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Original Research

Predictors of Extended Length of Stay Following Open Reduction and Internal Fixation for Proximal Humerus Fractures

Matthew Kim, BA, [*] Emma Smolev, BA, [*] Samer Al-Humadi, MD, [†] Ryan P. Tantone, MD, [†] Hee-Yon Park, BA, [*] Kenny Ling, MD, [†] David E. Komatsu, PhD, [†] Edward D. Wang, MD [†]

[*] *Renaissance School of Medicine at Stony Brook University, Stony Brook, NY*
[†] *Department of Orthopaedics and Rehabilitation, Stony Brook University, Stony Brook, NY*

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Purpose: An extended length of stay following open reduction and internal fixation (ORIF) for proximal humerus fractures (PHFs) is associated with increased patient morbidity and health care costs. The primary purpose of this study was to identify risk factors for an extended length of stay following ORIF for PHF.
Methods: All patients who underwent ORIF for PHF between 2015 and 2021 were queried from the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database. Patient demographics, comorbid conditions, and postoperative complications within 30 days of procedure were collected. Extended length of stay (eLOS) was defined by $\geq$ 3 days from operation to discharge. Multivariate logistic regression was employed to identify predictors of eLOS following ORIF.
Results: Characteristics of patients significantly associated with eLOS included age $\geq$ 75 years ($p < .001$), male gender ($p < 0.001$), body mass index (BMI) < 18.5 ($P = .001$), American Society of Anesthesiologists (ASA) classification $\geq$ 3 ($P < .001$), dependent functional status ($P < .001$), noninsulin-dependent diabetes ($P = .037$), insulin-dependent diabetes ($P < .001$), chronic obstructive pulmonary disease ($P < .001$), congestive heart failure (CHF) ($P < .001$), hypertension ($P < 0.001$), dialysis ($P < .013$), disseminated cancer ($P < 0.001$), chronic steroid use ($P = .004$), and bleeding disorder ($P < .001$). Independent predictors of eLOS were age $\geq$ 75 years (OR = 2.69; $P < .001$), BMI < 18.5 (OR = 1.70; $P = .016$), ASA $\geq$ 3 (OR = 2.70; $P < .001$), dependent functional status (OR = 2.30; $P < .001$), CHF (OR = 3.57; $P < .001$), disseminated cancer (OR = 7.62; $P < .001$), and bleeding disorder (OR = 2.68; $P < .001$).
Conclusion: Age $\geq$ 75, BMI < 18.5, ASA $\geq$ 3, functional dependence, CHF, disseminated cancer, and bleeding disorder were independently associated with eLOS.
Clinical Relevance: Assessing specific patient factors prior to ORIF for PHF can assist in managing perioperative risks and decreasing expenses related to eLOS.
Level of Evidence: Prognosis III.

Proximal humerus fractures (PHFs) are the third most common nonvertebral fractures in elderly patients, following hip and distal radius fractures.[1] These typically occur because of ground-level falls in osteoporotic elderly patients but can also occur from high-energy accidents in younger individuals.[2] Low-energy fractures can often be managed nonsurgically with the use of sling immobilization.[3] However, surgical treatments can be necessary with procedures that include open reduction and internal fixation (ORIF), hemiarthroplasty (HA), total shoulder arthroplasty (TSA), closed reduction percutaneous pinning, and intramedullary (IM) nailing.[4–7] Recently, reverse TSA has become popular, particularly for patients over 65 years, because of improved postoperative outcomes.[8,9] Nevertheless, ORIF continues to be a viable surgical option, as some studies found that it offers improved range of motion and better functional outcomes scores compared to reverse TSA.[10,11]

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Corresponding author: Edward D. Wang, MD, Department of Orthopaedics and Rehabilitation, Stony Brook University Hospital, HSC T-18, Room 080, Stony Brook, NY 11794-8181.
E-mail address: Edward.Wang@stonybrookmedicine.edu (E.D. Wang).

