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Cost-effectiveness of Open Reduction and Internal Fixation Compared With Hemiarthroplasty in the Management of Complex Proximal Humerus Fractures

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Abstract

Objectives: To determine if open reduction and internal fixation (ORIF) is more cost-effective than hemiarthroplasty (HA) in the management of proximal humerus fracture.
Design: Retrospective cohort study with cost-effectiveness analysis.
Setting: Tertiary referral center in Rochester, NY.
Patients/participants: The records of 459 consecutive patients in whom a proximal humerus fracture was treated surgically at our institution between the years 2002 and 2012 were studied retrospectively. We identified 30 consecutive patients with a mean follow-up of 60.3 months (13.6–134.5 months) of which 15 patients underwent primary ORIF and another 15 underwent primary HA for the management of head-splitting fracture or fracture-dislocation of the proximal humerus.
Intervention: HA or ORIF for the management of proximal humerus fracture.
Main outcome measurements: SF-36 scores were converted to utility weights, and a cost-effectiveness model was designed to evaluated ORIF and HA.
Results: Given the baseline assumptions, ORIF was slightly more costly but also more effective (0.75 quality-adjusted life years [QALY] vs 0.67 QALY) than HA. The incremental cost-effectiveness ratio (ICER) was $5319/QALY for ORIF compared to HA, which is less than the cost-effectiveness standard utilized based on a willingness to pay of $50,000/QALY.
Conclusions: Compared to HA, ORIF is the more cost-effective approach for the surgical management of complex proximal humerus fractures. These data are limited by patient selection which would impact the relative utility scores. These results suggest that ORIF should be considered the preferable surgical approach given payer and patient perspectives.
Level of Evidence: This is a Level III retrospective, cohort therapeutic study.

Keywords
Open reduction and internal fixation, hemiarthroplasty, complex proximal humerus fractures, open reduction and internal fixation, hemiarthroplasty, cost-effective

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Introduction

Proximal humerus fractures are common and present complicated treatment dilemmas. Complications are commonly encountered when treating displaced, complex proximal humerus fractures nonoperatively which can cause significant functional disability for patients.[1] Surgical management decisions are controversial, and while some authors may advocate for open reduction

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and internal fixation (ORIF), others advocate for arthroplasty, whether hemiarthroplasty (HA) or reverse total shoulder arthroplasty (TSA) for displaced Neer 3- and 4-part fractures.[1–8] Debate remains whether ORIF or HA is superior in adults with complex proximal humerus fractures and fracture-dislocations, and few studies examine the difference in outcomes.[1,7,9]

Proximal humerus fractures account for 10% of all fractures in the elderly and their management consumes significant health-care resources.[10] The number of proximal humerus fractures is expected to triple by 2030 due to the increase in life expectancy trends, further exacerbating the problem.[11] Disproportionate health-care costs are driving proposals to implement practice guidelines that focus on comparative cost-effectiveness, and given the current economic condition in the United States, these considerations will likely influence treatment choices.[12,13] Previous studies comparing ORIF to HA have failed to consider cost, but a recent study from our institution has elucidated some of the factors that drive cost upward in the surgical management of proximal humerus fractures.[14,15] In that study, the most dominant cost drivers included complications and readmission: complications and readmission increased in-hospital cost by 2.44-fold ($P = .011$) and 5.68-fold ($P < .001$), respectively. Perhaps more importantly, ORIF was associated with 29% lower in-hospital cost compared to HA ($P = .011$) after controlling for confounding variables. This study expands upon the prior, with a goal of comparing the cost-effectiveness of the 2 operative approaches for the management of complex proximal humerus fractures using a decision analytic model. We hypothesize that ORIF will be the more cost-effective surgical approach when compared to HA.

