Renal disease is a risk factor for complications and mortality after open reduction internal fixation of proximal humerus fractures.

Journal

JSES International, 6(5)

Authors

Ahlquist, Seth
Hsiue, Peter
Chen, Clark
et al.

Publication Date

2022-09-01

DOI

10.1016/j.jseint.2022.05.015

JSES International 6 (2022) 736–742

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

Renal disease is a risk factor for complications and mortality after open reduction internal fixation of proximal humerus fractures

Seth Ahlquist, MD[a], Peter P. Hsiue, MD[a], Clark J. Chen, MD[a], Brendan Shi, MD[a], Alexander Upfill-Brown, MD[a], Ben V. Kelley, MD[a], Peyman Benharash, MD[b], Christos Photopoulos, MD[c], Alexandra I. Stavrakis, MD[a,*]

[a]Department of Orthopaedic Surgery, David Geffen School of Medicine at UCLA, Santa Monica, CA, USA
[b]Department of Cardiac Surgery, David Geffen School of Medicine at UCLA, Los Angeles, CA, USA
[c]Kerlan-Jobe Orthopaedic Institute, Los Angeles, CA, USA

ARTICLE INFO

Keywords:
Proximal humerus fracture
Open reduction internal fixation
Chronic renal disease
End-stage renal disease
Dialysis
Readmission

Level of evidence: Level III; Retrospective Cohort Comparison using Large Database; Treatment Study

Background: Renal osteodystrophy predisposes renal disease patients to fracture. Proximal humerus fractures (PHFs) frequently undergo open reduction internal fixation (ORIF); however, the effect of renal disease on outcomes is unknown.
Methods: A retrospective review of the Nationwide Readmissions Database used International Classification of Diseases, 9th Revision, codes to identify patients who underwent ORIF for closed PHF from 2010 to 2014 with no renal disease, predialysis chronic renal disease (CRD), and end-stage renal disease (ESRD).
Results: A total of 85,433 patients were identified, including 5498 (6.4%) CRD and 636 (0.7%) ESRD. CRD and ESRD patients had increased age, comorbidities, and rates of Medicare insurance. After adjusting for differences, CRD and ESRD patients were at increased risk of any complication (odds ratio [OR] 2.48, 1.66), blood transfusion (OR 1.85, 3.31), respiratory complications (OR 1.14, 1.59), acute renal failure (OR 4.80, 1.67), systemic infection (OR 2.00, 3.14), surgical site infection (OR 1.52, 3.87), longer length of stay (7.1 and 12.9 days vs. 5.9 days), and higher cost ($21,669 and $35,413 vs. $20,394) during index hospitalization, as well as surgical site infection (OR 1.43, 3.03) and readmission (OR 1.61, 3.69) within 90 days of discharge, respectively, compared with no renal disease patients. During index hospitalization, CRD patients also had increased risk for periprosthetic fracture (OR 4.97) and cardiac complications (OR 1.47), whereas ESRD patients had increased risk of mortality (OR 5.79), wound complication (2.67), and deep vein thrombosis (OR 16.70).
Conclusion: These findings suggest renal patients are at increased risk for complications after PHF ORIF, highlighting the importance of close perioperative monitoring and appropriate patient selection in this population, including strong consideration of nonoperative management.

Proximal humerus fractures (PHFs) are the third most common fracture pattern elderly, frequently resulting from low-energy falls.[5,6] Many PHFs are minimally displaced and can successfully be treated nonoperatively,[21] but operative management may be indicated in displaced fractures to reduce long-term pain and dysfunction. Given improvements in implants and surgical technique, the number of operatively treated fractures has increased over time.[12] Historically, 3- and 4-part PHFs have been treated with either open reduction internal fixation (ORIF) or hemiarthroplasty. The advent of proximal humeral locking plate technology has greatly increased the range of PHFs amenable to ORIF and results in satisfactory clinical outcomes.[15,27,30,35,36] Although indications for total shoulder arthroplasty and reverse total shoulder arthroplasty (rTSA) have been recently expanding, ORIF remains the most common surgical treatment for PHF.[12] There are multiple technical challenges associated with ORIF in the geriatric population, including fracture displacement, comminution, and poor bone quality,[1,38,39] with complications rates as high as 44%.[1,3,7,20,46] There is thought these challenges may be obviated by correct surgical technique[33,40] including attention to optimal screw positioning and medial column support.[13,29,31] However, it is also important to understand how patient-related factors including comorbidities might affect clinical outcomes and thus inform appropriate patient selection.

Institutional review board approval was exempt for this study.

*Corresponding author: Alexandra I. Stavrakis, MD, Department of Orthopaedic Surgery, David Geffen School of Medicine at UCLA, 1250 16th Street, Suite 2100, Santa Monica, CA 90404, USA.
E-mail address: astavrakis@mednet.ucla.edu (A.I. Stavrakis).

https://doi.org/10.1016/j.jseint.2022.05.015
2666-6383/

Renal disease is one of the most common medical comorbidities in the global population, affecting about 9% of individuals, with a spectrum of severity from chronic renal disease (CRD) of varying stages to end-stage renal disease (ESRD) requiring dialysis.[11] Multiple studies have established that patients with renal disease are at an increased risk for pathologic fractures secondary to renal osteodystrophy, which broadly incorporates the biochemical abnormalities and skeletal manifestations of renal patients.[4,8,16]

Perioperatively, renal disease is further known to complicate operative management of various fractures. ESRD is associated with increased mortality, medical complications, readmission, and revision surgery in hip fractures.[17,23,32,41] More generally, renal disease has been associated with increased rates of postoperative infection, osteonecrosis, nonunion, and implant failure.[9,19,22]

Despite a substantial number of renal patients undergoing PHF ORIF, the effect of CRD and ESRD on postoperative outcomes is unknown. The purpose of this study was to evaluate complications during the index hospitalization and within 90 days of discharge, as well as resource utilization outcomes.

