Surgical Management of Proximal Humeral Fractures: The Emerging Role of Reverse Total Shoulder Arthroplasty

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abstract

Acute proximal humeral fractures are common injuries in elderly patients. These fractures can lead to significant pain and functional loss. Nonoperative treatment offers high rates of satisfactory function and pain relief in the majority of fractures, particularly in elderly patients. Open reduction and internal fixation, closed reduction and percutaneous pinning, and hemiarthroplasty are used for treating displaced proximal humeral fractures, depending on patient and fracture characteristics. Recently, reverse total shoulder arthroplasty has gained popularity for treatment of complex proximal humeral fractures due to a rapid recovery of active elevation and activities of daily living function. Although complications remain a concern, early results of reverse total shoulder arthroplasty for proximal humeral fractures have been promising. Future comparative outcome studies are needed to define the indications for reverse total shoulder arthroplasty instead of nonoperative and other operative options. Optimal treatment of proximal humeral fractures requires clinical judgment based on fracture characteristics, bone quality, patient factors, and surgeon experience with the array of available techniques. [*Orthopedics*. 2016; 39(3):e465-e473.]

Proximal humeral fractures account for 4% to 5% of all fractures, particularly afflicting osteoporotic elderly patients after low-energy trauma.[1] According to data from a 2008 Nationwide Emergency Department sample study, 370,000 emergency department visits were for humeral fractures, 50% of which were for fractures of the proximal humerus.[2] Proximal humeral fractures have been increasing in incidence as life expectancy has increased in recent decades.[3,4] Patients sustaining proximal humeral fractures often have significant pain and functional loss, particularly those with 3- and 4-part fractures.[5-7]

Multiple treatment options exist for proximal humeral fractures, including nonoperative treatment,[5,6,8] closed reduction and percutaneous pinning (CRPP),[9,10] open reduction and internal fixation (ORIF),[6,11-13] transosseous suture fixation,[14] and hemiarthroplasty,[5,13] and there has been a recent trend toward increased

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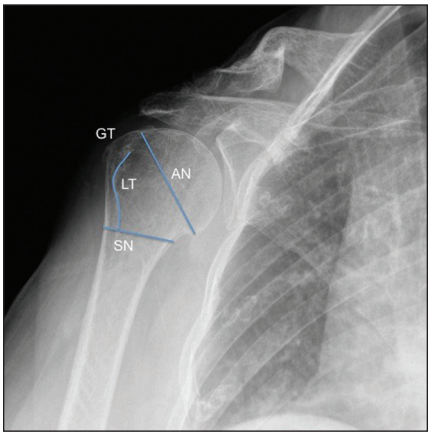

Figure 1: The Neer classification divides the proximal humerus into 4 segments: surgical neck (SN), greater tuberosity (GT), lesser tuberosity (LT), and anatomic neck (AN).

use of primary reverse total shoulder arthroplasty (TSA).[15-31] The indications for the various surgical options continue to evolve, but superiority of operative over nonoperative treatment has not been clearly established, and nonoperative treatment often yields satisfactory functional outcomes in complex fractures with low rates of subsequent surgery.[32,33] Although controversy continues to surround treatment of this fracture, optimal treatment for patients with proximal humeral fractures depends on patient factors, fracture characteristics, bone quality, and surgeon preference and experience. The purpose of this review is to provide an overview of management for proximal humeral fractures, with emphasis on studies comparing different treatment options and the emerging use of reverse TSA for acute proximal humeral fractures.

Classification

The Neer classification is most commonly used to evaluate proximal humeral fractures and guide treatment.[34] Neer's classification divides the proximal humerus into 4 segments based on physeal lines: surgical neck, greater tuberosity, lesser tuberosity, and anatomic neck (**Figure 1**).[34,35] Based on these segments, Neer then classifies fractures based on number of fracture parts, with a separate part defined as displaced more than 1 cm or angulated more than 45°.[34] The greater tuberosity is classified as a part if there is greater than 5 mm of displacement. Neer classification is one consideration in determining surgical treatment, along with patient factors such as age, bone quality, rotator cuff status, and glenohumeral degenerative changes. Younger patients generally undergo ORIF or CRPP for Neer 2-, 3-, and 4-part fractures, whereas older patients more often undergo hemiarthroplasty or reverse TSA for 3- and 4-part fractures.