Materials and Methods

A decision analytic tree was developed to compare competing operative treatment strategies for the management of complex proximal humeral fractures. The base case scenario was a nonemergent proximal humerus fracture in a middle-aged, otherwise healthy individual who otherwise did not have any other traumatic injuries or complications in their hospital course. The 2 included operative strategies were ORIF and HA. The decision analytic tree was developed using proprietary software (TreeAge Pro 2013 Software, Williamstown, MA) (Figure 1). The tree began at operative intervention for proximal humerus fracture. After choice of ORIF or HA, the tree incorporated the development of perioperative complications within 30 days following surgery. The model then included whether a long-term, procedure-related orthopedic complication occurred: complications most likely requiring revision surgery or disability were included in each cohort. Specific complications in the ORIF cohort were avascular necrosis (AVN) of the humeral head or hardware complications including primary or secondary screw perforation of the humeral head, implant breakage, prominence, or impingement. Included complications in the HA cohort included all tuberosity complications, including malunion, nonunion, and resorption. The decision tree terminal node then concluded with whether or not these complications necessitated a revision operation.

Base case assumptions and sensitivity ranges for uncertainty surrounding these estimates are reported in Table 1. Parameter estimations for the base case scenario were based on best modeling practices.[16] Event probabilities for 30-day perioperative complications, orthopedic-specific complications, and revision rates following ORIF and HA were extracted from literature review.[3,6–8,17–32] In-hospital cost estimates for procedure and perioperative complications were determined using the Medicare Claims database which was evaluated for cases from Monroe County, New York from January 1, 2008 to September 30, 2009, as described previously.[15] Inclusion criteria were Medicare beneficiaries with a primary ICD-9-CM procedure code for ORIF or HA and with a primary ICD-9-CM diagnosis code for proximal humerus fracture. Cases were excluded if inpatient mortality occurred or if cost and demographic data were missing. Perioperative complications were categorized into surgical complications and medical complications and were included if occurring within 30-days postoperatively. Surgical complications included infection, bleeding, or orthopedic-specific complications. Medical complications included cardiac, respiratory, vascular, or renal complications.

Effectiveness was defined using quality-adjusted life years (QALY) based on a single institutional study evaluating clinical outcomes of ORIF versus HA in the management of complex articular fracture and fracture-dislocations of the proximal humerus.[33] SF-36 survey scores obtained from each cohort were converted to utility weights considered over a 1-year time horizon. Each branch of the decision tree was assigned a utility score, a value ranging from 0 to 1 measured in QALYs. A value of 0 represents death, a value of 1 is considered perfect health, and a value between 0 and 1 represents a health state with some level of disability over a 1-year time horizon.

The overall cost-effectiveness was analyzed using the incremental cost-effectiveness ratio (ICER). The ICER is estimated using the difference in cost between the 2 interventions divided by the unit difference in effect, or QALYs in this particular case. The determination of cost-effectiveness was based on the willingness to pay threshold, which was set at \$50 000/QALY, which is consistent with prior US studies.[34,35]

Sensitivity analysis was then performed to incorporate the impact of uncertainty around the baseline