Materials and methods

The study cohort was identified from the Nationwide Readmissions Database (NWRD) from 2010 to 2014. NWRD is a nationally representative database developed and validated through a federal–state–industry partnership sponsored by the Healthcare Cost and Utilization Project (HCUP). The HCUP confirms incorporation of data from the State Inpatient Databases of 28 states, encompassing approximately 51% of the total US population and 59% of all US hospitalizations. The HCUP creates a verified patient linkage number in the State Inpatient Databases that is used to track patients across multiple hospitals. The NWRD uses a stratified 2-stage cluster algorithm based on discharge weights reported by statewide HCUP contributors for approximately 35 million discharges to generate estimates of nationally representative statistics. The database is sufficiently deidentified such that this study was deemed exempt by the institutional review board at our institution.

Patients aged >18 years who underwent PHF ORIF were identified using the International Classification of Diseases, 9th Revision, (ICD-9) diagnosis codes for PHF and the procedure code for humerus ORIF (Table I). At the time of data retrieval, the study years of 2010-2014 were selected to preserve homogeneity in coding, such that only ICD-9 codes were used and not the first few years of ICD-10 coding also. Patients were separated into cohorts based on the diagnosis of CRD (all 5 stages) or ESRD (Table I). Open PHFs were excluded to avoid confounding, given open fractures are known to have higher complication rates and represent a higher energy injury mechanism, as well as the fact they are very rare occurrences in this anatomical region. Cases of bilateral PHF ORIF were also excluded. All subsequent readmissions were considered for these 2 cohorts. Baseline comorbidity was quantified using the Elixhauser Comorbidity Index.

The primary outcomes included mortality, blood transfusion, readmission within 90 days, and postoperative complications during index hospitalization. ICD-9 codes were used to identify the reasons for revision surgery. Multivariate logistic regression was performed while adjusting for age, sex, insurance type, and comorbidities. Of note, comorbidities related to renal disease, including renal failure, fluid/electrolyte disorders, and coagulopathy, were excluded from the regression model to avoid collinearity when examining CRD and ESRD outcomes.

The secondary outcomes included length of stay (LOS) and cost during index hospitalization. Individual hospitalization costs were calculated using Diagnosis-Related Group codes multiplied by hospital-specific cost-to-charge ratios provided by the Agency for Healthcare Research and Quality from the Centers for the NWRD and then adjusted for inflation using the yearly gross domestic product. These estimates were further adjusted for through the use of the HCUP indices of the Diagnosis-Related Group to account for differences in hospitalization severity.

Table I
ICD-9 codes used to identify patients of interest.

Diagnosis	ICD-9 codes
Proximal humerus fracture	
Closed	812.00-812.03, 812.09, 812.20
Open	812.10-812.13, 812.19
Chronic renal disease stages I to V	585.1-5, 585.9
End-stage renal disease	585.6
Procedures	**ICD-9 codes**
Open reduction and internal fixation	79.31

ICD-9, International Classification of Diseases, Ninth Revision.

All result sample sizes represented national estimates taking into account the NWRD's stratified 2-stage cluster design using Stata's SVY (survey data) commands while incorporating individual discharge-level weights. Descriptive analysis was used to describe baseline characteristics and outcome parameters within each comparison group. Categorical variables are presented as adjusted odds ratios (ORs) and compared using the Chi-square statistic, except when individual cell counts were less than 10, in which case Fisher's exact test was used. Continuous variables were reported using mean and 95% confidence interval, and P values and were compared using Student t-test after ensuring normal distributions. For skewed distributions, continuous variables are presented as median (interquartile range), and the Wilcoxon rank-sum test was used. Statistical analysis was performed by separately comparing patients from CRD and ESRD groups to no renal disease (NRD) patients. Data were stored and analyzed using Stata 16.1 (College Station, TX). All tests were unpaired and 2 tailed with a significance value set at $P < .05$.

Results

A total of 85,433 patients undergoing proximal humerus ORIF were identified during the 5-year study period. There were 79,300 (92.8%) NRD patients, 5498 (6.4%) CRD patients, and 636 (0.7%) ESRD patients (Fig. 1).

Patient characteristics

CRD and ESRD patients were older compared with NRD patients (75.4 and 66.4 years vs. 63.7 years, respectively, $P < .01$; Table II). The mean Elixhauser Comorbidity Index was higher for CRD patients (4.94 vs. 2.17, $P < .0001$) and ESRD patients (4.99 vs 2.17, $P < .0001$) compared with NRD patients. There was a significantly higher proportion of males in the CRD and ESRD (33.6% and 48.3% vs. 29.4%, respectively, $P < .001$; Table III). Patients with CRD and ESRD were more likely to have Medicare (82.3% vs. 52.1%, $P < .0001$) and less likely to have private (11.1% and 9.1% vs. 29.6%, respectively, $P < .0001$) or self-insurance (1.0% and 1.3% vs. 4.8%, respectively, $P < .01$) than NRD patients. CRD patients were also less likely to have Medicaid insurance than NRD patients (3.2% vs. 6.1%, $P = .0001$). CRD patients were more likely to be treated at urban nonteaching hospitals (44.1% vs. 37.1%, $P < .0001$) and less likely to be treated at urban teaching hospitals (46.1% vs. 53.1%, $P < .0001$) than NRD patients. ESRD patients were less likely to be treated at rural hospitals than NRD patients (5.0% vs. 9.8%, $P = .01$). CRD and ESRD patients were less likely to be treated at a small hospital than NRD patients (8.3% and 5.3% vs. 10.9%, respectively, $P \leq .0132$). CRD