The AO/OTA classification of proximal humeral fractures is less commonly used than the Neer classification but has the advantage of encompassing head-splitting fractures and separating valgus-impacted anatomic neck fractures as a distinct entity from true 4-part fractures.[36] In some cases, computed tomography (CT) may be obtained in addition to plain radiographs for enhanced fracture pattern delineation. Nevertheless, several studies have found substantial interobserver variability of both AO and Neer classification systems and minimal to no improvement of interobserver reliability of Neer or AO classification with the addition of CT to plain radiographs.[37-40] The current authors recommend the use of CT on a selective basis when the fracture pattern is equivocal on plain radiographs and treatment choice could be affected by the CT scan. The main indications for CT are to assess tuberosity comminution, suspected head-split or head-depression fractures, and possible fracture-dislocation. For example, if CT showed nonreconstructable tuberosities due to comminution, this might sway treatment toward reverse TSA. A suspected head-split or associated glenoid rim fracture in a young patient would benefit from CT for preoperative planning to ensure these lesions were optimally addressed during ORIF. Magnetic resonance imaging (MRI) is not routinely performed but may be used in select cases to provide further information on rotator cuff tear and fatty infiltration. Other classification systems and modifications besides the Neer and AO/OTA have been proposed, but these are the 2 most commonly used.

Consideration of proximal humeral blood supply based on fracture pattern is an additional important factor in determining treatment. Historically, the anterior circumflex humeral artery was deemed to be the primary source of proximal humeral vascularity, but Hettrich et al[41] recently determined that the posterior humeral circumflex contributes approximately two-thirds of the blood supply to the proximal humerus. Hertel et al[42] defined radiographic criteria predictive of humeral head ischemia after proximal humeral fracture: metaphyseal head extension less than 8 mm (ie, the amount of posteromedial metaphysis remaining attached to the humeral head), medial hinge disruption greater than 2 mm (based on continuity of medial calcar), and anatomic neck fracture pattern. Hertel et al[42] found that if all 3 factors are present, there was a 97% positive predictive value for humeral head ischemia. The information is a useful adjunct to the Neer classification when weighing the surgical treatment options for proximal humeral fractures because development of symptomatic avascular necrosis of the proximal humerus following ORIF could result in a secondary arthroplasty procedure. However, recent evidence indicates that there may be no relationship between humeral head osteonecrosis and shoulder outcome scores, so humeral head osteonecrosis may be commonly asymptomatic in the setting of good rotator cuff function from an intact rotator cuff and anatomically positioned tuberosities.[10]

Nonoperative Treatment

In most cases, proximal humeral fractures are nondisplaced or minimally displaced and can be managed nonoperatively.[34,43] In addition, nonoperative treatment of valgus-impacted fractures and dis-

placed 2-part surgical neck fractures yields outcomes similar to operative fixation, particularly in elderly patients.[44-46] Some authors have reported satisfactory results in approximately half of 2-part greater tuberosity fractures and in fewer than half of 3- and 4-part fractures.[34,43,47] Fractures involving the humeral articular surface (head-splitting), those in varus alignment, and those with medialized surgical neck are more amenable to operative management. Patient factors are critical in treatment decision making, including age, bone quality, and activity level.

However, more recently, Edelson et al[32] evaluated the natural history of 63 nonoperatively treated displaced 3-part and shield fractures in patients with an average age of 66 years and a mean follow-up of 42 months. They found significant loss of motion (forward flexion, 72% of the uninjured side; external rotation with arm at the side, 53%; external and internal rotation with 90° abduction, 60% and 55%, respectively), but with acceptable pain and function on the simple shoulder test. Malunions occurred in all cases. There was 1 case of nonunion (1.6%) and 1 case of AVN (1.6%), but neither patient went on to subsequent surgery.[32] Hanson et al[33] reported the results of nonoperative management of 160 proximal humeral fractures at 1-year follow-up in patients with a mean age of 63 years, although only 25 (16%) were Neer 3- or 4-part fractures. They found small but significant differences between preoperative status (Disabilities of the Arm, Shoulder and Hand [DASH] score decrease from baseline of 10.2 points) and the contralateral shoulder (Constant score difference, 8.2). Eleven (7%) patients had delayed or nonunion, 4 (3%) had internal fixation, and 5 (3%) had subacromial impingement requiring subacromial decompression.[33]

Nonoperative treatment typically involves a brief period of sling immobilization followed by early mobilization within a week of injury. For displaced or unstable fractures, initial immobilization may be longer. Pendulum exercises and passive range of motion (ROM) are begun first. Based on fracture healing and pain, supine passive ROM exercises typically begin at 4 to 6 weeks after injury, with active ROM beginning 6 to 8 weeks after injury.

