Trauma Surgery & Acute Care Open

A nationwide analysis of geriatric proximal humerus fractures: trends, outcomes, and cost

Teresa Cheng ,[1] Kevin Galicia,[2,3] Purvi P Patel,[2] Michael J Anstadt,[2] Richard P Gonzalez,[2,3] John Kubasiak[2,3]

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/tsaco-2022-001055).

[1]Department of Surgery, Loyola University Chicago Stritch School of Medicine, Maywood, Illinois, USA
[2]Department of Surgery, Loyola University Medical Center, Maywood, Illinois, USA
[3]Burn and Shock Trauma Research Institute, Loyola University Medical Center, Maywood, Illinois, USA

Correspondence to
Dr Kevin Galicia; kgalicia@luc.edu

Received 4 November 2022
Accepted 16 June 2023

To cite: Cheng T, Galicia K, Patel PP, *et al*. *Trauma Surg Acute Care Open* 2023;**8**:e001055.

ABSTRACT

Background In the USA, proximal humerus fractures (PHF) are the third most common fracture among the elderly. Although most geriatric PHF are treated conservatively, surgical management remains an option. This retrospective study compares annual trends, patient outcomes, and hospital costs between operatively and non-operatively managed geriatric PHF.

Methods The Healthcare Cost and Utilization Project Nationwide Inpatient Sample was queried from 2012 to 2015. Geriatric patients with PHF were identified and those who underwent operative or non-operative management were compared in trends, outcomes and costs.

Results In total, 137 810 patients met inclusion criteria, of which 51 795 (37.6%) underwent operative management. The operative cohort was younger (76.6 vs 80.9, p<0.001) with a greater proportion of females (81.8% vs 77.6%, p<0.001). The operative cohort demonstrated less frailty and lower Elixhauser Comorbidity Scores (both p<0.001). The operative cohort was also more likely to be discharged home (30.4% vs 13.9%, p<0.001). There was no significant linear trend in age-adjusted and sex-adjusted proportions of operative versus non-operative geriatric PHF (p=0.071), but a positive linear trend was statistically significant for total cost of operative geriatric PHF (p<0.001). Multivariable analyses demonstrated similar overall complication rates between cohorts (OR 0.95, 95% CI 0.89 to 1.00; p=0.06), although surgical intervention increased length of stay (LOS) by 0.15 days (95% CI 0.03 to 0.27; p<0.001) and median cost of hospitalization by US$10 684 (95% CI US$10 384 to US$10 984; p<0.001).

Conclusions This study identifies a positive linear trend in total cost of operatively managed geriatric PHF from 2012 to 2015. Operative management of geriatric PHF is associated with a similar overall complication rate and greater likelihood of being discharged home. Although non-operative management is associated with decreased LOS and hospital expenses, providers should consider surgical PHF treatment options when available and appropriate in the context of patient-focused outcomes, particularly long-term disposition after intervention.

Level of Evidence This level IV retrospective study identifies.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Both operative and non-operative interventions exist to manage geriatric proximal humerus fractures (PHF); however, most retrospective studies lack generalizability to the US population in regard to trends, patient outcomes, and associated costs.

WHAT THIS STUDY ADDS

⇒ Compared with non-operative management, operative management of PHF is associated with a similar rate of overall complications and a greater chance of being discharged home.

⇒ Conversely, non-operative management of PHF is associated with decreased risk of PHF complications and overall decreased hospital costs and length of stay.

⇒ From an operative approach, the increase in length of stay is minimal (<1 day) and median hospital costs is likely reflective of an overall increase across the healthcare system.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Operative approaches to PHF in the geriatric population are reasonable and safe to pursue.

⇒ Further study is necessary to better understand patient-specific factors that contribute to the selection of operative versus non-operative treatments.

⇒ Outcomes after hospital discharge, including long-term disposition, should be followed longitudinally and assessed for correlations with management type.

INTRODUCTION

With an aging US population, the incidence of fragility fractures continues to rise. Proximal humerus fractures (PHF) are the third most common fracture among the elderly, trailing only those of the hip and distal radius in frequency.[1 2] In older patients, PHF can greatly impair the ability to perform activities of daily living.[2] Additionally problematic are the many associated morbidities,[1 3 4] as well as the rising costs for osteoporotic-related care in the USA.[3 5]

The majority of geriatric PHF are treated conservatively with closed reduction and immobilization.[6] However, there has been increasing use of surgical alternatives, including percutaneous techniques, open reduction and internal fixation (ORIF), intramedullary nailing, and arthroplasty.[7] With operative management of geriatric PHF, survival rates and functional outcomes have been shown to be high and satisfactory, respectively.[8 9] Yet, much remains ill-defined regarding trends, outcomes, and costs when comparing operative and non-operative management of geriatric PHF. To date, most large

studies of geriatric PHF have been limited to Medicare claims data, while reports on operative trends and associated costs are often outdated or lack generalizability at the national level.[8 10]

Using the Healthcare Cost and Utilization Project (HCUP) National Inpatient Sample (NIS), this study aims to provide updated, nationally representative data regarding geriatric PHF. In particular, it aims to compare annual trends, patient outcomes, and hospital costs between geriatric patients with PHF who underwent operative versus non-operative management over a 4-year study period. We hypothesize that operative management of PHF will be associated with a higher rate of complications, prolonged length of stay (LOS), and increased cost of hospitalization.

METHODS

Data source and design

Primary analyses were performed using the HCUP NIS, the largest publicly available all-payer (Medicare, Medicaid, private, and uninsured) inpatient healthcare database in the USA. Maintained by the Agency for Healthcare Research and Quality (AHRQ),[11] NIS is a weighted sample drawn from the HCUP State Inpatient Databases by a complex, single-cluster survey design stratified on geographic area, urban/rural location, ownership, teaching status, and bed size.[12] NIS is also standardized across years to facilitate trend analyses. It was developed to produce US regional and national estimates of inpatient utilization, access, cost, quality, and outcomes.