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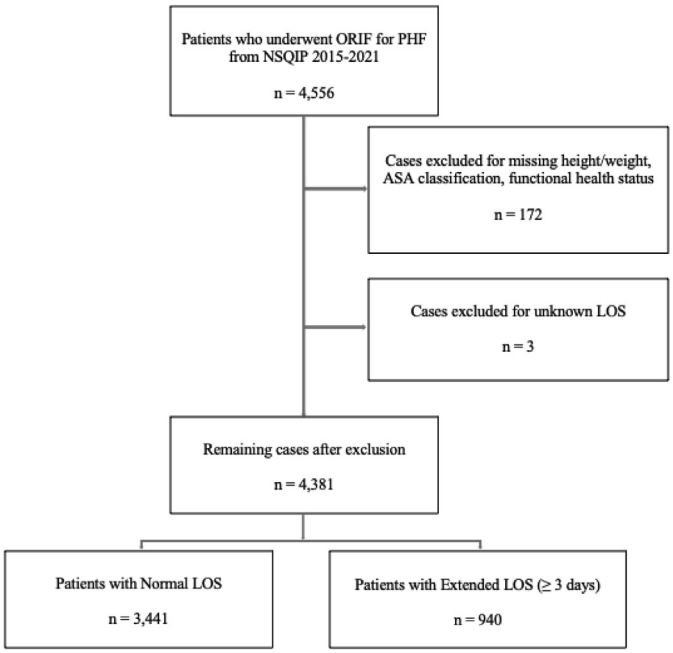

Figure 1. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) diagram with inclusion and exclusion criteria. ASA, American Society of Anesthesiologists; LOS, length of stay; NSQIP, National Surgical Quality Improvement Program; ORIF, open reduction internal fixation; PHF, proximal humerus fracture.

Hospital length of stay is often considered a measure of surgical efficiency, with extended LOS (eLOS) commonly being associated with readmissions and hospital mortality.[12–14] Because of this, it is important to identify factors predicting eLOS to alleviate the economic impact on health care systems, optimize patient outcomes, and enhance the effective use of hospital resources for patient benefit. In the field of orthopedic surgery, research has been conducted to identify risk factors for eLOS in relation to total ankle arthroplasty and total joint arthroplasty.[15,16] Additionally, one study examined patient factors affecting the length of stay across 14 prevalent orthopedic procedures.[17] Nevertheless, there is a lack of similar studies focusing on surgical treatments for PHFs.

The purpose of this study was to identify risk factors for an eLOS following ORIF for PHFs. A secondary objective of this study was to identify patient characteristics and postoperative complications that are associated with an eLOS following this procedure.

Materials and Methods

We queried the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database for all patients who had undergone ORIF for PHF from 2015 to 2021. As the NSQIP database is fully anonymized, the study did not require approval from our university's institutional review board. The database gathers data from over 600 US hospitals and is maintained by trained surgical clinical reviewers, with regular audits to ensure data quality.

Inclusion criteria were postoperative diagnosis of PHF and surgical treatment with ORIF. Postoperative diagnoses of PHFs were defined by International Classification of Disease (ICD)-9 (812.0, 812.00, 812.01, 812.02, 812.03, 812.09) or ICD-10 codes (Supplement 1, available online on the Journal's website at https://www.jhsgo.org). Current Procedural Terminology codes selected for ORIF included 23615, 23616, 23630, 23670, and 23680. Cases were excluded if any of the following variables had missing information: age, height, weight, American Society of Anesthesiologists (ASA) classification, functional health status, or hospital length of stay (LOS). The above exclusions resulted in the retention of total of 4,381 cases for our statistical analysis (Figure 1).The study population was then stratified into two groups based on their LOS: normal LOS (0–2 days) and extended LOS (≥ 3 days).

Variables collected in this study included procedure type, procedure characteristics, patient demographics, comorbid conditions, reoperation rates, readmission rates, and discharge destination. Patient demographics and comorbid conditions recorded in this study included age, gender, height, weight, ASA physical classification class, smoking status, diabetes, chronic obstructive

Table 1
Characteristics of Patients Who Underwent ORIF for PHF in both the Normal LOS and Extended LOS Groups