Several randomized, controlled trials have compared early vs delayed mobilization of proximal humeral fractures.[48-50] Hodgson et al[48,49] randomized patients with minimally displaced proximal humeral fractures to initiate therapy within 1 week of fracture vs immobilization for 3 weeks followed by therapy. They found significantly greater disability by the Croft shoulder disability questionnaire in the delayed therapy group at 1-year follow-up, which was no longer significant at 2-year follow-up.[49] Pain and shoulder function were significantly better in the early mobilization group at 16-week follow-up, but these differences were no longer significant at 1-year follow-up.[48] Lefevre-Colau et al[50] randomized patients to early therapy within 3 days of fracture vs 3 weeks of immobilization, finding significantly better Constant score and pain in the early therapy group at 6 weeks and 3 months, although Constant scores no longer significantly favored the early mobilization group at 6 months. Neither study noted cases of displacement or nonunion in the early motion group.[48,50] Overall, the literature suggests that early mobilization after proximal humeral fracture is safe and improves short-term recovery, although with long-term follow-up there may be no difference.

Fracture Fixation: Open Reduction and Internal Fixation Versus Closed Reduction Percutaneous Fixation

Isolated Greater Tuberosity Fractures

For greater tuberosity fractures displaced greater than 5 mm that could lead to subsequent impingement or rotator cuff dysfunction, the small size and relative osteopenia of the fracture fragment is often insufficient for plate fixation. Authors have reported success with open reduction and tension band fixation with a figure-of-eight construct incorporating the rotator cuff.[14] More recently, transosseous sutures and transosseous-equivalent technique using suture anchors have superseded tension band constructs for displaced greater tuberosity fractures.[51] Operative treatment of these displaced greater tuberosity fractures has been reported to result in superior outcomes compared with nonoperative treatment.[52]

Closed Reduction and Percutanous Pinning

Closed reduction and percutaneous pin fixation is a viable option, particularly for patients with adequate bone stock and 2- or 3-part fractures. This technique may be appropriate for displaced surgical neck fractures and valgus impacted fractures with intact medial hinge. Medial calcar comminution is a contraindication to pinning, and other treatments should be considered. Percutaneous fixation avoids dissection and can result in stable fixation, early motion, and good early clinical results.[53] Harrison et al[10] reported intermediate outcomes of CRPP at a mean of 50 months, with a 26% rate of osteonecrosis and 37% rate of posttraumatic osteoarthritis correlated directly with increasing number of Neer parts. None of the patients undergoing CRPP for 2-part fractures had osteonecrosis or posttraumatic arthritis at follow-up.[10]

Open Reduction and Internal Fixation

Open reduction and internal fixation with plate fixation is an option for displaced 2-, 3-, and 4-part proximal humeral fractures, particularly in younger patients. Nonoperative treatment has been reported to yield poor results for many patients with 3- and 4-part fractures as well as 2-part greater tuberosity fractures.[43,47] However, more recent studies argue that for older patients, nonoperative treatment can provide satisfactory results with modest functional deficits despite radiographic

Figure 2: Anteroposterior (A, C) and scapular Y (B, D) radiographs of a displaced and impacted 4-part proximal humeral fracture (A, B) with valgus orientation and partially intact medial hinge. This fracture was treated with open reduction and internal fixation with a proximal humeral locking plate and supplementary lag screw fixation into the lesser tuberosity (C, D).

malunion.[33,54] A multicenter prospective cohort study found that both nonoperative and operative treatments were successful for 2-part surgical neck fractures, with significant differences noted for early postoperative ROM and pain reduction but no differences in final follow-up ROM and functional outcomes.[55]