Patient population

In 2012, NIS was redesigned to optimize national estimates with a sample of discharge data from all HCUP-participating hospitals rather than all discharge data from a sample of hospitals. NIS was queried from 2012 to 2015 to identify geriatric patients (≥65 years of age) with any diagnosis of PHF, using the International Classification of Disease (ICD), Ninth Revision (ICD-9) diagnosis codes (online supplemental table 1). Given the conversion to ICD, Tenth Revision (ICD-10) on October 1, 2015, query was completed through September 2015. Patients sustaining polytrauma, defined as an Injury Severity Score (ISS) >15, were excluded from analysis.[13] ISS was determined using open-access ICD and R statistical software (ICDPIC-R). For each valid ICD-9-Clinical Modification injury diagnosis, ICDPIC-R is programmed to generate an approximate Abbreviated Injury Scale (AIS) and body region (head/neck, face, chest, abdomen and pelvic contents, extremities and pelvic bones, and general), as previously described by Baker *et al*.[14] Patients missing data related to race/ethnicity, primary payer, disposition, in-hospital mortality, or total charges information were also excluded from analysis (online supplemental figure 1).

Study variables

Demographic data included age, sex, race/ethnicity, and primary payer information. Clinical data included PHF diagnosis and operation (online supplemental table 1), AHRQ comorbidity measures, Elixhauser Comorbidity Score, ISS, frailty, hospital location/teaching status, and hospital bed size. Frailty was defined based on the 10 clusters of frailty-defining diagnoses that comprise the Johns Hopkins Adjusted Clinical Groups frailty-defining diagnosis indicator; this is a binary variable, using ICD-9 diagnosis codes, as previously described (online supplemental table 2).[15 16] Elixhauser Comorbidity Scores were calculated, as previously described.[17] The primary outcomes for this analysis were complication rate, LOS, and cost of hospitalization. Additional outcomes included general complications, PHF complications, disposition, and in-hospital mortality. Complications were identified using ICD-9 diagnosis and procedure codes (online supplemental table 3). General complications included: acute kidney injury (AKI), cardiac arrest, deep venous thrombosis (DVT), intubation, myocardial infarction (MI), pneumonia, pulmonary embolism (PE), sepsis, transfusion for blood loss anemia, and urinary tract infection (UTI). PHF complications included avascular necrosis of the humeral head, device complications, malunion/non-union, nervous injury to the axillary, musculocutaneous, or subscapular nerves, surgical site infection (SSI), and tendon rupture/injury to the long head of the biceps. These were evaluated as individual and composite prevalence rates.

NIS also contains data on total charges for each admission. While a 'charge' represents the amount a hospital billed for services, the 'cost' is defined as the actual expense incurred through the production of hospital services, such as wages, supplies, and utility. Total hospital charges were converted to total hospital costs using the HCUP cost-to-charge ratio files, which provide hospital-specific or weighted average ratios for hospitals in peer groups defined by hospital characteristics and state.

Statistical analyses

Age-adjusted, sex-adjusted, and survey-adjusted, year-to-year variability for (1) proportions of operative versus non-operative management of PHF and (2) total costs of operative management of PHF were modeled between 2012 and 2015, testing for the assumption of linearity and using an approach for multiyear survey data.[18] We included the interaction between stratum and year to account for geographic region. The Student's t-test and χ^2 test were used for univariate survey-adjusted comparisons between operative and non-operative groups. Multivariate survey-adjusted logistic regression was used to assess the association between operative management and the development of any complication. Multivariate survey-adjusted linear regressions were used to identify associations between (1) operative management and LOS and (2) operative management and cost of hospitalization, each relative to the effects of other determinates of these outcomes. All regression models controlled for age, sex, race/ethnicity, PHF diagnosis, PHF operation, Elixhauser Comorbidity Score, ISS, and frailty. Linear regression models also controlled for development of any complication. Covariates were included in regression analyses regardless of significance. SEs were calculated for all models. A p value <0.05 was considered statistically significant for all analyses. Statistical analyses were conducted using RStudio (V.1.4.1717) and the R 'survey' package (V.4.1-1).[19–21]

RESULTS

Demographic and clinical characteristics

A total sample of 44 565 was identified with PHF between 2012 and 2015, representing 0.17% of the total NIS during that period. Exclusion of non-geriatric patients (<65 years) and those sustaining polytrauma (ISS >15) resulted in a sample of 29 963. In addition, 2401 entries missing race/ethnicity, primary payer, disposition, in-hospital mortality, and total charges information were excluded from survey adjustment and further analysis (online supplemental figure 1).

After survey adjustment, a total cohort of 137 810 was identified with geriatric PHF, of which 51 795 (37.6%) underwent operative management and 86 015 (62.4%) underwent

non-operative management. In both cohorts, the majority of PHF were identified by ICD-9 diagnosis codes 812.01, 'fracture of surgical neck of humerus closed' (28.6% vs 39.1%, p<0.001); 812.00, 'fracture of unspecified part of upper end of humerus closed' (36.4% vs 30.2%, p<0.001); and 812.09, 'other closed fractures of upper end of humerus' (24.5% vs 20.6%, p<0.001). Open fractures were more likely to undergo operative management, with the exception of those involving the greater tuberosity. A majority of patients undergoing operative management underwent ORIF (53.4%), followed by reverse shoulder arthroplasty (RSA; 23.5%) or hemiarthroplasty (HA; 17.2%). A minority underwent total shoulder arthroplasty (TSA; 1.2%), open reduction without internal fixation (OR-NOIF; 0.7%), or application of an external fixator device (EXFIX; 0.5%). Full fracture type and operation type data are presented in table 1.