Characteristic	Normal LOS		Extended LOS (≥ 3 Days)		*P* Value*
	Number	Percent	Number	Percent	
Total	3,441	100%	940	100%	
Age (y)					
18–39	323	9.4%	44	4.7%	**< .001**
40–64	1,707	49.6%	298	31.7%	**< .001**
65–74	926	26.9%	280	29.8%	.08
≥ 75	485	14.1%	318	33.8%	**< .001**
Gender					**< .001**
Female	2,467	71.7%	653	69.5%	
Male	974	28.3%	287	30.5%	
Body mass index (kg/m^2)					
< 18.5	76	2.2%	40	4.3%	**.001**
18.5–29.9	2,020	58.7%	555	59.0%	.852
30–34.9	683	19.8%	176	18.7%	.441
35–39.9	383	11.1%	98	10.4%	.540
≥ 40	279	8.1%	71	7.6%	.578
ASA classification					**< .001**
1–2	2,018	58.6%	259	27.6%	
≥3	1,423	41.4%	681	72.4%	
Functional status					**< .001**
Independent	3,367	97.8%	854	90.0%	
Dependent	74	2.2%	86	9.1%	
Smoking					.821
No	2,746	79.8%	747	79.5%	
Yes	695	20.2%	193	20.5%	
Diabetes					
No	2,853	82.9%	722	76.8%	**< .001**
Noninsulin	357	10.4%	120	12.8%	**.037**
Insulin	231	6.7%	98	10.4%	**< .001**
COPD					**< .001**
No	3,294	95.7%	860	91.5%	
Yes	147	4.3%	80	8.5%	
Ascites					.999
No	3,441	100.0%	939	99.9%	
Yes	0	0.0%	1	0.1%	
Congestive heart failure					**< .001**
No	3,428	99.6%	912	97.0%	
Yes	13	0.4%	28	3.0%	
Hypertension					**< .001**
No	1,937	56.3%	388	41.3%	
Yes	1,504	43.7%	552	58.7%	
Dialysis					**.013**
No	3,437	99.9%	935	99.5%	
Yes	4	0.1%	5	0.5%	
Disseminated cancer					**< .001**
No	3,437	99.9%	927	98.6%	
Yes	4	0.1%	13	1.4%	
Chronic steroid use					**.004**
No	3,344	97.2%	896	95.3%	
Yes	35	2.8%	44	4.7%	
Bleeding disorders					**< .001**
No	3,368	97.9%	863	91.8%	
Yes	73	2.1%	77	8.2%	

ASA, American Society of Anesthesiologists; COPD, chronic obstructive pulmonary disease; LOS, length of stay.
* Bold *P* values indicate statistical significance with $P < .05$.

Table 2
Bivariate Analysis of 30-day Postoperative Complications in Both the Normal LOS and Extended LOS Groups

Postoperative Complication	Normal LOS		Extended LOS (≥ 3 Days)		*P* Value*
	Number	Percent	Number	Percent	
Superficial SSI	8	0.2%	8	0.8%	**.006**
Deep SSI	11	0.3%	3	0.3%	.968
Organ space SSI	4	0.1%	4	0.4%	.054
Wound disruption	1	0.0%	1	0.1%	.336
Reoperation	56	1.6%	44	4.4%	**< .001**
Stroke/CVA	3	0.1%	3	0.3%	.095
Acute renal failure	0	0.0%	2	0.2%	**.008**
Cardiac arrest	0	0.0%	5	0.5%	**< .001**
Myocardial infarction	5	0.1%	7	0.7%	**.002**
Bleeding transfusions	38	1.1%	126	12.6%	**< .001**
DVT/Thrombophlebitis	6	0.2%	5	0.5%	.058
Sepsis	7	0.2%	4	0.4%	.244
Septic shock	0	0.0%	3	0.3%	**< .001**
Failure to wean	0	0.0%	3	0.3%	**.001**
Reintubation	2	0.1%	10	1.0%	**< .001**
Readmission	77	2.2%	73	7.3%	**< .001**
Mortality	4	0.1%	15	1.5%	**< .001**
Pneumonia	5	0.1%	21	2.1%	**<. 001**
Urinary tract infection	13	0.4%	11	1.1%	**.004**
Nonhome discharge	751	21.1%	502	50.3%	**< .001**
Still in hospital > 30 days	0	0.0%	2	0.2%	**.008**
C. difficile infection	1	0.0%	2	0.2%	.060

CVA, cerebrovascular accident; DVT, deep vein thrombosis; LOS, length of stay; SSI, surgical site infection.
* Bold *P* values indicate statistical significance with $P < .05$.