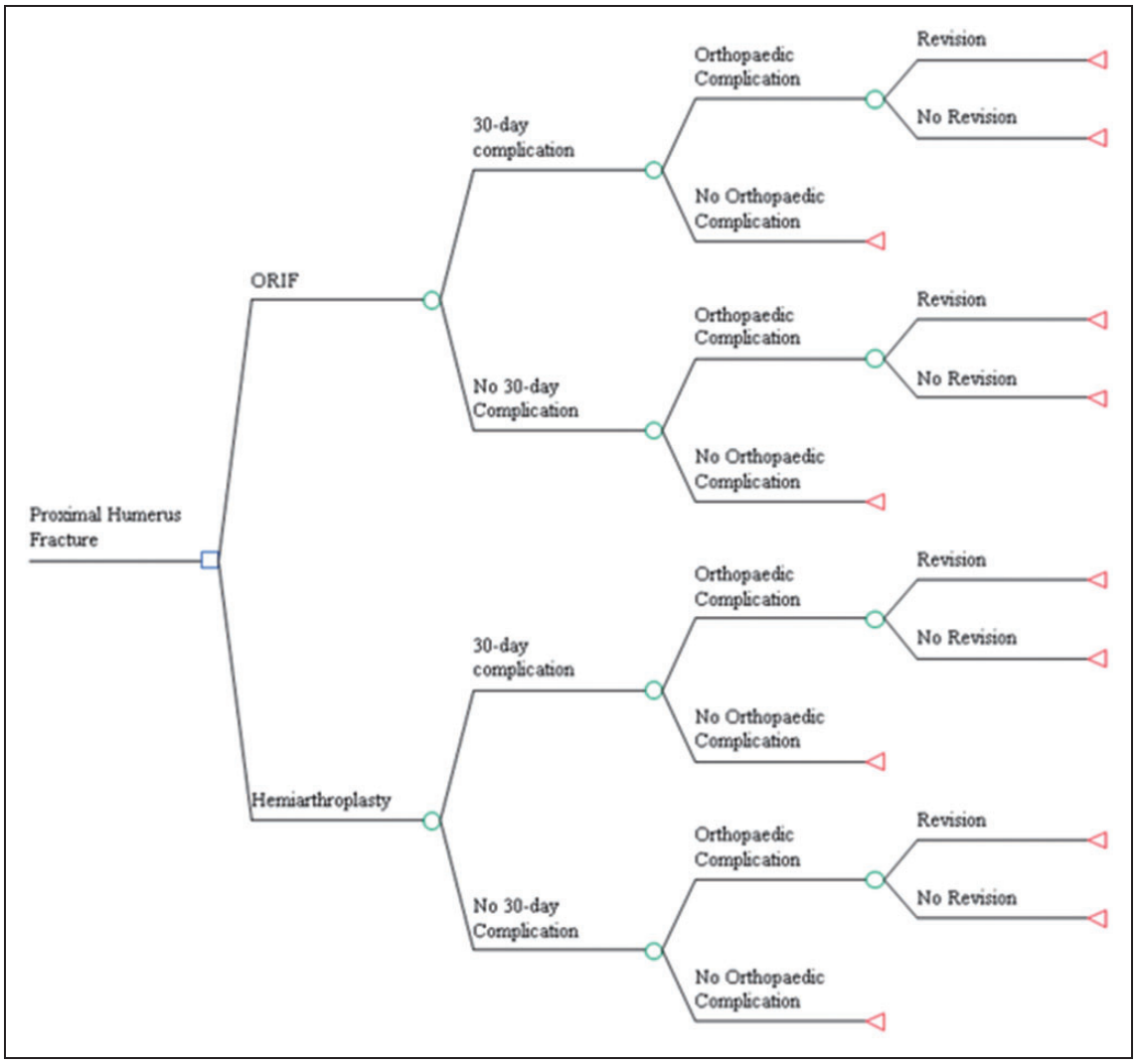

Figure 1. Decision analytic tree comparing ORIF to hemiarthroplasty in complex proximal humerus fractures. ORIF, open reduction and internal fixation.

model assumptions. This analysis varies each variable across the specified range to test whether and at what point the cost-effectiveness result changes. This technique is widely used in economic evaluations to determine the validity of study conclusions based on the assumed parameter estimates. Uncertainty about the parameter estimates can create uncertainty about the estimates cost-effectiveness ratios. Ranges were based on the variation reported in prior studies, confidence intervals for cost estimates and QALY estimates. Where uncertainty is considerable, sensitivity ranges were made to be large.

Results

Patients

The records of 459 consecutive patients in whom a proximal humerus fracture was treated surgically at our institution between the years 2002 and 2012 were studied retrospectively. We identified 30 consecutive patients with mean follow-up of 60.3 months (13.6–134.5 months) of which 15 patients underwent primary ORIF and another 15 underwent primary HA for the management of head-splitting fracture or fracture-dislocation of the proximal humerus. Fracture characteristics of each group are defined in Table 2. Mean age of the patients were 58.5 years and 73.1 years in the ORIF and HA cohorts, respectively, which represented a statistically significant difference.