The operative cohort was younger (76.6 years vs 80.9 years, p<0.001) with a greater proportion of females (81.8% vs 77.6%, p<0.001) and those privately insured (8.1% vs 5.8%, p<0.001). They were also more likely to be obese (11.8% vs 6.9%, p<0.001). Nonetheless, the non-operative cohort was more comorbid, demonstrating a higher prevalence of AHRQ comorbidity measures (online supplemental table 4) and higher Elixhauser Comorbidity Scores (6.66 vs 3.25, p<0.001). The non-operative cohort was also more severely injured (ISS 5.50 vs 4.63, p<0.001) and more likely to meet frailty criteria (12.4% vs 8.7%, p<0.001). Full demographic and clinical data are presented in table 1.

Trends

Between 2012 and 2015, there was no significant linear trend in age-adjusted and sex-adjusted proportions of operatively versus non-operatively managed cases of geriatric PHF (p=0.071; figure 1A), with operative incidence remaining relatively stable. Alternatively, a statistically significant, positive linear trend was observed when examining total cost of operatively managed geriatric PHF (p<0.001; figure 1B).

Univariate analyses

Univariate analysis demonstrated a higher prevalence of overall complication (45.9% vs 35.1%, p<0.001) among non-operative patients, as compared with those undergoing surgical intervention. The non-operative cohort experienced higher rates of AKI, intubation, UTI, MI, DVT, PE, and mortality (all p<0.001). The operative cohort experienced higher rates of anemia requiring blood transfusion, SSI, device complications, malunion/nonunion, nerve injury, and tendon rupture/injury (all p<0.001). There were no differences among rates of sepsis and avascular necrosis of the humeral head (all p>0.05). Full complication data are presented in table 2. The operative cohort was more likely to be discharged home (30.4% vs 13.9%, p<0.001) and required shorter LOS (4.36 days vs 4.9 days, p<0.001). In contrast, the non-operative cohort was more frequently transferred to skilled nursing facilities, intensive care facilities, or other related medical facilities (69.4% vs 49.5%, p<0.001). Finally, surgical intervention was found to have a higher median cost of hospitalization when compared with non-operative management (US$16 447 vs US$7226, p<0.001; table 2).

Multivariate analyses

To better understand the relationship between operative management and complications, we performed a multivariable survey-adjusted analysis with development of any complication as the dependent outcome. This model demonstrated that operative

Table 1 Demographic and clinical characteristics of geriatric patients diagnosed with PHF treated from 2012 to 2015

	Non-operative N=86 015	Operative N=51 975
Age (years)	80.95 (SD 0.1)	76.64 (SD 0.1)
Age group (years)		
65–69	9530 (11.1%)	11 220 (21.7%)
70–74	10 550 (12.3%)	10 860 (21.0%)
75–79	13 565 (15.8%)	10 670 (20.6%)
80–84	17 150 (19.9%)	9525 (18.4%)
85–89	18 780 (21.8%)	6865 (13.2%)
90–94	16 440 (19.0%)	2655 (5.1%)
95+	n<11 (0.0%)	n<11 (0.0%)
Sex		
Male	19 265 (22.4%)	9620 (18.2%)
Female	66 750 (77.6%)	42 355 (81.8%)
Race/Ethnicity		
White	75 090 (87.3%)	45 930 (88.7%)
Black	2965 (3.4%)	1070 (2.1%)
Hispanic	4915 (5.8%)	2865 (5.5%)
Asian/Pacific Islander	1150 (1.3%)	600 (1.2%)
Native American	300 (0.3%)	140 (0.3%)
Other	1595 (1.9%)	1190 (2.3%)
Insurance status		
Medicare	79 055 (91.8%)	46 015 (88.8%)
Medicaid	695 (0.8%)	360 (0.7%)
Private	4950 (5.8%)	4145 (8.1%)
Self-pay	390 (0.5%)	255 (0.5%)
No charge	25 (0.03%)	20 (0.04%)
Other	900 (1.1%)	1000 (1.9%)
Elixhauser Comorbidity Score	6.66 (SD 0.1)	3.25 (SD 0.1)
Frailty	10 640 (12.4%)	4495 (8.7%)
ISS	5.50 (SD<0.01)	4.63 (SD<0.01)
Diagnosis/Fracture type		
Anatomical neck, closed	1415 (1.6%)	950 (1.8%)
Anatomical neck, open	20 (0.02%)	25 (0.05%)
Greater tuberosity, closed	7075 (8.2%)	4225 (8.2%)
Greater tuberosity, open	15 (0.02%)	n<11 (0.0%)
Surgical neck, closed	33 685 (39.2%)	14 745 (28.6%)
Surgical neck, open	75 (0.09%)	130 (0.3%)
Upper end, closed (other)	17 940 (20.5%)	12 695 (24.5%)
Upper end, closed (unspec)	26 025 (30.2%)	18 875 (36.4%)
Upper end, open (other)	45 (0.05%)	50 (0.1%)
Upper end, open (unspec)	45 (0.05%)	100 (0.2%)
Operation type		
CRIF		1820 (3.5%)
EXFIX		260 (0.5%)
HA		8925 (17.2%)
OR-NOIF		350 (0.7%)
ORIF		27 610 (53.4%)
RSA		12 190 (23.5%)
TSA		645 (1.2%)
Hospital setting		
Rural	11 390 (13.2%)	5605 (10.8%)
Urban, non-teaching	32 840 (38.2%)	20 440 (39.5%)
Urban, teaching	41 875 (48.6%)	25 750 (49.7%)
Hospital bed size		
Small	15 520 (18.0%)	9000 (17.4%)
Medium	24 295 (29.0%)	14 790 (28.6%)
Large	45 570 (53.0%)	28 005 (54.0%)

In compliance with the HCUP DUA, cells with n<10 observations should be marked '<11'.
CRIF, closed reduction and internal fixation; DUA, data user agreement; EXFIX, external fixator device; HA, hemiarthroplasty; HCUP, Healthcare Cost and Utilization Project; ISS, Injury Severity Score; ORIF, open reduction and internal fixation; OR-NOIF, open reduction with no internal fixation; PHF, proximal humerus fractures; RSA, reverse shoulder arthroplasty; TSA, total shoulder arthroplasty; unspec, unspecified.