Several randomized, controlled trials have failed to show significant differences in outcome between nonoperative treatment vs ORIF of 3- and 4-part proximal humeral fractures.[5,6,56] Fjalestad et al[56] randomized patients to ORIF vs nonoperative treatment of displaced 3- and 4-part fractures and reported improved radiographic outcomes in the ORIF group but no significant difference in American Shoulder and Elbow Surgeons (ASES) score or Constant score at 1-year follow-up. Olerud et al[6] randomized patients with 3-part fractures to ORIF with locking plate vs nonoperative treatment and reported a trend toward improved health-related quality of life and functional outcomes for ORIF, although this was not statistically significant. Moreover, 30% of patients in the ORIF group underwent additional surgery at 2-year follow-up.[6] Finally, Zyto et al[8] randomized patients with displaced 3- and 4-part proximal humeral fractures to nonoperative treatment vs tension band osteosynthesis and reported improved radiological outcomes for operative treatment without a difference in functional outcome. Therefore, the decision between ORIF and nonoperative treatment depends on the consideration of multiple factors, including fracture pattern, displacement, patient age and medical comorbidities, and patient functional demands. For younger patients, ORIF is generally indicated for displaced fractures given higher patient functional demands and better bone quality (**Figure 2**).

Benefits of ORIF when compared with arthroplasty include preservation of bone stock and avoidance of arthroplasty-related complications such as loosening and wear. Benefits of ORIF when compared with nonoperative treatment include anatomic reduction, a decreased rate of malunion or nonunion, and the ability to begin early motion. Disadvantages of ORIF include loss of reduction, loss of fixation, screw cutout or intra-articular migration, avascular necrosis, and stiffness.[11,12,57]

HEMIARTHROPLASTY

In cases of 3- and 4-part proximal humeral fractures, particularly with osteoporotic bone, hemiarthroplasty is a viable treatment option resulting in pain relief but often not a full return to baseline function (**Figure 3**).[26,58,59] The current authors' ideal hemiarthroplasty patient characteristics are outlined in **Table 1**.

Although hemiarthroplasty avoids some complications of ORIF, such as humeral head avascular necrosis, it introduces a different set of complications, including nonunion of the tuberosities, infection, glenoid wear, and subsequent failure of the rotator cuff with proximal humeral migration and pseudoparalysis.[58-64] The loss of anatomic landmarks can make reconstruction of the center of rotation and reconstruction of the tuberosities challenging.[65] The single greatest

determinant of postoperative function is tuberosity malnunion, nonunion, and/or resorption.[59,64,66] A recent comprehensive systematic review found an overall complication rate of 11.3% for hemiarthroplasty, compared with 15% for ORIF, 28.4% for CRPP, and 18.9% for reverse TSA.[67] Tuberosity nonunion was estimated at 15.4% for hemiarthroplasty. Within this systematic review,[67] although patients who underwent ORIF were younger on average, multivariate regression controlling for age demonstrated ORIF to have improved DASH and Constant scores as compared with hemiarthroplasty and reverse TSA. However, ORIF had the highest reoperation rate.[67] Two conflicting randomized clinical trials compared nonoperative treatment with hemiarthroplasty for 4-part proximal humeral fractures. Olerud et al[5] conducted a study comparing hemiarthroplasty with nonoperative treatment for 4-part fractures. At an average follow-up of 2 years, the authors noted improved health-related quality of life and EuroQol Five Dimensions Health Index and DASH scores in the hemiarthroplasty group but no differences in ROM. In contrast, Boons et al[68] conducted a similar study and noted that at an average follow-up of 1 year, there were no differences in Constant or Simple Shoulder Test scores. Cai et al[69] randomized elderly patients with a mean age of 71.9 years into hemiarthroplasty vs locking plate ORIF for displaced 4-part proximal humeral fractures. At 2-year follow-up, they noted slight benefits of functional outcomes and health-related quality of life in favor of hemiarthroplasty, although these differences were statistically insignificant.[69]