Effectiveness

At final follow-up, several SF-36 subscores were significantly better in the ORIF cohort including physical functioning (81.7 ± 22.3 vs 56.3 ± 28.4, $P = .008$), bodily pain (84.4 ± 20.5 vs 65.6 ± 22.2, $P = .02$), and physical

Table 1. Baseline Assumptions.

Variable	Root definition	Sensitivity range
30-Day complication, ORIF	6.9%	0–1
30-Day complication, hemi	8.4%	0–1
Orthopedic complication, ORIF	30%	0–1
Revision rate, ORIF	58%	0–1
Orthopedic complication, hemi	34%	0–1
Revision rate, hemi	6.4%	0–1
Baseline cost, ORIF	$8792	$7412–$10 840
Baseline cost, Hemi	$9853	$9174–$14 304
Complication cost, ORIF	$6436	$1049–$17 743
Complication cost, Hemi	$4313	$1259–$16 752
Utility, ORIF	0.81	0–1
Utility, hemi	0.70	0–1
Utility of complication, nonop, ORIF	0.69	0–1
Utility of revision, ORIF	0.60	0–1
Utility of complication, nonop, Hemi	0.64	0–1
Utility of revision, Hemi	0.47	0–1

ORIF, open reduction and internal fixation.

Table 2. Fracture Characteristics of Each Cohort.

Fracture Type	ORIF (n = 15)	Hemiarthroplasty (n = 15)
Isolated fracture-dislocation	9 (60%)	3 (20%)
Isolated head-split	2 (13.3%)	8 (53.3%)
Fracture-dislocation with head-split or articular impaction	4 (26.7%)	4 (26.7%)

ORIF, open reduction and internal fixation.

composite score (49.6 ± 10.6 vs 39.7 ± 10.6, $P = .02$). No differences between the groups were observed for the remaining SF-36 subscores, including role physical, general health, vitality, social functioning, role emotional, mental health, or mental composite score. SF-36 scores for each cohort were converted to utility weights for uncomplicated procedure, nonoperative complications, and complications necessitating revision surgery and are presented in Table 1. A primary, uncomplicated ORIF represented the most optimal health state (0.81), while revision for complicated HA represented the least optimal health state (0.47).

Costs

Medicare claims data over a 2-year time horizon demonstrated baseline in-hospital cost of ORIF and HA at $8792 (SD, $7412–$10 840) and $9853 (SD, $9174–$14 304), respectively. Perioperative complication costs within 30-days postoperatively for ORIF and HA were $6436 (SD, $1049–$17 743) and $4313 (SD, $1259–$16 752), respectively.

Cost-effectiveness

Results of the decision analytic tree are detailed in Figure 2. Given the probabilities of 30-day perioperative complications, orthopedic-specific complications, and revision rates and the associated costs and utility values, ORIF was found to be slightly more costly than HA ($10 950 vs $10 514) but more effective (0.75 QALY vs 0.67 QALY). The ICER for ORIF versus HA, or cost per a single additional QALY when choosing ORIF instead of HA, was $5319/QALY. This value falls well below the accepted standard of a willingness to pay of $50 000/QALY, making ORIF the more cost-effective approach.

Sensitivity Analysis

The variables that had the greatest impact on ICER estimation were probability of any immediate postoperative complication after ORIF followed by probability of any orthopedic-specific complication after ORIF. Other variables that impacted ICER included the utility of an orthopedic-specific complication without subsequent revision, the baseline costs for both procedures, the utility of revision after ORIF, and the probability of reoperation after ORIF. Remaining variables have only a small impact on the ICER.