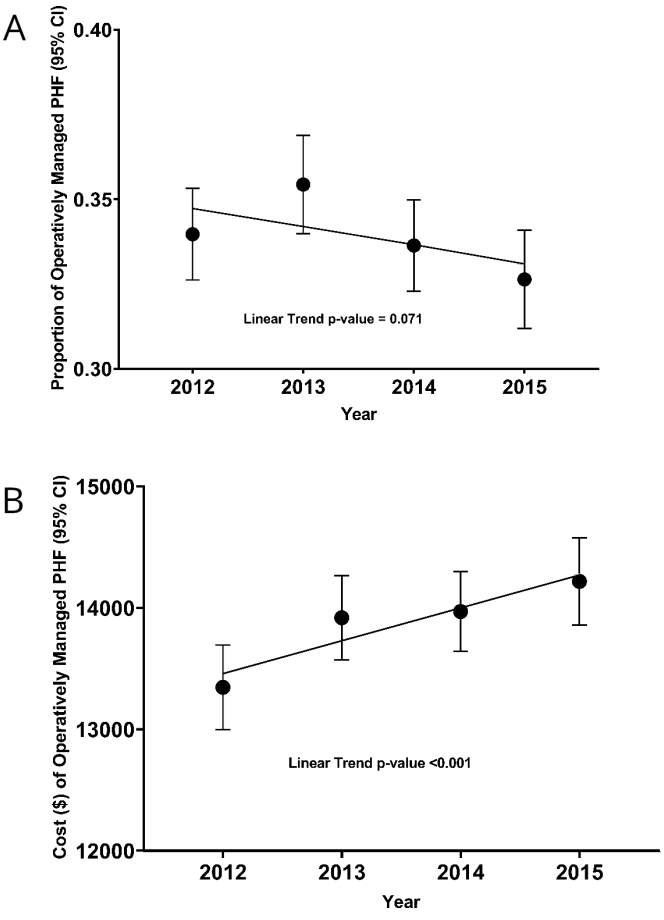

Figure 1 (A) Proportion of operatively managed geriatric PHF between 2012 and 2015. (B) Cost of operatively managed geriatric PHF between 2012 and 2015. PHF, proximal humerus fractures.

management was associated with similar overall complication occurrence (OR 0.95; 95% CI 0.89 to 1.00; p=0.06; table 3). This association was independent of age, sex, race/ethnicity, PHF diagnosis, PHF operation, Elixhauser Comorbidity Score, ISS, and frailty.

To assess the associations between (1) operative management and LOS and (2) operative management and cost, we performed multivariable survey-adjusted analyses. Our models included the following variables: age, sex, race/ethnicity, PHF diagnosis, PHF operation, Elixhauser Comorbidity Score, ISS, and frailty, and overall complication. These analyses revealed that surgical intervention increased LOS by 0.15 days (95% CI 0.03 to 0.27; p=0.008). Other factors independently associated with prolonged LOS included (table 4): identifying as black or other relative to white race/ethnicity; increased Elixhauser Comorbidity Score; increased ISS; frailty; and development of any complication (all p<0.05). Increased age, female sex, open fractures of the anatomic neck were factors found to be significantly associated with decreased LOS (all p<0.05). Surgical intervention was found to increase median cost of hospitalization by US$10 684 (95% CI US$10 384 to US$10 984; p<0.001). Other factors independently associated with increased cost included (table 5): identifying as Hispanic or other relative to white race/ethnicity; increased Elixhauser Comorbidity Score; increased ISS; frailty; development of any complication; and any PHF operation (all p<0.05).

Table 2 Patient outcomes, hospital costs, and complications of geriatric patients diagnosed with PHF and treated from 2012 to 2015

	Non-operative N=86 015	Operative N=51 975
General complication	39 500 (45.9%)	18 170 (35.1%)
Acute kidney injury	12 880 (15.0%)	3850 (7.4%)
Sepsis	2465 (2.9%)	340 (0.7%)
Intubation	1395 (1.6%)	520 (1.0%)
Anemia requiring blood transfusion	12 645 (14.7%)	10 975 (21.3%)
Pneumonia	6240 (7.3%)	1545 (3.0%)
Urinary tract infection	16 855 (19.6%)	5540 (10.7%)
Cardiac arrest	435 (0.5%)	135 (0.3%)
Myocardial infarction	2140 (2.5%)	490 (1.0%)
Deep venous thrombosis	725 (0.8%)	225 (0.5%)
Pulmonary embolism	610 (0.7%)	250 (0.5%)
PHF complication	305 (0.4%)	935 (1.8%)
Surgical site infection	n<11 (0.0%)	35 (0.1%)
Avascular necrosis	55 (0.1%)	70 (0.1%)
Device complications	n<11 (0.0%)	450 (0.9%)
Malunion/Non-union	235 (0.3%)	265 (0.5%)
Nerve injury	15 (0.02%)	100 (0.2%)
Tendon rupture/Injury	n<11 (0.0%)	50 (0.1%)
Length of stay (days)	4.9 (SD<0.01)	4.36 (SD 0.01)
Disposition		
Routine (home)	11 925 (13.9%)	15 720 (30.4%)
Transfer to short-term hospital	2210 (2.6%)	345 (0.7%)
Transfer to SNF, ICF, or other	59 685 (69.4%)	25 660 (49.5%)
Home healthcare	9675 (11.2%)	9715 (18.7%)
Died	2115 (2.5%)	290 (0.6%)
Against medical advice	335 (0.4%)	60 (0.1%)
Unknown	70 (0.1%)	n<11 (0.0%)
Hospital cost (US$)	7226.00 (IQR 4556.44–12 353.40)	16 446.53 (IQR 12 029.80–22 833.98)

In compliance with the HCUP DUA, cells with n<10 observations should be marked '<11'.
DUA, data user agreement; HCUP, Healthcare Cost and Utilization Project; ICF, intensive care facility; PHF, proximal humerus fractures; SNF, skilled nursing facility.

