasty. A, Transverse and longitudinal placement of the sutures. B, The final placement and reconstruction of the tuberosities.

The humeral component is placed in 20 to 30 degrees of retroversion, and trial reduction is performed. Range of motion and deltoid tension are carefully assessed, the trial implants are removed and the final glenosphere is impacted into place. The humeral stem is subsequently inserted (press fit or cemented).

At this point, attention is directed toward careful reconstruction of the greater and lesser tuberosities. The transverse sutures initially placed within the tuberosities are placed around the medial aspect of the humerus and passed through the other tuberosity in an "inside-out" manner at the muscle—tendon junction and a minimum of 2 to 4 transverse sutures are placed. Next, the final humeral tray component is impacted, and the joint is reduced. The longitudinal sutures previously placed through the shaft are subsequently passed through the superior portion of the greater and lesser tuberosities. The transverse sutures are tied followed by the longitudinal sutures. The shoulder is passively abducted and rotated to ensure that the reconstruction is stable. Final wound closure is performed over drains if necessary.

Postoperative Rehabilitation

Patients are immobilized in a shoulder sling with an abduction pillow for a minimum of 6 weeks to facilitate union of the greater and lesser tuberosities. During this period, active distal range of motion is encouraged, and gentle passive range of motion to 120 degrees in pendulum exercises are initiated to facilitate shoulder range of motion. If follow-up radiographs reveal adequate tuberosity healing with no evidence of migration, active range of motion is initiated at approximately 6 weeks postoperatively.

Results of RTSA After Acute PHFs

Short-term outcome data for RTSA is limited to small retrospective series. These studies, highlight 2 important concepts: that functional outcome is not reliant upon tuberosity union and that there is a relatively high complication rate. These points warrant consideration when considering RTSA and during patient education.

Lenarz et al[74] retrospectively reviewed 30 patients, with Neer 3- or 4-part fractures and a mean follow-up of 23 months (12 to 36 mo). Their mean age was 77 years and they reported short-term improvement in shoulder function as well as pain with average active external rotation of 27 degrees (0 to 45 degrees) and active flexion of 130 degrees (90 to 180 degrees). Their outcomes scores demonstrated effective pain relief with the mean American Shoulder and Elbow Surgeons (ASES) score of 78 (36 to 98) and the mean postoperative visual analog score of 1.1 (0 to 5). They demonstrated excellent range of motion scores, although there was limited focus on the tuberosity outcomes.

Bufquin et al[34] prospectively evaluated 43 consecutive patients (mean age 78 y), with a mean follow-up of 22 months (6 to 58 mo). They only achieved tuberosity fixation in 41.5% of patients (17 of 43 patients). This low rate of fixation resulted in decreased external rotation but the Constant scores remained similar at a mean of 44 (16 to 69). For range of motion scores, their mean active flexion was 97 degrees (35 to 160 degrees) and mean external rotation was 30 degrees (0 to 80 degrees). In addition, they had a complication rate of 29.2%, including scapular notching in over 25% of patients, neuropraxia, reflex sympathetic dystrophy, deltoid dehiscence, and anterior dislocation. They concluded after RTSA, adequate shoulder range of motion could be achieved despite frequent loss of tuberosity fixation.

A recent retrospective study by Grisch et al,[75] studied 29 patients (mean age 80 y), with a mean follow-up of 17 months (12 to 60 mo). All patients had either 3- or 4-part PHFs. They reported excellent outcomes scores, with an average Constant score of 67 (34 to 84). Range of motion at final follow-up consisted of a mean forward flexion of 130 degrees (80 to 160 degrees), and mean external rotation of 21 degrees (−30 to 70 degrees). In addition, they reported no decline in functional outcomes from the first to the second year of follow-up and all patients returned to baseline activity level. Their complication rate of 10.4% (3 patients) included 2 hematomas and 1 periprosthetic fracture. Although longer follow-up continues to be warranted, this study demonstrated excellent short-term results.

Longer follow-up has only recently been published. One study looked at 36 patients (mean age 75 y), with a follow-up of 6.6 years (1 to 16 y).[76] A majority of these patients had osteoporotic fractures confirmed by pathology and 27.7% (10 of 36) were fracture-dislocations. Of note, their Constant scores decreased on average from 58.5 to 53 from 1- to 6-year follow-up, respectively. Despite increased high rates of radiographic evidence of glenoid loosening and scapular notching, their complication rate was 20%. Only 1 patient underwent revision, which occurred 12 years postoperatively. Further long-term follow-up studies must be carried out for a final consensus on RTSA but these results do prompt continued investigation into longer-term outcomes.

Comparison of Hemiarthroplasty Versus RTSA

Gallinet and colleagues retrospectively evaluated 40 patients who underwent either hemiarthroplasty (21 patients) or RTSA (19 patients) for complex 3- and 4-part fractures. The functional outcomes favored the RTSA group.[77] The mean follow-up was 16.5 months for hemiarthroplasty patients and 12.4 months for RTSA group. Overall, the RTSA group had better range of motion scores with mean abduction and forward flexion of 91 and 97.5 degrees, respectively, compared with 60 and 53.5 degrees in the hemiarthroplasty group. In addition, the Constant scores of RTSA were 14 points higher than the hemiarthroplasty group (53 vs. 39). They demonstrated that overall functionally the RTSA has better outcomes.