Discussion

There remains debate regarding whether ORIF or HA is superior in adults with complex proximal humerus fractures, and few studies examine the difference in clinical outcomes.[1,7,9] Some surgeons argue that younger patients should undergo ORIF of displaced fractures. However, the optimal treatment for more complex fractures including Neer 3- and 4-part fractures and fracture-dislocations in older patients with reduced bone quality remains controversial. If anatomic reduction can be achieved, locking plate fixation of 3- and 4-part fractures remains a reasonable option, and evidence suggests that medial column support is imperative.[36,37] However, complications are common when treating 3- and 4-part fractures with locked plating including loss of fixation with varus collapse and screw cutout, and AVN of the humeral head.[1,7] Because of these complications, some authors recommend HA in the management of 3- and 4-part proximal humerus fractures. This is especially true in elderly patients who are low-demand, particularly those with osteopenia, varus malalignment, and when anatomic reduction cannot be achieved

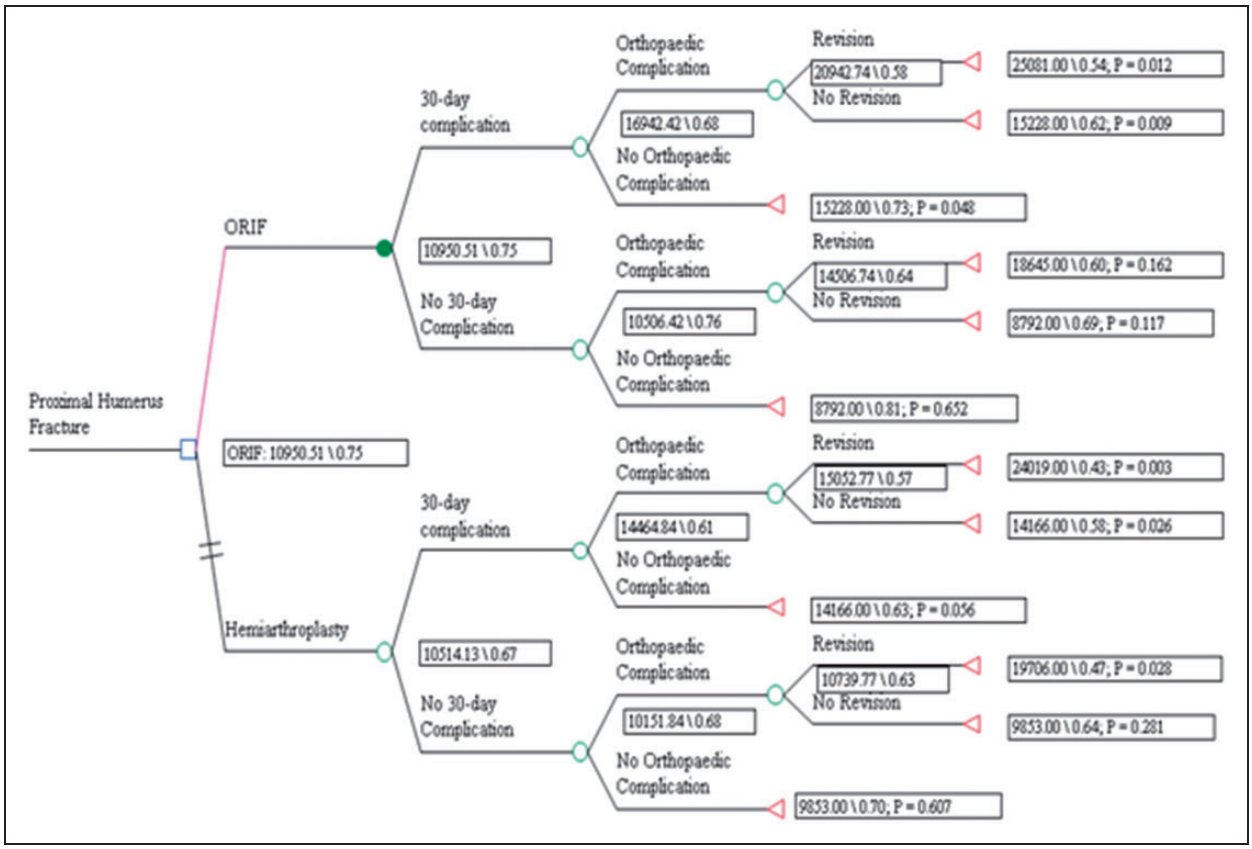

Figure 2. Decision analytic tree results comparing ORIF to hemiarthroplasty in complex proximal humerus fractures. Values represent cost/utility, probability of occurrence (*P*). ORIF, open reduction and internal fixation.