DISCUSSION

Despite the significant prevalence of geriatric PHF and escalating PHF-attributable expenditures,[6] much remains ill-defined regarding the optimal management of PHF in the elderly. Using NIS, this study aims to compare annual trends, patient outcomes, and hospital costs between operatively and non-operatively managed cases of geriatric PHF. Retrospective review of NIS did not demonstrate a linear trend in operative incidence between 2012 and 2015. It did, however, identify a positive linear trend in total cost of operatively managed geriatric PHF over the same time period. Operative management appears to be associated with a similar overall complication rate and a greater likelihood of being discharged home. Conversely, non-operative management avoids the risk of PHF complication and appears to be associated with decreased hospital expenses and decreased LOS.

The present study identified an operative incidence of 37.6% from 2012 to 2015. This is significantly higher compared with prior investigations using 2004–2012 Medicare claims data. In separate works, both Hasty *et al* and Bell *et al* found that approximately 15% of all geriatric PHF were treated surgically.[10 22] A portion of this relative increase can be attributed to

Table 3 Multivariate regression models for overall complication occurrence among geriatric patients with PHF between 2012 and 2015

	Any complication		
	OR	95% CI	P value
Operation	0.95	0.89 to 1.00	0.06
Age	1.02	1.017 to 1.024	**<0.001**
Sex (female)	1.10	1.03 to 1.17	**0.004**
Race/Ethnicity			
White	–	–	–
Black	1.18	1.02 to 1.37	**0.03**
Hispanic	1.00	0.90 to 1.11	0.98
Asian or Pacific Islander	1.05	0.85 to 1.29	0.64
Native American	0.89	0.56 to 1.42	0.64
Other	1.02	0.85 to 1.21	0.86
Specific diagnosis			
Anatomical neck, closed	–	–	–
Anatomical neck, open	1.04	0.30 to 3.62	0.95
Greater tuberosity, closed	0.85	0.69 to 1.05	0.13
Greater tuberosity, open	1.08	0.07 to 16.31	0.896
Surgical neck, closed	1.11	0.91 to 1.35	0.29
Surgical neck, open	0.54	0.26 to 1.12	0.10
Upper end, closed (other)	1.03	0.85 to 1.26	0.75
Upper end, closed (unspec)	1.09	0.90 to 1.33	0.37
Upper end, open (other)	1.36	0.90 to 3.76	0.55
Upper end, open (unspec)	0.92	0.42 to 2.04	0.85
Procedure type			
Non-operative	–	–	–
CRIF	1.06	0.85 to 1.32	0.60
EXFIX	0.67	0.36 to 1.23	0.19
HA	1.08	0.85 to 1.36	0.53
OR-NOIF	0.59	0.32 to 1.08	0.09
ORIF	0.90	0.72 to 1.13	0.37
RSA	0.95	0.75 to 1.20	0.66
TSA	0.61	0.39 to 0.97	**0.03**
Elixhauser Comorbidity Score	1.06	1.059 to 1.065	**<0.001**
ISS	1.07	1.06 to 1.08	**<0.001**
Frailty	0.98	0.90 to 1.06	0.59

A p-value <0.05 is considered statistically significant; the values are bolded to emphasize that.
CRIF, closed reduction and internal fixation; EXFIX, external fixator device; HA, hemiarthroplasty; ISS, Injury Severity Score; ORIF, open reduction and internal fixation; OR-NOIF, open reduction with no internal fixation; RSA, reverse shoulder arthroplasty; TSA, total shoulder arthroplasty; unspec, unspecified.

Table 4 Multivariate regression model for LOS in the hospital among geriatric patients with PHF between 2012 and 2015

	LOS		
	Coefficient (days)	95% CI	P value
Operation	0.15	0.03 to 0.27	**0.008**
Age	−0.02	−0.03 to 0.015	**<0.001**
Sex (female)	−0.33	−0.46 to 0.20	**<0.001**
Race/Ethnicity			
White	–	–	–
Black	0.79	0.28 to 1.29	**0.002**
Hispanic	0.16	−0.06 to 0.38	0.16
Asian or Pacific Islander	0.18	−0.97 to 1.33	0.76
Native American	−0.24	−0.92 to 0.44	0.48
Other	0.57	0.15 to 0.99	**0.008**
Specific diagnosis			
Anatomical neck, closed	–	–	–
Anatomical neck, open	1.91	−3.03 to 0.80	**<0.001**
Greater tuberosity, closed	0.17	−0.25 to 0.59	0.44
Greater tuberosity, open	3.09	−3.40 to 9.59	0.35
Surgical neck, closed	0.20	−0.15 to 0.55	0.26
Surgical neck, open	0.56	−0.90 to 2.03	0.45
Upper end, closed (other)	0.21	−0.15 to 0.56	0.26
Upper end, closed (unspec)	0.16	−0.20 to 0.41	0.38
Upper end, open (other)	0.38	−2.31 to 1.55	0.70
Upper end, open (unspec)	0.72	−2.05 to 0.61	0.29
Procedure type			
Non-operative	–	–	–
CRIF	0.29	−0.63 to 0.06	0.10
EXFIX	0.34	−0.63 to 1.32	0.49
HA	−0.11	−0.48 to 0.27	0.58
OR-NOIF	0.06	−0.74 to 0.62	0.86
ORIF	0.20	−0.55 to 0.16	0.28
RSA	0.46	−0.82 to 0.10	**0.01**
TSA	0.63	−1.21 to 0.06	**0.03**
Elixhauser Comorbidity Score	0.09	0.08 to 0.093	**<0.001**
ISS	0.21	0.18 to 0.24	**<0.001**
Frailty	0.82	0.63 to 1.01	**<0.001**
Any complication	1.88	1.78 to 1.99	**<0.001**