Another study compared 47 consecutive patients (23 hemiarthroplasty and 24 RTSA), with an average follow-up of 30 months.[78] Again, all patients had complex 3 or 4-part fractures with either severe greater tuberosity comminution or an articular humeral head split. At 1 year postoperatively, 39% (9 of 23) of the hemiarthroplasty group had tuberosity reabsorption, and 17% (4 of 24) of the RTSA had reabsorption. Significantly better outcomes were noted in the RTSA. The RTSA group had a mean ASES score of 77. The hemiarthroplasty group had a mean ASES score of 62. For range of motion, average forward flexion was 139 degrees in the RTSA group and 100 degrees in the hemiarthroplasty group. Interestingly, if the tuberosities united then hemiarthroplasty had good results (61% of the time). They concluded that due to he unpredictability of tuberosity healing potential, RTSA has significantly better outcomes in patients greater than 70 years old.

Midterm results were evaluated by Garrigues et al[79] in 19 patients (9 hemiarthroplasty with mean age of 69 y and 10 RTSA with mean age of 80.5 y), with an average follow-up of 3.6 years (1.3 to 8 y). ASES scores for the RTSA group were substantially better than those of hemiarthroplasty (81 vs. 47). In addition, RTSA outperformed hemiarthroplasty with regard to range of motion: mean active forward flexion of 122 versus 90 degrees and active external rotation of 33 versus 31 degrees. Despite good results the RTSA had a complication rate of 44% compared with the hemiarthroplasty group of 10%. They concluded that longer-term follow-up for RTSA shows promising results but the cost and longevity of the patient must be taken into account before making a final surgical decision (Fig. 5).

RTSA for Failed Hemiarthroplasty

Until the invention of the RTSA, many complications and failures after a hemiarthroplasty were not revisable. Recently more literature has evaluated outcomes of RTSA after failed hemiarthroplasty for PHFs. These complications associated with failure include rotator cuff insufficiency, glenoid wear, glenohumeral malalignment, and humeral bone loss. This technical challenge presents another potential role for the RTSA in PHFs management.

Levy et al[80] reported on a series of 29 patients with failed hemiarthroplasties that were revised to RTSA (mean age 69 y) with a mean follow-up of 35 months. All hemiarthroplasty failures were related to tuberosity malunion or resportion, or to glenoid wear. All patients had significantly improved shoulder

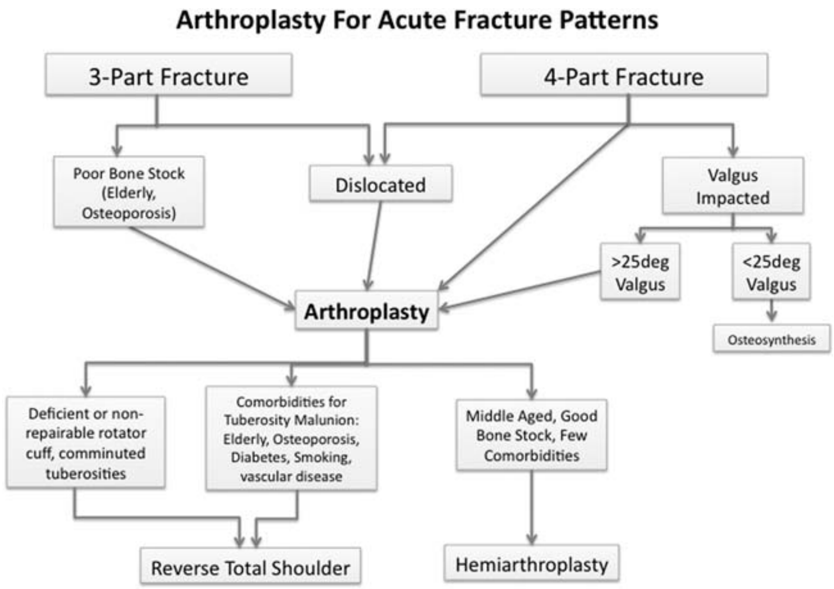

FIGURE 5. The authors' preferred arthroplasty treatment algorithm after acute proximal humerus fracture. Patient's with most 3- and 4-part fractures and deficient rotator cuff, comminuted tuberosities, or comorbidities for tuberosity malunion (elderly, osteoporosis, diabetes, smoking, or vascular disease) all are strong indications for reverse total shoulder rather than standard hemiarthroplasty.

outcome scores and range of motion. Their mean ASES score was 52.1, which was improved from 22.3 preoperatively. The mean active forward flexion improved from 38.1 to 72.7 degrees postoperatively. Overall their complication rate was 28%.

Boileau et al[81] reviewed 19 patients (mean age 67 y) with mean follow-up of 40 months, who all underwent conversion to RTSA for failed hemiarthroplasty. They reported an improvement in mean forward flexion from 56 to 113 degrees as well as improvement in ASES and Constant scores. They concluded that RTSA is a good treatment option for complications associated with primary hemiarthroplasty.

CONCLUSIONS

Complex 3 and 4-part PHFs are a complicated surgical problem. Open reduction and internal fixation allows preservation of the anatomic relationships, bone stock, and humeral head vascularity. In those fracture patterns where the risk of AVN is unacceptably high or patient-specific factors limit its success, arthroplasty options may be considered. Historically, hemiarthroplasty is the answer for such patients, but outcomes are heavily reliant upon technical and biological factors. More recently, RTSA has come into the spotlight. Proponents suggest that RTSA can help offset potential complicating factors such as severe osteoporosis, rotator cuff pathology, tuberosity resorption or malunion that are common in this patient population. Early reports for RTSA show its promise, but also note a high complication rate. It becomes difficult to make concrete recommendations with a lack of RCT and prospective literature. Overall the best management has yet to be determined and varies based on the surgeons experience and familiarity with all potential surgical options.

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