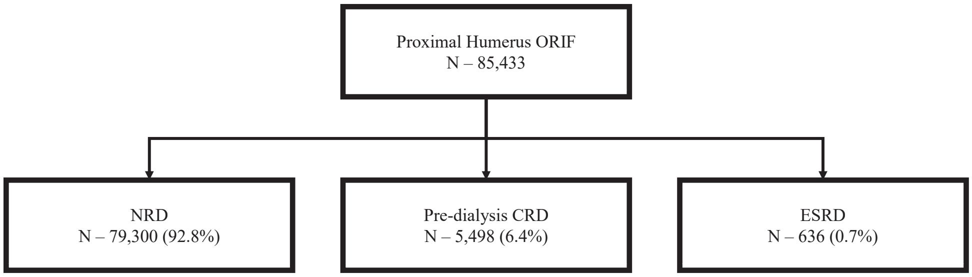

Figure 1 All closed proximal humerus fracture patients who underwent open reduction and internal fixation from 2010-2014 were identified. These patients were then separated into 3 groups based on whether they had a diagnosis of predialysis CRD or ESRD. *ORIF*, open reduction internal fixation; *NRD*, no renal disease; *CRD*, chronic renal disease; *ESRD*, end-stage renal disease.

Table II
Age and elixhauser comorbidity index.

	Age (yr)			Elixhauser comorbidity index		
	Mean	95% CI	*P* value*	Mean	95% CI	*P* value*
NRD	63.7	63.4-64.1	-	2.17	2.14-2.19	-
Predialysis CRD	75.4	74.8-76.0	<.0001	4.94	4.85-5.02	<.0001
ESRD	66.4	64.5-68.3	.0067	4.99	4.76-5.22	<.0001

NRD, no renal disease; *CRD*, chronic renal disease; *ESRD*, end-stage renal disease; *CI*, confidence interval.
*P value when compared with NRD group.

Table III
Patient demographics.

	NRD		Predialysis CRD		ESRD	
	n (%)	*P* value	n (%)	*P* value*	n (%)	*P* value*
Sex						
Male	23,354 (29.4)	-	1845 (33.6)	**.0006**	307 (48.3)	**<.0001**
Female	55,946 (70.6)	-	3653 (66.4)		329 (51.7)	
Insurance						
Medicare	41,342 (52.1)	-	4524 (82.3)	**<.0001**	523 (82.3)	**<.0001**
Medicaid	4840 (6.1)	-	176 (3.2)	**.0001**	28 (4.4)	.1770
Private	23,447 (29.6)	-	609 (11.1)	**<.0001**	58 (9.1)	**<.0001**
Self	3800 (4.8)	-	58 (1.0)	**<.0001**	8 (1.3)	**.0013**
Hospital type						
Rural	7745 (9.8)	-	538 (9.8)	.9766	32 (5.0)	**.0144**
Urban nonteaching	29,443 (37.1)	-	2425 (44.1)	**<.0001**	259 (40.7)	.2495
Urban teaching	42,112 (53.1)	-	2535 (46.1)	**<.0001**	345 (54.3)	.7179
Hospital size						
Small	8644 (10.9)	-	454 (8.3)	**.0007**	34 (5.3)	**.0132**
Medium	17,357 (21.9)	-	1317 (24.0)	.0627	150 (23.5)	.5377
Large	53,299 (67.2)	-	3727 (67.8)	.6493	453 (71.2)	.1951
Discharge						
Home	40,665 (51.2)	-	1433 (26.1)	**<.0001**	137 (21.6)	**<.0001**
Home with HH	14510 (18.3)	-	990 (18.0)	.7606	115 (18.0)	.9224
SNF	23,091 (29.1)	-	2886 (52.4)	**<.0001**	345 (54.3)	**<.0001**
LTACH	483 (0.6)	-	72.9 (1.3)	**.0027**	4 (0.6)	.9538

NRD, no renal disease; *CRD*, chronic renal disease; *ESRD*, end-stage renal disease; *HH*, home health; *SNF*, skilled nursing facility; *LTACH*, long-term acute care hospital.
Bold values indicate statistical significance.
*P value when compared with NRD group.

and ESRD patients had lower rates of discharge to home (26.1% and 21.6% vs. 51.2%, $P < .0001$) and higher rates of discharge to skilled nursing facility (52.4% and 54.3% vs. 29.1%, $P < .0001$). CRD also had a higher rate of discharge to long-term acute care hospitals than NRD patients (1.3% vs. 0.6%, $P = .0027$).

CRD clinical outcomes

During the index hospitalization, CRD patients were at increased risk of any complication (OR 2.48, $P < .001$), blood transfusion (OR 1.85, $P < .001$), cardiac complications (OR 1.47, $P < .001$), respiratory complications (OR 1.14, $P < .001$), acute renal failure (ARF; OR 4.80, $P < .001$), and systemic infection (OR 2.00, $P = .002$), compared with NRD patients (Table IV). There were no instances of deep vein thrombosis (DVT) in this cohort. In terms of surgical complications during the index hospitalization, the CRD cohort was at increased risk of periprosthetic fracture (OR 4.97, $P = .022$) and surgical site infection (SSI; 1.52, $P = .012$). Within 90 days of discharge, CRD patients were at increased risk of readmission (OR 1.61, $P < .001$) and SSI (OR 1.43, $P = .033$).