CRIF, closed reduction and internal fixation; EXFIX, external fixator device; HA, hemiarthroplasty; ISS, Injury Severity Score; LOS, length of stay; ORIF, open reduction and internal fixation; OR-NOIF, open reduction with no internal fixation; PHF, proximal humerus fractures; RSA, reverse shoulder arthroplasty; TSA, total shoulder arthroplasty; unspec, unspecified.

the mid-2000s development of locking plate technology, which expanded the indications for ORIF.[22] Likewise, there has been a well-documented increase in the utilization of RSA over the past decade.[8 10 23 24] Interestingly, this investigation did not identify a statistically significant linear trend in operative incidence during its 4-year study period. Further exploration of more recent datasets is required to resolve this finding.

In contrast, retrospective review of NIS did demonstrate a positive linear trend in operative cost. Following surgery for geriatric PHF, median cost of hospitalization rose from US$13 459 in 2012 to US$14 270 in 2015. Recent studies stratifying cost by operative intervention have identified significant differences,[25 26] with the highest charges seen in RSA (US$21 486–US$16 151), followed by HA (US$9348–US$17 255) and ORIF (US$6745–US$11 183). Additionally, complications and hospital readmission after operative management continue to drive costs upward. Thorsness *et al* found that readmission increased in-hospital cost by US$54 345, while complications increased in-hospital cost by US$23 300.[27] The increase in median cost of hospitalization observed likely reflects overall increases in healthcare costs over time. While the cost of index-operative PHF hospitalizations have remained stable, complications and hospital readmissions after operative management continue to drive associated costs upward. This further highlights the need to reach consensus on best practice.

The present study did not find operative management to be an independent predictor of overall complication rate. However, multivariable analysis demonstrated that operative management increased the odds of suffering a PHF complication by 1.88 times (95% CI 1.78 to 1.99; p<0.001). The increase in PHF complications would be expected and is believed to fall within

Table 5 Multivariate regression model for hospital costs among geriatric patients with PHF between 2012 and 2015

	Hospital costs		
	Coefficient (US$)	95% CI	P value
Operation	10684.03	10383.63 to 10984.44	**<0.001**
Age	−121.66	−138.05, to 105.27	**<0.001**
Sex (female)	−1269.54	−1577.18, to 961.89	**<0.001**
Race/Ethnicity			
White	–	–	–
Black	444.22	−226.77 to 1115.20	0.19
Hispanic	626.51	98.46 to 1154.55	**0.02**
Asian or Pacific Islander	2203.42	−88.11 to 4494.95	0.06
Native American	254.84	−1757.17 to 2266.84	0.80
Other	2219.27	1120.84 to 3317.70	**<0.001**
Specific diagnosis			
Anatomical neck, closed	–	–	–
Anatomical neck, open	9359.17	−12891.08 to 5827.25	**<0.001**
Greater tuberosity, closed	32.60	−844.87 to 910.07	0.94
Greater tuberosity, open	4877.32	−10607.04 to 852.39	0.10
Surgical neck, closed	247.88	−1042.58 to 546.82	0.54
Surgical neck, open	2413.35	−5156.02 to 329.32	0.08
Upper end, closed (other)	5.37	−818.28 to 807.54	0.99
Upper end, closed (unspec)	440.88	−1236.16 to 354.41	0.28
Upper end, open (other)	3004.30	−8852.69 to 2844.10	0.31
Upper end, open (unspec)	3875.18	−8080.93 to 330.58	0.07
Procedure type			
Non-operative	–	–	–
CRIF	1366.94	(1070.87 to 2328.93	**<0.001**
EXFIX	5408.28	(1535.88 to 9280.98)	**<0.006**
HA	5112.52	(4044.43 to 6180.61)	**<0.001**
OR-NOIF	3755.69	(1138.54 to 6372.84)	**0.005**
ORIF	2366.94	(1373.74 to 3360.15)	**<0.001**
RSA	9248.18	(8167.33 to 10329.02)	**<0.001**
TSA	7750.45	(5725.03 to 9775.88)	**<0.001**
Elixhauser Comorbidity Score	170.55	(154.41 to 186.70)	**<0.001**
ISS	1090.07	(1021.75 to 1158.40)	**<0.001**
Frailty	1537.09	(1126.14 to 1948.04)	**<0.001**
Any complication	4240.80	(3996.37 to 4485.22)	**<0.001**

CRIF, closed reduction and internal fixation; EXFIX, external fixator device; HA, hemiarthroplasty; ISS, Injury Severity Score; ORIF, open reduction and internal fixation; OR-NOIF, open reduction with no internal fixation; PHF, proximal humerus fractures; RSA, reverse shoulder arthroplasty; TSA, total shoulder arthroplasty; unspec, unspecified.

the normal range for surgical intervention in an elderly patient population. Both the overall and PHF complication rates are provided as references, allowing for more informed decision-making by clinicians and patients alike. Comparison of these outcomes with those of frail and non-frail adults (≥18 and <65 years) is beyond the scope of the current study. However, future investigation into such differences is needed to best convey risks associated with PHF management in frail and/or aging trauma populations.