intraoperatively.[1,2,38] While studies evaluating HA have consistently demonstrated predictable pain relief, they have unfortunately also demonstrated inconsistent functional outcomes.[3,24,26,28,32,39,40] The variable clinical results of HA are likely multifactorial, relating to surgeon experience, the degree of postoperative rehab, anatomic positioning of the stem, and anatomic healing of the tuberosities. Without definitive evidence favoring one treatment over another for these complex fractures, societal cost implications may compel hospitals, surgeons, and patients to choose the most cost-effective treatment. Clearly, as health-care decisions increasingly require economic consideration, data regarding comparative cost-effectiveness are becoming imperative.

Utilizing the Medicare claims database in New York State over a 2-year time period, we were able to identify in-hospital costs of both ORIF and HA for the management of proximal humerus fractures. Cost data were combined with clinical, health-related quality of life data from a cohort of 30 patients undergoing primary ORIF or HA for a head-split fracture, or fracture-dislocation of the proximal humerus in order to determine the comparative cost-effectiveness of each procedure. Utilizing baseline assumptions obtained from literature review for complication rates and revision rates, we determined that ORIF is the more cost-effective approach for the management of complex proximal humerus fractures and fracture-dislocations. With an ICER of $5319/QALY, ORIF represents a significant cost-effective approach considering the standard willingness to pay in the United States is given a threshold of $50 000/QALY. Put in other terms, when choosing ORIF over HA, an incremental cost of $5319 would be required to provide 1 patient an additional life-year in an optimal health state.

We hypothesized that given prior data suggesting that ORIF is the overall less costly procedure compared to HA, [15] that if clinical outcomes for ORIF were superior, then the treatment would be more cost-effective. However, given the various fracture patterns and rates of complications that often correlate with severity of fracture, we determined that the optimal strategy for defining clinical efficacy would be to evaluate the most complicated fractures, namely head-split fractures and fracture-dislocations. These fracture patterns have a notoriously high rate of AVN and hardware complications[7,9,41] and often present a treatment dilemma for surgeons, especially in young patients where preservation of native anatomy and avoidance of arthroplasty is preferable. By determining that ORIF is the more cost-effective approach for the management of these complex injuries,

these data can be extrapolated to less severe proximal humerus fractures including simple 3- and 4-part fractures without head-split or dislocation components. These simpler fracture patterns have lower rates of AVN and hardware complications and thus should have lower revision rates and, in theory, cost.

Proximal humerus fractures are a significant burden on our health-care system, with in-hospital costs of $14 967 and $20 508 for ORIF and HA, respectively.[15] We previously identified factors associated with increased cost of surgical management of proximal humerus fractures including readmission, nonroutine discharge, comorbidities, and complications, with readmission having the most significant impact on direct cost.[15] Hospital readmissions account for a large proportion of health-care expenditure and have high personal costs for patients.[42–44] As the elderly population continues to expand, and the incidence of proximal humerus fractures increases,[11] a significant financial burden will be placed on health-care systems. The ability to identify older patients at risk for readmission is essential to decrease cost, and a number of clinical risk scores exist for readmission.[45–49] Utilization of such scores may be beneficial in fragility fracture situations in order to predict patients at risk for readmission, thus helping to consume limited health-care resources most efficiently.

Ensuring routine discharge for elderly patients with fragility fractures can be optimized by utilizing interdisciplinary, protocoled clinical models for reducing length of stay and improving quality of care. Geriatric fracture programs exist whose goal is to reduce length of stay and optimize patient outcomes. These programs prioritize patient-centered care using standardized protocols with co-management of patients between orthopedic surgeons and medical physicians.[50–52] Multiple studies exist that have demonstrated that an organized geriatric fracture management protocol improves quality of patient care and lowers overall costs.[53,54] If such programs were to be implemented for the management of osteoporotic proximal humerus fractures, patient outcomes and costs would likely improve.