ESRD clinical outcomes

During the index hospitalization, ESRD patients were at increased risk of any complication (OR 1.66, $P = .002$), mortality (OR 5.79, $P < .001$), blood transfusion (OR 3.31, $P < .001$),

Table IV
NRD versus predialysis CRD clinical outcomes.

Index hospitalization	NRD, n (%)	Predialysis CRD, n (%)	OR	95% CI	*P* value
Any complication	25,771 (32.5)	3557 (64.7)	2.48	2.18-2.82	**<.001**
Medical complications					
Mortality	348 (0.4)	109 (2.0)	1.64	0.99-2.73	.056
Blood transfusion	13,520 (17.0)	1952 (35.5)	1.85	1.64-2.08	**<.001**
Cardiac	22,052 (27.8)	2745 (49.9)	1.47	1.28-1.69	**<.001**
Respiratory	4828 (6.1)	535 (9.7)	1.14	0.93-1.40	**<.001**
PE	387 (0.5)	18 (0.3)	0.70	0.34-1.44	.33
DVT	21 (0)	-	-	-	-
ARF	2672 (3.4)	1763 (32.1)	10.52	8.77-12.61	**<.001**
Systemic infection	743 (0.9)	122 (2.2)	2.00	1.29-3.09	**.002**
Surgical complications					
Periprosthetic fracture	28 (0)	7 (0.1)	4.97	1.27-19.50	**.022**
Dislocation	95 (0.1)	14 (0.2)	1.49	0.37-5.99	.576
Revision	38 (0)	-	-	-	-
Revision to arthroplasty	1403 (1.8)	114 (2.1)	1.20	0.80-1.79	.388
SSI	1883 (2.4)	269 (4.9)	1.52	1.10-2.11	**.012**
Wound complication	574 (0.7)	50 (0.9)	1.19	0.68-2.10	.540
Complications within 90 days of discharge					
Readmission	9184 (11.6)	1206 (21.9)	1.61	1.38-1.88	**<.001**
Periprosthetic fracture	22 (0)	5 (0.1)	3.80	0.87-16.64	.077
Dislocation	78 (0.1)	6 (0.1)	0.74	0.17-3.33	.698
Revision	21 (0)	-	-	-	-
Revision to arthroplasty	949 (1.2)	76 (1.4)	1.05	0.64-1.72	.836
SSI	1250 (1.6)	170 (3.1)	1.43	1.03-1.98	**.033**
Wound complication	524 (0.7)	50 (0.9)	1.02	0.50-2.07	.952

NRD, no renal disease; *CRD*, chronic renal disease; *PE*, pulmonary embolism; *DVT*, deep vein thrombosis; *ARF*, acute renal failure; *SSI*, surgical site infection; *CI*, confidence interval; *OR*, odds ratio.
Bold values indicate statistical significance.

Table V
NRD vs. ESRD clinical outcomes.

Index hospitalization	NRD, n (%)	ESRD, n (%)	OR	95% CI	*P* value
Any complication	25,771 (32.5)	346 (54.4)	1.66	1.21-2.29	**.002**
Medical complications					
Mortality	348 (0.4)	31 (4.9)	5.79	2.90-11.55	**<.001**
Blood transfusion	13,520 (17.0)	277 (43.6)	3.31	2.52-4.36	**<.001**
Cardiac	22,052 (27.8)	283 (44.5)	1.37	0.98-1.94	.069
Respiratory	4828 (6.1)	91 (14.3)	1.59	1.11-2.27	**.012**
PE	387 (0.5)	2 (0.4)	0.75	0.08-6.70	.798
DVT	21 (0)	4 (0.7)	16.7	3.49-80.0	**<.001**
ARF	2672 (3.4)	55 (8.7)	1.67	1.06-2.65	**.029**
Systemic infection	743 (0.9)	32 (5.0)	3.14	1.72-3.5.73	**<.001**
Surgical complications					
Periprosthetic fracture	28 (0)	-	-	-	-
Dislocation	95 (0.1)	3 (0.5)	2.57	0.36-18.3	.346
Revision	38 (0)	-	-	-	-
Revision to arthroplasty	1403 (1.8)	10 (1.5)	1.01	0.36-2.84	.986
SSI	1883 (2.4)	77 (12.1)	3.87	2.61-5.75	**<.001**
Wound complication	574 (0.7)	15 (2.3)	2.67	1.20-5.92	**.016**
Complications within 90 days of discharge					
Readmission	9184 (11.6)	232 (36.5)	3.69	2.73-4.99	**<.001**
Periprosthetic fracture	22 (0)	-	-	-	-
Dislocation	78 (0.1)	3 (0.5)	2.67	0.39-18.30	.317
Revision	21 (0)	-	-	-	-
Revision to arthroplasty	949 (1.2)	7 (1.1)	1.02	0.31-3.42	.973
SSI	1250 (1.6)	47 (7.4)	3.03	1.87-4.93	**<.001**
Wound complication	524 (0.7)	11 (1.7)	1.98	0.71-5.52	.192

NRD, no renal disease; *ESRD*, end-stage renal disease; *PE*, pulmonary embolism; *DVT*, deep vein thrombosis; *ARF*, acute renal failure; *SSI*, surgical site infection; *CI*, confidence interval; *OR*, odds ratio.
Bold values indicate statistical significance.

respiratory complications (OR 1.59, $P = .012$), DVT (OR 16.70, $P < .001$), ARF (OR 1.67, $P = .029$), systemic infection (OR 3.14, $P < .001$), SSI (OR 3.87, $P < .001$), and wound complication (OR 2.67, $P = .016$) compared with NRD patients (Table V). Within 90 days of hospital discharge, ESRD patients were at increased risk of readmission (OR 3.69, $P < .001$) and SSI (OR 3.03, $P < .001$).