Operative management of PHF is generally associated with prolonged LOS. Between 2007 and 2015, Wu *et al* demonstrated that ORIF, RSA, and HA resulted in increased LOS by 1.8, 2.3, and 3.2 days relative to non-operative management.[28] The present study also identified operative management as an independent predictor of increased LOS, but only by an additional 0.15 days. In fact, when looking at specific procedure type, surgical treatment with RSA or TSA demonstrated an association with shortened LOS relative to non-operative management (both $p<0.05$). These findings may allude to increased and improved utilization of RSA and TSA as surgical treatments for PHF over time.[8 29 30]

Finally, the present study demonstrates that operative management of PHF is associated with a greater likelihood of being discharged home, both with and without home healthcare. This may be explained by the fact that the operative cohort was significantly less frail, less comorbid, and less severely injured at presentation. Nonetheless, several studies have shown that discharge to rehabilitation facilities is related to adverse outcomes, including increased readmission and mortality, following any trauma-related surgery in the geriatric population.[31 32] Despite the study trends and associations identified with operative PHF management including longer LOS and higher cost, it may be beneficial to consider surgical approaches in the context of patient-focused outcomes, given the increased likelihood of being discharged directly home after intervention. Given that NIS is limited to a single hospital admission, direct inferences cannot be drawn from this study with regard to readmission or other outcomes that occur after discharge. Therefore, additional research is necessary to better assess outcomes after initial disposition in the setting of operatively versus non-operatively managed geriatric PHF.[33 34]

Limitations

This work does have certain limitations to consider. By nature, this study is a retrospective review of a large institutional dataset. Thus, it is inherently susceptible to omitted variables, selection bias, and sampling error. We only queried data from 2012 to 2015 using ICD-9 diagnosis codes given the conversion to ICD-10 codes in order to keep our datasets consistent, which does decrease the potential sample size had we investigated to also include more recent years. With regard to reporting complications, we attempt to present both general and PHF-specific sequalae, as possible within the confines of NIS. However, we recognize the inability of NIS to capture complications that occur after hospital discharge. We acknowledge that many PHF complications may arise at an interval greater than the average LOS reported in this study, which was approximately 4 days. NIS is also unable to capture geriatric PHF that are initially treated non-operatively, only to undergo operative management on readmission or on an outpatient basis. The HCUP Nationwide Readmissions Database and Nationwide Ambulatory Surgery Sample are better designed to identify this subset of patients. Finally, this work is unable to assess differences in functional outcomes between non-operative and operative cohorts. Functional recovery and return to independent living are crucial measures in the successful management of geriatric PHF. This merits further investigation, as meaningful conclusions regarding the current landscape of geriatric PHF may be difficult to establish without this key information.

CONCLUSION

This study demonstrates a non-significant linear trend in operatively managed cases of geriatric PHF and a significant, positive linear trend in total cost of operatively managed geriatric PHF over the 2012–2015 time period. Operative management appears to be associated with a similar overall complication rate and a greater likelihood of being discharged home. Conversely, non-operative management avoids the increased risk for PHF complication and appears to be associated with decreased hospital expenses and decreased LOS. Taken as a whole, the use of operative PHF management in the geriatric patient population remained stable with a small increase in cost. Despite these

trends, the operative approach to PHF appears to be safe, minimally prolongs LOS by <1 day relative to non-operative management, and conveys a greater chance of being discharged to home. As current operative methods continue to improve, healthcare providers should consider surgical PHF treatment options when available and appropriate in the context of patient-focused outcomes, including long-term disposition. Further study is needed to better understand the patient-specific factors that lead to the selection of operative versus non-operative management of geriatric PHF.

Contributors KG, JK, PPP, MJA, and RPG were involved with the conception of this project. TC and KG completed data collection and analysis. TC, KG, and JK drafted the initial version of the manuscript, including tables and supplementary material. All the authors contributed to final edits and concurred with the major revisions for resubmission, with KG acting as guarantor.

Funding KG is supported through NIH T32 NIGMS 2T32GM008750-21A1.

Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval This study was deemed exempt by the Loyola University Chicago Institutional Review Board.

Provenance and peer review Not commissioned; internally peer reviewed.

Data availability statement Data are available on reasonable request. Data, including the code, are available on reasonable request should the occasion arise.