Table 3
Multivariate Analysis of 30-Day Postoperative Complications in Patients with Extended Length of Stay (≥ 3 Days) Adjusted for Significantly Associated Patient Demographics and Comorbid Conditions

Postoperative Complication	Odds Ratio	95% CI	*P* Value*
Age ≥ 75 y (reference: < 65 y)	2.69	2.16–3.35	**< .001**
BMI < 18.5 (reference: 18.5–29.9)	1.70	1.11–2.62	**.016**
ASA class ≥ 3	2.70	2.25–3.25	**< .001**
Dependent functional status	2.30	1.62–3.26	**< .001**
Congestive heart failure	3.57	1.78–7.17	**< .001**
Disseminated cancer	7.62	2.40–24.22	**< .001**
Bleeding disorder	2.68	1.88–3.81	**< .001**

ASA, American Society of Anesthesiologists; BMI, body mass index.
* Bold *P* values indicate statistical significance with $P < .05$.

pulmonary disorder (COPD), congestive heart failure (CHF), hypertension, preoperative corticosteroid use, and functional health status. The NSQIP database categorizes functional health status as “independent,” “partially dependent,” or “totally dependent.” Here, gender refers to the biological differences between males and females. For this study, the statuses were reclassified as "independent" or "dependent," with the latter including both “partially dependent” and “totally dependent” patients. Postoperative outcomes, such as reoperation and readmission, were documented within 30 days of the procedure. Discharge destinations were reclassified as “home” or “nonhome.” Here, “home” encompassed patients discharged to their own home or a facility serving as their home, whereas “nonhome” included those discharged to rehab, separate acute care, skilled care, or unskilled facilities.

Statistical analyses were conducted using SPSS Software version 26.0 (IBM Corp., Armonk, NY, USA). Patient demographics, comorbid conditions, and procedural characteristics were compared between the normal and extended LOS groups using bivariate analysis. Multivariate logistic regression, adjusted for all significantly associated patient comorbid conditions, patient demographics, and procedural characteristics, was used to identify predictors of reoperation, readmission, and nonhome discharge. Odds ratios (OR) were reported with accompanying 95% confidence intervals (CIs). The level of significance was set to $P < .05$.

Results

The characteristics of patients significantly associated with eLOS were age ≥ 75 years ($P < .001$), male gender ($P < .001$), BMI <18.5 ($P = .001$), ASA ≥ 3 ($P < .001$), dependent functional status ($P < .001$), noninsulin-dependent diabetes ($P = .037$), insulin-dependent diabetes ($P < .001$), COPD ($P < .001$), CHF ($P < .001$), hypertension ($P < .001$), dialysis ($P < .013$), disseminated cancer ($P < .001$), chronic steroid use ($P = .004$), and bleeding disorder ($P < .001$). Complete results are presented in Table 1.

The 30-day postoperative complications that were significantly associated with eLOS were superficial surgical site infection (SSI) ($P = .006$), reoperation ($P < .001$), acute renal failure ($P = .008$), cardiac arrest ($P < .001$), myocardial infarction ($P = .002$), bleeding transfusions ($P < .001$), septic shock ($P < .001$), failure to wean ($P = .001$), reintubation ($P < .001$), readmission ($P < .001$), mortality ($P < .001$), pneumonia ($P < .001$), urinary tract infection ($P = .004$), nonhome discharge ($P < .001$), and still in hospital > 30 days ($P = .008$). Complete results are presented in Table 2.

After adjusting for all significantly associated patient variables, the characteristics of patients independently associated with eLOS included age ≥ 75 years (reference < 65 years; OR = 2.69; 95% CI, 2.16–3.35; $P < .001$), BMI < 18.5 (reference 18.5–29.9; OR = 1.70, 95% CI, 1.11–2.62; $P = .016$), ASA ≥ 3 (OR = 2.70, 95% CI 2.25–3.25; *P*

< .001), dependent functional status (OR 2.30, 95% CI 1.62–3.26; $P <$ .001), CHF (OR = 3.57, 95% CI 1.78–7.17; $P <$ .001), disseminated cancer (OR 7.62, 95% CI 2.40–24.22; $P <$ 0.001), and bleeding disorder (OR = 2.68, 95% CI, 1.88–3.81; $P <$ .001). Complete results are presented in Table 3.

Discussion

In this study, we investigated the risk factors for eLOS after ORIF for PHF from 2015 to 2021 using a large national database. Independent risk factors for eLOS were age ≥ 75 years, BMI < 18.5, ASA ≥ 3, dependent functional status, CHF, disseminated cancer, and bleeding disorder.