Index hospitalization LOS and cost

CRD patients and ESRD patients had an increased average hospital LOS (7.1 and 12.9 days vs. 5.5 days, respectively, $P < .0001$) compared with NRD patients (Table VI). CRD patients and ESRD patients had an increased mean hospitalization cost ($21,669 and $35,413 vs. $20,394 $P < .01$) compared with NRD patients.

Table VI
Index hospitalization LOS and cost.

	LOS (d)			Cost ($)		
	Mean	95% CI	*P* value*	Mean	95% CI	*P* value*
NRD	5.5	5.4-5.7	-	20,393.82	19,886.34-20,901.31	-
Predialysis CRD	7.1	6.7-7.4	<.0001	21,668.93	20,757.78-22,580.09	.009
ESRD	12.9	11.0-14.8	<.0001	35,412.70	30,823.23-40,002.18	<.0001

NRD, no renal disease; *CRD*, chronic renal disease; *ESRD*, end-stage renal disease; *CI*, confidence interval; *LOS*, length of stay.
*P value when compared with NRD group.

Discussion

To the best of our knowledge, this is the first study to examine the impact of CRD vs. ESRD on the clinical outcomes of ORIF for PHF. We found that both CRD and ESRD patients have worse clinical outcomes than NRD patients after undergoing PHF ORIF.

The present study demonstrates that both renal disease cohorts have a greater than 50% chance of complication during index hospitalization for PHF ORIF (Tables IV and V). Both cohorts were more likely to experience postoperative medical complications, namely, cardiac, respiratory, and renal complications as well as systemic infection. In particular, both CRD and ESRD patients were at an increased risk for ARF. This is likely because of the increased physiological stress of surgery and the possible perioperative use of nephrotoxic antibiotics, which may exacerbate even mild preexisting renal dysfunction. These findings underscore the need for a critical assessment of kidney function preoperatively as well as for close monitoring postoperatively.

Our findings suggest that both CRD and ESRD patients are at an increased risk for blood transfusion during PHF ORIF index hospitalization compared with NRD patients. This is consistent with the findings of a prior study by Malchercyzk et al.[25] Renal disease is frequently accompanied by hematologic aberrations, including anemia and coagulopathy. As a result of decreased hematopoiesis and impaired coagulation pathways, these patients are susceptible to clinically significant blood loss, and lower transfusion thresholds may be considered. On the other hand, renal patients can also exhibit a paradoxical hypercoagulable state. In our study, both cohorts had low rates of PE, not significantly higher than the NRD group (Tables IV and V). This is mirrored by the results of work by Heyer et al demonstrating that there is a low rate of VTE in PHF patients overall.[14] In our study, the rate of DVT was found to be higher in the ESRD cohort compared to NRD cohort. This result has been reported previously in a large prospective study, with the mechanism attributed to the pro-inflammatory state present during nephrotic syndrome.[44]

In terms of index hospitalization surgical complications, our study demonstrated that CRD patients are at increased risk for periprosthetic fracture (Table IV). This result is intuitive, given the association of renal disease with poor bone quality from osteoporosis and osteodystrophy. Periprosthetic fractures are unfortunate because they may require revision surgery or result in decreased function, specifically it has been shown that the majority of patients with mechanical complications following PHF ORIF require arthroplasty.[18] Both cohorts were also at increased risk for SSI during index hospitalization. This may be expected given renal disease patients have multiple risk factors for poor wound healing, including generally increased age, frequently comorbid diabetes and peripheral vascular disease, and decreased physical mobility increasing the risk for the development of pressure-related wounds. SSIs can be costly to treat and can lead to systemic infections, ultimately putting these patients at risk for fatal events.

Readmission after PHF ORIF is relatively rare, with prior studies reporting 2%-8% and ~15% within 30 and 90 days of surgery, respectively.[2,42,43,46] In our study, 22% of CRD patients 90-day readmissions and ESRD ~37%. Prior studies have not examined the impact of renal dysfunction on readmission in PHF ORIF. Nevertheless, our results are consistent with the hip fracture literature, which found that patients with ESRD are at higher risk for readmission and complications after surgery.[9,17,19,22,23,41] When examining specific causes for 90-day readmission, SSI was the most common in both cohorts. Interestingly, there was no concurrent increased risk of reoperation, suggesting these were likely superficial SSI amenable to antibiotics.

CRD and ESRD patients in our study had significantly longer index hospitalization LOS after PHF ORIF compared with NRD patients. The increased LOS compared with NRD patients was minimal for CRD patients (additional 1.6 days) but substantial for ESRD patients (additional 7.4 days). A prior study demonstrated that patients with PHF treated operatively with greater numbers of comorbidities have higher LOS, but renal disease has never been isolated as an independent risk factor.[24] Our analysis showed that ORIF in renal disease patients increased total cost by approximately 6.3% and 73.6% for CRD and ESRD patients, respectively (Table VI). A staggering increase in cost, but it is understandable given the mean LOS for ESRD patients was nearly 3 times that for NRD patients. Estimates of the increased financial burden associated with PHF ORIF in renal disease patients have not been previously examined in the literature.