Regarding proximal humerus fractures, evidence suggests that greater surgeon volume for HA and TSA is associated with significant cost savings which amounts to approximately 15% of the cost of an ORIF and 13% of the cost of a HA.[50] Such data are compelling, as minimum surgeon volume requirements for orthopedic procedures could potentially result in significant cost savings for both hospitals and patients.

This study had several limitations as is the case with all cost-effectiveness studies. Regarding the cost data, the Medicare claims database does not provide sufficient information regarding fracture classification or complexity of injury, both of which could influence complications after surgical management of proximal humerus fractures. Further, cost was modeled from all patients who had a primary procedure ICD9-CM code for ORIF or HA and a primary diagnosis ICD9-CM code for proximal humerus fracture. Thus, all proximal humerus fractures including simpler patterns were included in the cost model by necessity. Thus, true cost may not be reflected in these data for more complex injuries including head-splits and fracture-dislocations, as this subset of cost data was not available. Further, the cohorts represent a limited sample size and the costs are a regional estimate which may vary by health-care system.

Using a decision analysis model, the model is only as good as the quality of its assumptions. Assumptions for rates of complications were obtained from literature review, most of which were lower level of evidence, retrospective case series. The true rate of AVN and hardware complications following ORIF of complex proximal humerus fractures is unknown, but this study used a conservative estimate of 30% based on literature review, which was similar to the rate observed in our cohort of 26.7%.[33] Rates of tuberosity complications in the literature are variable, but again a conservative estimate of 34% was utilized, which was smaller than that observed in our cohort at 53%.[33] Given the paucity of health-related quality of life scores in the literature regarding surgical management of proximal humerus fractures, SF-36 scores were obtained from a small cohort of 30 patients from our institution who were evaluated with a mean 5-year follow-up. Utility scores obtained from these SF-36 scores must be interpreted with caution, as there was a significant difference in age between the patients who underwent ORIF and HA. Thus, while ORIF demonstrated consistently better utility scores, the patients were significantly younger in age, which may be reflected in the better utility scores. Further, this is a small sample size at a single institution with fractures treated by a variety of subspecialized and general orthopedic surgeons, and so the utility scores may not be representative of those obtained in an institution with subspecialty trained surgeons who deal with a high volume of shoulder trauma.

On sensitivity analysis, our conclusion was robust with regard to parameter estimation variation, even though probabilities were varied over a broad range. Sensitivity analysis suggests the main determinants of the cost-effectiveness difference were probability of sustaining a complication following ORIF, whether this be a perioperative or orthopedic-specific complication. As such, if the likelihood of AVN and hardware complications is significantly higher than the assumptions made in this study, ORIF will cease to be cost-effective.

Conclusion

Overall, in the management of complex articular fractures and fracture-dislocations of the proximal humerus, ORIF is more cost-effective than HA. Given the

conservative baseline assumptions and complex nature of these injuries, these data can be extrapolated to conclude that ORIF is more cost-effective than HA in simple 3- and 4-part fractures. This study should not disregard individual patient characteristics or surgeon and patient preferences, which should be the primary variables that guide treatment decision. It is recommended that an interdisciplinary, protocoled approach should be utilized in the management of these patients to ensure a routine discharge and decrease the risk of readmission. Surgeons and hospitals should be aware of these cost implications to help provide an optimal utilization of resources for managing patients with proximal humerus fractures.

Authors' Note

This manuscript is an original work that has never been published previously. It has been reviewed by all of the above authors. IRB Approval documentation is included with this submission.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Ilya Voloshin is a paid consultant for ''Zimmer,'' ''Arthrex,'' and ''Smith & Nephew.'' This author receives speaking fees from ''Zimmer,'' ''Arthrex,'' and ''Smith & Nephew.'' No other financial payments or benefits from any other commercial entity related to the subject of this article. The rest of the authors have no disclosures.

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