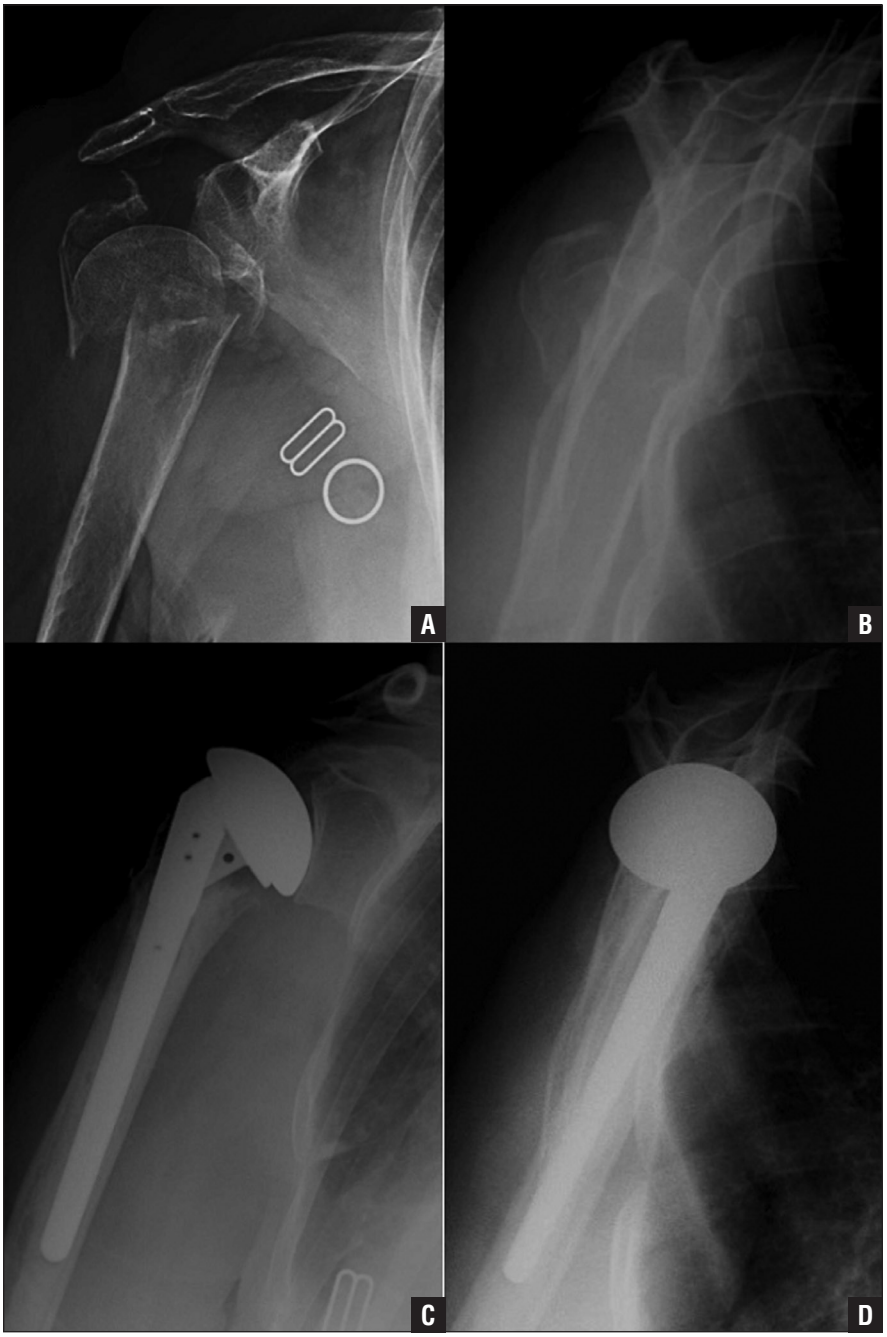

Figure 3: Anteroposterior (A, C) and scapular Y (B, D) radiographs of a displaced and impacted 4-part proximal humeral fracture (A, B) with complete loss of the medial calcar. This injury was treated with a cemented humeral hemiarthroplasty (C, D).

Reverse Total Shoulder Arthroplasty

Although initially developed for rotator cuff arthropathy, reverse TSA has gained in popularity in recent years for treatment of acute, complex, 3- and 4-part proximal humeral fractures in elderly patients (**Figure 4**).[29] Indications are controversial and not well established. The current authors' relative indications for reverse TSA include complex 3- and 4-part proximal humeral fractures in patients aged older than 70 years, nonreconstructable fractures, symptomatic nonunion or malunion, fractures with a high risk of avascular necrosis, preexisting arthritis, or the presence of a rotator cuff tear (**Table 2**). The preinjury status of the rotator cuff of the involved shoulder is usually unknown, and given the known increased in-

Table 1

Characteristics of the Ideal Patient for Hemiarthroplasty

Characteristic	Value
Age	Typically 50-70 y, "physiologically young"
Bone quality	No metadiaphyseal comminution, intact calcar
Fracture pattern	Humeral head unreconstructable, risk of ischemic head based on Hertel criteria
Timing	Optimal timing 6-14 d after injury for hemiarthroplasty and tuberosity osteosynthesis
Tuberosities	Intact fragments, no comminution
Preceeding arthritis	None
Preceeding rotator cuff pathology	None
Range of motion	Ability to raise arm above shoulder level prior to injury