Previous studies have reported the presence of certain medical comorbidities may increase the risk of complications/mortality after PHF ORIF.[10,28] Specifically, diabetes has been shown to have an increased risk of sepsis, pneumonia, mortality and increased hospital LOS, and obesity with infection and complications.[26,34,45] However, the present study is the first to identify renal disease as a risk factor for mortality, readmission, and overall complications in PHF ORIF. A prior study, however, found an association of hypoalbuminemia with complications and readmission after PHF ORIF. As a marker of malnourishment, hypoalbuminemia can often be associated with renal disease due to protein wasting in this condition.[43]

This study has several advantages. The large, nationally representative sample size is more likely to accurately represent this patient population and identify significant differences in relatively rare complications. Furthermore, because this study includes data from both private and Medicare insurance makes our findings more externally valid. Readmission data allow for a more complete representation of early complications, rather than only those identified during the index hospitalization.

There are several limitations to this study. First, there are inherent shortcomings associated with large administrative databases, including inconsistencies in coding and potential errors in data entry. In addition, our study period of 90 days postsurgery results in a decreased ability to capture long-term complications. Potential confounding exists despite multivariate analysis, given possible different DVT prophylaxis, perioperative antibiotics, implants, and surgical techniques that may be used at individual institutions. Selection bias may exist where the threshold for indicating renal disease patients for PHF ORIF may be higher than that for NRD patients. Specifically, only renal patients with the most severe fracture patterns or most reasonable bone quality may be preferentially indicated for ORIF. These effects, however, may negate each other as renal disease patients with more severe fractures would be expected to have relatively poorer outcomes and those with enhanced bone quality would be expected to have improved outcomes. It should also be noted that selection bias may also exist for patients with multiple injuries being more likely to be indicated for ORIF for their PHF to enhance their overall mobility/rehabilitation. Our study was also unable to isolate data regarding the time of surgery, which has previously been shown to affect outcomes.[37] Given the nature of the data available in this database, we do not have information on postoperative function or patient satisfaction. In addition, our analysis only considered 2 levels of renal dysfunction, predialysis CRD and ESRD. With a slightly older data set time, there is a potential surgical indication pattern to have changed over time (including the increased use of rTSA); however, ORIF continues to be the most common surgical treatment for PHF by a wide margin.[12] Taken together, the strengths of the present study outweigh its limitations. The data presented allow orthopedic surgeons to consider both the presence and severity of renal disease when weighing the potential risks and benefits of performing PHF ORIF in patients with renal dysfunction.

Conclusion

This study demonstrates that patients with varying levels of renal disease, namely, CRD and ESRD, are at an elevated risk of developing adverse outcomes after PHF ORIF. This should help inform surgical decision-making, including the consideration of renal disease as a relative contraindication to performing PHF ORIF as well as nonoperative management in this high-risk patient population.

Disclaimers:

Funding: No funding was disclosed by the authors.
Conflicts of interest: The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Barlow JD, Logli AL, Steinmann SP, Sems SA, Cross WW, Yuan BJ, et al. Locking plate fixation of proximal humerus fractures in patients older than 60 years continues to be associated with a high complication rate. J Shoulder Elbow Surg 2020;29:1689-94. https://doi.org/10.1016/j.jse.2019.11.026.
2. Bovonratwet P, Suhardi VJ, Andarawis-Puri N, Ricci WM, Fu MC. Outpatient surgical fixation of proximal humerus fractures can be performed without increased rates of short-term complications or readmissions. J Orthop Trauma 2021;28. https://doi.org/10.1097/BOT.0000000000002072.
3. Brunner F, Sommer C, Bahrs C, Heuwinkel R, Hafner C, Rillmann P, et al. Open reduction and internal fixation of proximal humerus fractures using a proximal humeral locked plate: a prospective multicenter analysis. J Orthop Trauma 2009;23:163-72. https://doi.org/10.1097/BOT.0b013e3181920e5b.
4. Coco M, Rush H. Increased incidence of hip fractures in dialysis patients with low serum parathyroid hormone. Am J Kidney Dis 2000;36:1115-21.
5. Court-Brown CM, Clement ND, Duckworth AD, Aitken S, Biant LC, McQueen MM. The spectrum of fractures in the elderly. Bone Joint J 2014;96-B:366-72. https://doi.org/10.1302/0301-620X.96B3.33316.
6. Court-Brown CM, Garg A, McQueen MM. The epidemiology of proximal humeral fractures. Acta Orthop Scand 2001;72:365-71.
7. Cvetanovich GL, Chalmers PN, Verma NN, Nicholson GP, Romeo AA. Open reduction internal fixation has fewer short-term complications than shoulder arthroplasty for proximal humeral fractures. J Shoulder Elbow Surg 2016;25:624-631.e3. https://doi.org/10.1016/j.jse.2015.09.011.
8. Dukas L, Schacht E, Stähelin HB. In elderly men and women treated for osteoporosis a low creatinine clearance of <65 ml/min is a risk factor for falls and fractures. Osteoporos Int 2005;16:1683-90. https://doi.org/10.1007/s00198-005-1903-7.
9. Endo A, McTague MF, Allen E, von Keudell A, Weaver MJ. End-stage renal disease increases risk of postoperative complications after lower extremity fracture. Arch Orthop Trauma Surg 2021;141:925-8. https://doi.org/10.1007/s00402-020-03490-8.
10. Evans DR, Saltzman EB, Anastasio AT, Guisse NF, Belay ES, Pidgeon TS, et al. Use of a 5-item modified Fragility Index for risk stratification in patients undergoing surgical management of proximal humerus fractures. JSES Int 2020;5:212-9. https://doi.org/10.1016/j.jseint.2020.10.017.
11. GBD Chronic Kidney Disease Collaboration. Global, regional, and national burden of chronic kidney disease, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet 2020;395:709-33. https://doi.org/10.1016/S0140-6736(20)30045-3.
12. Hasty EK, Jernigan EW 3rd, 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. https://doi.org/10.3928/01477447-20170411-03.
13. Hettrich CM, Neviaser A, Beamer BS, Paul O, Helfet DL, Lorich DG. Locked plating of the proximal humerus using an endosteal implant. J Orthop Trauma 2012;26:212-5. https://doi.org/10.1097/BOT.0b013e318243909c.
14. Heyer JH, Parker RL, Lynch T, Parry T, Neviaser AS. Rate of venous thromboembolism after surgical treatment of proximal humerus fractures. Arch Orthop Trauma Surg 2021;141:403-9. https://doi.org/10.1007/s00402-020-03505-4.
15. Hirschmann MT, Fallegger B, Amsler F, Regazzoni P, Gross T. Clinical longer-term results after internal fixation of proximal humerus fractures with a locking compression plate (PHILOS). J Orthop Trauma 2011;25:286-93. https://doi.org/10.1097/BOT.0b013e3181f2b20e.
16. Jadoul M, Albert JM, Akiba T, Akizawa T, Arab L, Bragg-Gresham JL, et al. Incidence and risk factors for hip or other bone fractures among hemodialysis patients in the Dialysis Outcomes and Practice Patterns Study. Kidney Int 2006;70:1358-66. https://doi.org/10.1038/sj.ki.5001754.
17. Jang SY, Ha YC, Cha Y, Kim KJ, Choy W, Koo KH. The influence of renal dialysis on all-Cause mortality in older patients with hip fracture: a Korean Nationwide cohort study. J Korean Med Sci 2020;35:e190. https://doi.org/10.3346/jkms.2020.35.e190.
18. Jost B, Spross C, Grehn H, Gerber C. Locking plate fixation of fractures of the proximal humerus: analysis of complications, revision strategies and outcome. J Shoulder Elbow Surg 2013;22:542-9. https://doi.org/10.1016/j.jse.2012.06.008.
19. Karaeminogullari O, Demirors H, Sahin O, Ozalay M, Ozdemir N, Tandogan RN. Analysis of outcomes for surgically treated hip fractures in patients undergoing chronic hemodialysis. J Bone Joint Surg Am 2007;89:324-31. https://doi.org/10.2106/JBJS.E.01320.
20. Klug A, Wincheringer D, Harth J, Schmidt-Horlohé K, Hoffmann R, Gramlich Y. Complications after surgical treatment of proximal humerus fractures in the elderly-an analysis of complication patterns and risk factors for reverse shoulder arthroplasty and angular-stable plating. J Shoulder Elbow Surg 2019;28:1674-84. https://doi.org/10.1016/j.jse.2019.02.017.
21. Koval KJ, Gallagher MA, Marsicano JG, Cuomo F, McShinawy A, Zuckerman JD. Functional outcome after minimally displaced fractures of the proximal part of the humerus. J Bone Joint Surg Am 1997;79:203-7.
22. Kuo LT, Lin SJ, Hsu WH, Peng KT, Lin CL, Hsu RW. The effect of renal function on surgical outcomes of intracapsular hip fractures with osteosynthesis. Arch Orthop Trauma Surg 2014;134:39-45. https://doi.org/10.1007/s00402-013-1884-5.
23. Lin JC, Liang WM. Mortality and complications after hip fracture among elderly patients undergoing hemodialysis. BMC Nephrol 2015;16:100. https://doi.org/10.1186/s12882-015-0099-0.
24. 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. https://doi.org/10.5435/JAAOS-D-19-00491.
25. Malcherczyk D, Klasan A, Ebbinghaus A, Greene B, Bäumlein M, Ruchholtz S, El-Zayat BF. Factors affecting blood loss and blood transfusion in patients with proximal humeral fractures. J Shoulder Elbow Surg 2019;28:e165-74. https://doi.org/10.1016/j.jse.2019.01.018.
26. Martinez-Huedo MA, Jiménez-García R, Mora-Zamorano E, Hernández-Barrera V, Villanueva-Martinez M, Lopez-de-Andres A. Trends in incidence of proximal humerus fractures, surgical procedures and outcomes among elderly hospitalized patients with and without type 2 diabetes in Spain (2001-2013). BMC Musculoskelet Disord 2017;18:522. https://doi.org/10.1186/s12891-017-1892-7.
27. Miyazaki AN, Fregoneze M, Santos PD, da Silva LA, do Val Sella G, Filho JM, Ferreira MT, Filho PR, Checchia SL. Results of open reduction and internal fixation of severe fractures of the proximal humerus in elderly patients. Rev Bras Ortop 2014;49:25-30. https://doi.org/10.1016/j.rboe.2014.01.002.
28. Myeroff CM, Anderson JP, Sveom DS, Switzer JA. Predictors of mortality in elder patients with proximal humeral fracture. Geriatr Orthop Surg Rehabil 2017;9:2151458517728155. https://doi.org/10.1177/2151458517728155.