ORCID iD

Teresa Cheng http://orcid.org/0000-0002-3145-9039

REFERENCES

1 Palvanen M, Kannus P, Niemi S, Parkkari J. Update in the epidemiology of proximal Humeral fractures. *Clin Orthop Relat Res* 2006;442:87–92.
2 Court-Brown CM, Garg A, McQueen MM. The epidemiology of proximal Humeral fractures. *Acta Orthop Scand* 2001;72:365–71.
3 Hernlund E, Svedbom A, Ivergård M, Compston J, Cooper C, Stenmark J, McCloskey EV, Jönsson B, Kanis JA. Osteoporosis in the european union: medical management, epidemiology and economic burden. *Arch Osteoporos* 2013;8:136.
4 Maravic M, Briot K, Roux C, Collège Français des Médecins Rhumatologues (CFMR). Burden of proximal Humerus fractures in the French national hospital database. *Orthop Traumatol Surg Res* 2014;100:931–4.
5 Tarride J-E, Hopkins RB, Leslie WD, Morin S, Adachi JD, Papaioannou A, Bessette L, Brown JP, Goeree R. The burden of illness of osteoporosis in Canada. *Osteoporos Int* 2012;23:2591–600.
6 Helmy N, Hintermann B. New trends in the treatment of proximal Humerus fractures. *Clin Orthop Relat Res* 2006;442:100–8.
7 Gupta AK, Harris JD, Erickson BJ, Abrams GD, Bruce B, McCormick F, Nicholson GP, Romeo AA. Surgical management of complex proximal Humerus fractures-a systematic review of 92 studies including 4500 patients. *J Orthop Trauma* 2015;29:54–9.
8 Han RJ, Sing DC, Feeley BT, Ma CB, Zhang AL. Proximal Humerus fragility fractures: recent trends in Nonoperative and operative treatment in the Medicare population. *J Shoulder Elbow Surg* 2016;25:256–61.
9 Gallinet D, Cazeneuve J-F, Boyer E, Menu G, Obert L, Ohl X, Bonnevialle N, Valenti P, Boileau P, Société Française de Chirurgie Orthopédique et Traumatologique (SoFCOT). Reverse shoulder Arthroplasty for recent proximal Humerus fractures: outcomes in 422 cases. *Orthop Traumatol Surg Res* 2019;105:805–11.
10 Hasty EK, Jernigan EW III, Soo A, Varkey DT, Kamath GV. Trends in surgical management and costs for operative treatment of proximal Humerus fractures in the elderly. *Orthopedics* 2017;40:e641–7.
11 Agency for Healthcare Quality and Research. Healthcare cost and utilization project (HCUP). 2012.
12 Khera R, Angraal S, Couch T, Welsh JW, Nallamothu BK, Girotra S, Chan PS, Krumholz HM. Adherence to methodological standards in research using the National inpatient sample. *JAMA* 2017;318:2011–8.
13 Wong TH, Krishnaswamy G, Nadkarni NV, Nguyen HV, Lim GH, Bautista DCT, Chiu MT, Chow KY, Ong MEH. Combining the new injury severity score with an anatomical Polytrauma injury variable predicts mortality better than the new injury severity score and the injury severity score: a retrospective cohort study. *Scand J Trauma Resusc Emerg Med* 2016;24:25.
14 Baker SP, O'Neill B, Haddon W Jr, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma* 1974;14:187–96.
15 Nieman CL, Pitman KT, Tufaro AP, Eisele DW, Frick KD, Gourin CG. The effect of frailty on short-term outcomes after head and neck cancer surgery. *Laryngoscope* 2018;128:102–10.
16 Hopkins J. *The Johns Hopkins ACG® system version 11.0 technical reference guide*. Bloomberg School of Public Health: Johns Hopkins, 2014.
17 Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Medical Care* 1998;36:8–27.
18 Bieler GS, Brown GG, Williams RL, Brogan DJ. Estimating model-adjusted risks, risk differences, and risk ratios from complex survey data. *Am J Epidemiol* 2010;171:618–23.
19 Team, RStudio. *Rstudio: integrated development for R*. Boston, MA: RStudio, 2015.
20 Lumley T. *Survey: analysis of complex survey samples*. R package, 2020.
21 Lumley T. Analysis of complex survey samples. *J Stat Soft* 2004;9:1–19.
22 Bell J-E, Leung BC, Spratt KF, Koval KJ, Weinstein JD, Goodman DC, Tosteson ANA. Trends and variation in incidence, surgical treatment, and repeat surgery of proximal Humeral fractures in the elderly. *J Bone Joint Surg Am* 2011;93:121–31.
23 Kelly BJ, Myeroff CM. Reverse shoulder Arthroplasty for proximal Humerus fracture. *Curr Rev Musculoskelet Med* 2020;13:186–99.
24 Rajaee SS, Yalamanchili D, Noori N, Debbi E, Mirocha J, Lin CA, Moon CN. Increasing use of reverse total shoulder Arthroplasty for proximal Humerus fractures in elderly patients. *Orthopedics* 2017;40:e982–9.
25 London DA, Cagle PJ, Parsons BO, Galatz LM, Anthony SG, Zubizarreta N, Mazumdar M, Poeran J. Impact of increasing Comorbidity burden on resource utilization in patients with proximal Humerus fractures. *J Am Acad Orthop Surg* 2020;28:e954–61.
26 Rosas S, Kurowicki J, Yee T, Momoh E, Kalandiak SP, Levy JC. Cost of treatment for proximal Humerus fractures: an acute and 90-day cost evaluation. *J Long Term Eff Med Implants* 2018;28:173–9.
27 Thorsness R, Shields E, Iannuzzi JC, Zhang L, Noyes K, Voloshin I. Cost drivers after surgical management of proximal Humerus fractures in Medicare patients. *J Orthop Trauma* 2016;30:262–8.
28 Wu EJ, Zhang SE, Truntzer JN, Gardner MJ, Kamal RN. Cost-Minimization analysis and treatment trends of surgical and Nonsurgical treatment of proximal Humerus fractures. *J Hand Surg Am* 2020;45:698–706.
29 Sebastiá-Forcada E, Cebrián-Gómez R, Lizaur-Utrilla A, Gil-Guillén V. Reverse shoulder Arthroplasty versus Hemiarthroplasty for acute proximal Humeral fractures. A blinded, randomized, controlled, prospective study. *J Shoulder Elbow Surg* 2014;23:1419–26.
30 Khatib O, Onyekwelu I, Zuckerman JD. The incidence of proximal Humeral fractures in New York State from 1990 through 2010 with an emphasis on operative management in patients aged 65 years or older. *J Shoulder Elbow Surg* 2014;23:1356–62.
31 Ramos NL, Karia RJ, Hutzler LH, Brandt AM, Slover JD, Bosco JA. The effect of discharge disposition on 30-day readmission rates after total joint Arthroplasty. *J Arthroplasty* 2014;29:674–7.
32 Ottenbacher KJ, Karmarkar A, Graham JE, Kuo Y-F, Deutsch A, Reistetter TA, Al Snih S, Granger CV. Thirty-day hospital readmission following discharge from Postacute rehabilitation in fee-for-service Medicare patients. *JAMA* 2014;311:604–14.
33 Howard L, Berdusco R, Momoli F, Pollock J, Liew A, Papp S, Lalonde K-A, Gofton W, Ruggiero S, Lapner P. Open reduction internal fixation vs non-operative management in proximal Humerus fractures: a prospective, randomized controlled trial protocol. *BMC Musculoskelet Disord* 2018;19:299.
34 Handoll H, Brealey S, Rangan A, Keding A, Corbacho B, Jefferson L, Chuang L-H, Goodchild L, Hewitt C, Torgerson D. The Profher (proximal fracture of the Humerus: evaluation by Randomisation) trial - a pragmatic Multicentre randomised controlled trial evaluating the clinical effectiveness and cost-effectiveness of surgical compared with non-surgical treatment for proximal fracture of the Humerus in adults. *Health Technol Assess* 2015;19:1–280.