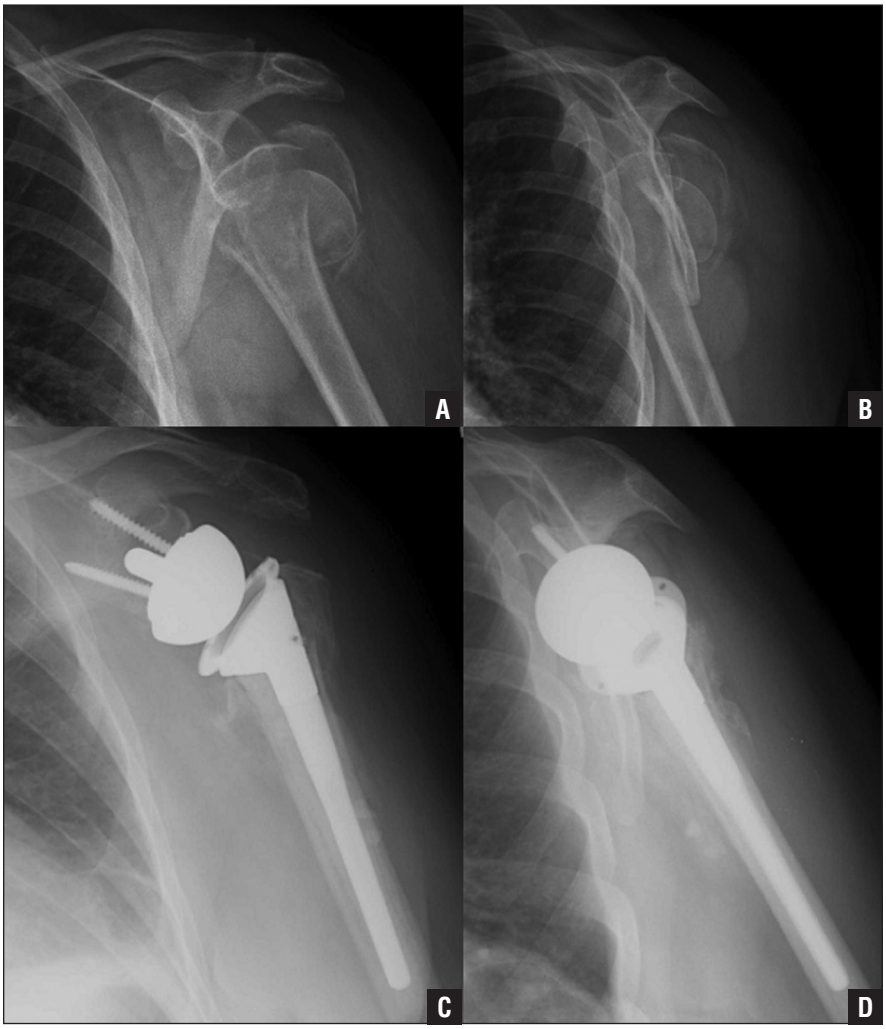

Figure 4: Anteroposterior (A, C) and scapular Y (B, D) radiographs of a displaced and impacted 4-part proximal humeral fracture (A, B) with medialization of the humeral shaft. Based on the fracture pattern age and function of the patient, this injury was treated with a reverse total shoulder arthroplasty (C, D).

cidence of rotator cuff tears with age (both symptomatic and asymptomatic),[70-72] this may be particularly concerning in the elderly patient population with proximal humeral fractures requiring surgical intervention. Rotator cuff tears can also occur at the time of injury. Reverse TSA would be contraindicated in patients with a dysfunctional deltoid or axillary nerve, or in patients with inadequate glenoid bone stock precluding baseplate fixation.[23] Potential benefits include avoidance of the complications of ORIF and hemiarthroplasty as outlined previously. In particular, reverse TSA outcomes are improved with tuberosity healing; however, they are not as critically dependent on greater tuberosity healing as are hemiarthroplasty outcomes. However, if the entire infraspinatus and teres minor are in discontinuity with the humerus, patients will typically have reduced postoperative active external rotation.[19,24,25] In addition, reverse TSA may have a reduced need for postoperative rehabilitation and supervised physiotherapy to achieve active elevation above 90° and activities of daily living function as compared with other treatment strategies.[73]