29. Neviaser AS, Hettrich CM, Dines JS, Lorich DG. Rate of avascular necrosis following proximal humerus fractures treated with a lateral locking plate and endosteal implant. Arch Orthop Trauma Surg 2011;131:1617-22. https://doi.org/10.1007/s00402-011-1366-6.
30. Ong CC, Kwon YW, Walsh M, Davidovitch R, Zuckerman JD, Egol KA. Outcomes of open reduction and internal fixation of proximal humerus fractures managed with locking plates. Am J Orthop (Belle Mead Nj) 2012;41:407-12.
31. Oppebøen S, Wikerøy AKB, Fuglesang HFS, Dolatowski FC, Randsborg PH. Calcar screws and adequate reduction reduced the risk of fixation failure in proximal humeral fractures treated with a locking plate: 190 patients followed for a mean of 3 years. J Orthop Surg Res 2018;13:197. https://doi.org/10.1186/s13018-018-0906-y.
32. Ottesen TD, Yurter A, Shultz BN, Galivanche AR, Zogg CK, Bovonratwet P, Rubin LE, Grauer JN. Dialysis Dependence is associated with significantly increased odds of perioperative adverse events after geriatric hip fracture surgery even after Controlling for Demographic factors and comorbidities. J Am Acad Orthop Surg Glob Res Rev 2019;3:e086. https://doi.org/10.5435/JAAOS-Global-D-19-00086.
33. Padegimas EM, Chang G, Namjouyan K, Namdari S. Failure to restore the calcar and locking screw cross-threading predicts varus collapse in proximal humerus fracture fixation. J Shoulder Elbow Surg 2020;29:291-5. https://doi.org/10.1016/j.jse.2019.06.014.
34. Patterson DC, Shin JI, Andelman SM, Olujimi V, Parsons BO. Increased risk of 30-day postoperative complications for diabetic patients following open reduction-internal fixation of proximal humerus fractures: an analysis of 1391 patients from the American College of Surgeons National Surgical Quality Improvement Program database. JSES Open Access 2017;1:19-24. https://doi.org/10.1016/j.jses.2017.03.006.
35. Robinson CM, Stirling PHC, Goudie EB, MacDonald DJ, Strelzow JA. Complications and long-term outcomes of open reduction and plate fixation of proximal humeral fractures. J Bone Joint Surg Am 2019;101:2129-39. https://doi.org/10.2106/JBJS.19.00595.
36. Schulte LM, Matteini LE, Neviaser RJ. Proximal periarticular locking plates in proximal humeral fractures: functional outcomes. J Shoulder Elbow Surg 2011;20:1234-40. https://doi.org/10.1016/j.jse.2010.12.015.
37. Siebenbürger G, Van Delden D, Helfen T, Haasters F, Böcker W, Ockert B. Timing of surgery for open reduction and internal fixation of displaced proximal humeral fractures. Injury 2015;46:S58-62. https://doi.org/10.1016/S0020-1383(15)30019-X.
38. Spross C, Platz A, Rufibach K, Lattmann T, Forberger J, Dietrich M. The PHILOS plate for proximal humeral fractures–risk factors for complications at one year. J Trauma Acute Care Surg 2012;72:783-92. https://doi.org/10.1097/TA.0b013e31822c1b5b.
39. Spross C, Zeledon R, Zdravkovic V, Jost B. How bone quality may influence intraoperative and early postoperative problems after angular stable open reduction-internal fixation of proximal humeral fractures. J Shoulder Elbow Surg 2017;26:1566-72. https://doi.org/10.1016/j.jse.2017.02.026.
40. Südkamp N, Bayer J, Hepp P, Voigt C, Oestern H, Kääb M, Luo C, Plecko M, Wendt K, Köstler W, Konrad G. Open reduction and internal fixation of proximal humeral fractures with use of the locking proximal humerus plate. Results of a prospective, multicenter, observational study. J Bone Joint Surg Am 2009;91:1320-8. https://doi.org/10.2106/JBJS.H.00006.
41. Suh YS, Won SH, Choi HS, Lee JC, Chun DI, Nho JH, Lee HW, Kim JH. Survivorship and complications after hip fracture surgery in patients with chronic kidney disease. J Korean Med Sci 2017;32:2035-41. https://doi.org/10.3346/jkms.2017.32.12.2035.
42. 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. https://doi.org/10.1097/BOT.0000000000000513.
43. Vora M, Sing DC, Yi PH, Cheah JW, Li X. Hypoalbuminemia is a risk factor for predicting early postoperative complications after proximal humerus fracture fixation. J Orthop 2019;19:106-10. https://doi.org/10.1016/j.jor.2019.11.022.
44. Wattanakit K, Cushman M, Stehman-Breen C, Heckbert SR, Folsom AR. Chronic kidney disease increases risk for venous thromboembolism. J Am Soc Nephrol 2008;19:135-40. https://doi.org/10.1681/ASN.2007030308.
45. Werner BC, Griffin JW, Yang S, Brockmeier SF, Gwathmey FW. Obesity is associated with increased postoperative complications after operative management of proximal humerus fractures. J Shoulder Elbow Surg 2015;24:593-600. https://doi.org/10.1016/j.jse.2014.08.028.
46. Zhang AL, Schairer WW, Feeley BT. Hospital readmissions after surgical treatment of proximal humerus fractures: is arthroplasty safer than open reduction internal fixation? Clin Orthop Relat Res 2014;472:2317-24. https://doi.org/10.1007/s11999-014-3613-y.