Reverse TSA has become increasingly popular treatment modality for PHF given its improved postoperative outcomes, especially for patients aged 65 years and older.[8,9] Nonetheless, ORIF remains a prevalent surgical treatment for PHF, as studies have shown improved range of motion and better functional outcomes scores compared to reverse TSA.[10,11] Despite the preference for ORIF, it has been linked to a number of complications, such as screw perforation, avascular necrosis, and fixation failure, which may necessitate further revision surgery, particularly in older patients.[18–20] Shi et al[21] showed that patients with specific comorbid conditions, such as CHF, uncontrolled diabetes, metastatic cancer, and psychosis, were more likely to undergo ORIF. This supports the general trend toward reverse TSA for patients without major comorbid conditions. The postoperative complications experienced by ORIF patients also help explain our study's findings, which showed increased eLOS for patients over 75 years and those with comorbid conditions, such as CHF, disseminated cancer, and bleeding disorders. In the same study by Shi et al,[21] it was reported that the average hospital stay was 0.6 days shorter for patients who underwent shoulder arthroplasty compared to ORIF.

Although the importance of hospital LOS may not be immediately evident, it is often used as an indicator of surgical efficiency, with eLOS frequently being linked to readmissions and hospital mortality.[12–14] LOS is of particular interest to hospitals and patients because of its direct correlation with health care costs. Over the past decade, the proportion of geriatric PHF surgeries has increased from 10% to 67%, underlining the importance of identifying risk factors of eLOS.[21]

This study identified patient demographic factors, including age ≥ 75 years, BMI < 18.5, ASA ≥ 3, and dependent functional status, as risk factors for eLOS following ORIF for PHF. The identification of age as a risk factor is crucial given that the prevalence of PHF has been shown to increase with an aging population.[22] Various studies investigating hip fractures have also indicated a significant correlation between age and hospital LOS.[23,24] Additionally, low BMI has been previously demonstrated to be associated with eLOS in other studies. Malnutrition has been cited to be associated with delayed wound healing, increased complications, morbidity, mortality, health care costs, and eLOS.[25,26] It has been noted that patients with a low BMI had eLOS and mortality and complication rates that were 3 to 4 times greater compared to patients with normal BMI.[25] Finally, ASA classification ≥ 3 was also found to be independently associated with eLOS in patients undergoing ORIF for PHF. ASA classification ranks patients across five broad groups based on disease severity and is globally used as a preoperative measurement in patients undergoing surgery to aid in risk stratification.[27] The association of higher ASA classification with surgical outcomes have been demonstrated in prior orthopedic studies, including outcomes in knee and hip arthroplasties. Higher rates of major complication, worse outcomes, and higher mortality rates have been shown in patients with ASA scores ≥ 3 undergoing knee and hip arthroplasties.[28–30]

Several patient comorbid conditions were also predictors of eLOS, including CHF, disseminated cancer, and bleeding disorder. The effect of comorbid conditions on eLOS likely involves an increased predisposition to various postoperative complications.[31] The influence of CHF as a risk factor for poor postoperative outcomes is documented in the literature. Gholson et al., found that CHF was among the factors with the greatest predictor of increased LOS of 1.46 days following orthopedic procedures.[17] Similarly, bleeding disorders was associated with an eLOS following PHF ORIF. This has also been supported in other orthopedic literature. In an analysis of postoperative complications after ORIF of the ankle in a cohort of patients with and without bleeding disorders, Malyavko et al[32] found that patients with a bleeding disorder had a significantly increased risk of any postoperative complication and experienced eLOS greater than 5 days.

The growing costs of health care in the US, especially in the fields of medical and surgical treatments, are unsustainable, accounting for approximately 20% of the GDP in 2020.[33] One study showed that approximately one-quarter of this spending is attributed to wasteful practices.[34] Our research highlights the potential to decrease the duration of patient hospitalization through preoperative enhancements of cardiac functionality, coagulation stability, and maintaining an appropriate body weight. Collaborating with medical professionals across disciplines to optimize patients' pre-existing medical conditions prior to surgery presents a considerable opportunity to systematically decrease hospital LOSs.

There were several limitations to this study that warrant further discussion. Our study was limited by the available information provided on the NSQIP database. The NSQIP database is limited to complications within a 30-day period following a procedure. Thus, our analysis cannot account for long-term complications beyond the 30-day postoperative period. In addition, given the nature of all statistical analyses, this study cannot demonstrate causation, but we were able to show a statistical association between eLOS for PHF ORIF and the risk of postoperative complications. Despite these noted limitations, this study used a large national database to analyze risk factors for eLOS following ORIF for PHF. Analyzing preoperative risk factors for eLOS can both aid in patient counseling, treatment plans, in-hospital monitoring, and discharge plans and aid physicians in preoperative risk stratification to minimize postoperative complications.

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