Outcomes of reverse TSA for complex proximal humeral fractures have been promising at short-term follow-up,[18-22,24,25] with a recent comprehensive systematic review reporting the following outcomes: mean active forward elevation, 114°; mean abduction, 92°; mean active external rotation, 20°; mean ASES score, 76; and mean Constant score, 50.3.[28] The review found that subjective and objective outcomes were similar between the reverse TSA and hemiarthroplasty groups.[28] Tuberosity repair and healing with reverse TSA leads to improved ROM and functional outcomes,[19] but good outcomes can be obtained regardless of tuberosity status, unlike hemiarthroplasty.[19,24,25,74] Long-term outcomes of reverse TSA for proximal humeral fractures are not known, and there is an absence of prospective data demonstrating the superiority of reverse TSA over nonopera-

tive management in elderly patients with proximal humeral fractures. Studies will be needed to define the indications of reverse TSA vs nonoperative and other operative treatment for these fractures.

Comparative studies of reverse TSA and ORIF or hemiarthroplasty for treatment of complex proximal humeral fractures are relatively limited to date. Two prospective studies have been reported,[26,75] both showing better clinical outcomes with similar complication rates and lower revision rates for reverse TSA. Retrospective comparative studies of reverse TSA and hemiarthroplasty have also demonstrated either equivalent or superior clinical outcomes for reverse TSA at reduced cost.[16,17,25,27,30]

Reverse TSA has been associated with high complication rates,[15] with complications including scapular notching, infection, hematoma, instability, baseplate failure, acromial stress fracture, neurologic injury, and periprosthetic fracture. A systematic review reported that the most common complications following reverse TSA for proximal humeral fractures were scapular notching (32%), ectopic ossification (8.7%), inferior spurs (8.1%), dislocation (3.5%), infection (2.9%), humeral bone loss (2.3%), baseplate progressive radiolucent line (2.3%), and reflex sympathetic dystrophy (1.7%).[74] Another study of complications following reverse TSA found that although the overall complication rate was 25%, the majority were minor medical complications, and the major complication rate was 10%.[76] Although common, scapular notching is of unclear clinical significance, and rates of notching are lower with innovations such as inferior translation and tilt and modern implants with lateralized center of rotation.[77] Management of these complications is often challenging. A recent systematic review found a 4-fold-higher rate of postoperative complications in the reverse TSA group compared with the hemiarthroplasty group.[28] However, the prospective comparative studies of reverse TSA and hemiarthroplasty have failed to demonstrate a difference in complications.[26,75] A study of the American Board of Orthopaedic Surgery database also found no difference in complication rate between reverse TSA and hemiarthroplasty for proximal humeral fractures.[29] Overall, complication rates after reverse TSA for proximal humeral fractures may not be as high as previously believed in appropriately selected patients with modern technical and implant improvements, particularly because the clinical significance of the most common complication scapular notching is largely unknown.

Conclusion

Treatment options for proximal humeral fractures include nonoperative treatment, CRPP, ORIF, transosseous suture fixation, hemiarthroplasty, and reverse TSA. Reverse TSA has gained popularity in recent years, particularly in patients older than 70 years with osteopenic bone because it may provide a more consistent outcome compared with hemiarthroplasty due to less dependence on tuberosity healing for an acceptable outcome. Short- and mid-term results of reverse TSA for proximal humeral fractures are promising, with most studies demonstrating equal or superior outcomes compared with alternative treatments. Long-term outcomes are pending. Complications of reverse TSA have been reported to be high and can be difficult to manage, although more recent literature suggests that complication rates may be similar for reverse TSA and hemiarthroplasty. Reverse TSA offers a potentially valuable treatment option for complex proximal humeral fractures in elderly patients, but future prospective studies are needed to assess comparative outcomes vs nonoperative treatment and other surgical options. Future research should address long-term outcomes and further refine indications for the various management options for proximal humeral fractures.

Table 2

Relative Indications for Reverse Total Shoulder Arthroplasty for Proximal Humeral Fractures

Three- and 4-part fractures in patients older than 70 y
Nonreconstructable fractures, particularly of the tuberosities
Symptomatic nonunion or malunion
Fractures with a high risk of avascular necrosis
Preexisting arthritis
Presence of a rotator cuff tear

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