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Original Research

Risk Factors for Infection After Distal Radius Fracture Fixation: Analysis of Impact on Cost of Care

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Purpose: Infection after distal radius fracture fixation can be a devastating complication, leading to potential hardware removal, prolonged antibiotic courses, multiple office visits, and increased costs. This study aimed to identify potential risk factors for infectious complications after distal radius fracture fixation and assess the impacts on cost.
Methods: This study used the PearlDiver national database, encompassing 53 million unique patients from January 1, 2010, to March 31, 2020. The cohort included patients undergoing distal radius fracture fixation. The endpoint was postoperative infection within 180 days of fixation. Two-sample *t* test was used to compare rates of infection between open and percutaneous fracture fixation techniques. A propensity-matched cohort was created using patient age, gender, and open fracture. Logistic regression analyses defined independent risk factors for developing a postoperative infection among all patients and within the matched cohorts. A Mann-Whitney U test was used to compare costs of care with and without infection.
Results: The database included 87,169 patients who underwent distal radius fracture fixation. Postoperative infections were identified in 781 patients (0.9%). There was a significant difference in rates of postoperative infection with percutaneous fixation (1.3%) versus open fixation (0.8%). Logistic regression analysis identified male gender, open fracture, lung disease, chronic kidney disease, diabetes, hypertension, liver disease, obesity, and tobacco to be independent risk factors for developing a postoperative infection. Logistic regression analysis of the propensity-matched cohorts identified tobacco use as a significant risk factor. The average cost of care for patients undergoing fracture fixation without an infection was $6,383, versus $23,355 for those with an infection, which was significantly different.
Conclusions: Multiple risk factors for postoperative infection were identified. Cost is significantly increased after postoperative infection, by almost 4-fold. Attempts to correct or optimize modifiable risk factors may lead to substantial cost savings, and potentially decreased rates of infection.
Type of study/level of evidence: Prognostic III.

Distal radius fractures are among the most common upper extremity traumas encountered by hand surgeons, with an incidence of approximately 16.2 per 10,000 person-years.[1] There are various indications for fixation of distal radius fractures; however, trends in fracture fixation techniques evolve over time.

Although nonsurgical management remains the most common treatment, fracture fixation has increasingly transitioned from percutaneous pinning to a variety of open treatments over the last 2 decades.[2] More recently, many hand surgeons have transitioned to a volar locking plate fixation technique, as it has been shown to lead to an earlier functional recovery within 3 months.[3,4]

Although relatively rare, infection after distal radius fracture fixation can be a devastating complication, leading to potential

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hardware removal, prolonged antibiotic courses, multiple office visits, and increased overall costs.[5] As health care costs continue to increase each year, private- and government-based insurance programs are developing innovative reimbursement models, like episode-based payments, which should accurately account for the impact of potential postoperative complications like infection.[6]

This study aims to identify potential risk factors for infectious complications after distal radius fracture fixation and assess the impacts on overall costs as a result of postoperative infection within a large national database. We hypothesized that modifiable risk factors like smoking would lead to higher rates of infection in distal radius fracture fixation, which potentially affords the hand surgeon an opportunity for decreasing rates of infection.

Materials and Methods

Database

The study used the PearlDiver (PearlDiver, Inc) patient database of privately insured patients across all regions of the country, encompassing 53 million unique patients from January 1, 2010, to March 31, 2020, in all treatment settings, including inpatient (hospital-based) and outpatient (hospital-, ambulatory surgical center-, and office-based) facilities. The information was accessed through a secure server using PearlDiver's proprietary software. The study used deidentified patient data from the database; however, studied groups with 10 patients or fewer were not reported by the database to protect privacy. Institutional review board approval for this study was not required, as the data studied are publicly available and are completely deidentified; thus the study was exempt from institutional review board approval. In order to ensure the validity of the study, we used the Strengthening the Reporting of Observational Studies in Epidemiology guidelines and checklists in performing the study.[7]

Study cohort

The study cohort included patients undergoing distal radius fracture fixation, identified by Current Procedural Terminology (CPT) codes 25606–25609, who actively had insurance 30 days prior to fixation and throughout the 180-day follow-up period. Patients exclusively undergoing percutaneous fixation (CPT code 25606) were assessed, as well as those undergoing open reduction and internal fixation (CPT codes 25607–25609). Patients undergoing external fixator placement alone (CPT code 20690) were excluded from the analysis, as this code is not specific to patients with radius fractures. Patient demographic data were collected, including age, gender, geographic region, and treatment setting. Pediatric patients were included in the cohort.

A study endpoint of postoperative infection within 180 days of surgical fixation was chosen. This 180-day period includes the global period; is likely to capture infections related to fracture fixation, given the nonspecificity of postoperative infection codes; and is within the typical follow-up period for bony infection.[8] Infection in our study was defined as a postoperative infection (both superficial and deep), periprosthetic infection, acute osteomyelitis, or hardware infection (Appendix, available on the *Journal*'s website at www.jhsgo.org), in order to account for all types of infection associated with fixation.

Statistical analysis

Frequencies of baseline patient demographics, comorbidities, fixation methods, and types of fracture were tabulated. A 2-sample *t* test was used to compare rates of infection between open and percutaneous fracture fixation techniques. The total direct cost of care to insurance related to the distal radius fracture fixation was assessed and calculated, which includes costs for all appointments, medications, surgical interventions, and postoperative rehabilitation. Indirect costs were not included in the analysis. Total costs for open reduction and internal fixation were compared to total costs of percutaneous fixation using a *t* test. A Mann-Whitney-Wilcoxon test was used to compare costs of care in cases with and without an infection, given that cost data are typically nonparametric.

We used a multivariable logistic regression analysis to define independent risk factors for developing postoperative infections after overall (percutaneous and open) distal radius fracture fixation. The 2 methods of surgical fixation were combined to represent the vast majority of distal radius fixation techniques. Common comorbid conditions, modeled off the Charlson Comorbidity Index, were included in the analysis. A cohort was propensity-matched 1-to-1 with calipers of 0.05, which represents the maximum tolerated distance between subjects matched, based on patient age, gender, and open fracture in order to control for the prospect of gross contamination associated with an open wound. A logistic regression analysis was then used on the propensity-matched cohorts to assess risk factors for developing infection within these matched cohorts. Throughout the study, a *P* value < .05 was considered statistically significant.

Table 1
Demographics of Patients Undergoing Distal Radius Fixation (n = 87169)

Demographics	No.	Percentage, %
Age, y		
<18	7077	8.1
18–64	44123	50.6
≥65	35969	41.3
Region		
Midwest	23558	27.0
Northeast	15203	17.4
South	35609	40.9
Unknown	188	0.2
West	12611	14.5
Gender		
Female	66842	76.7
Male	20327	23.3
Comorbidities		
Chronic obstructive pulmonary disease	28868	33.1
Cerebrovascular disease	19478	22.3
Chronic kidney disease	11874	13.6
Coronary artery disease	19491	22.4
Diabetes	26479	30.4
Hypertension	55084	63.2
Liver disease	12512	14.4
Previous cancer diagnosis	13276	15.2
Obesity	23330	26.8
Tobacco use	20914	24.0
Open fracture	4294	4.9
Treatment location		
Inpatient	10204	11.7
Office	379	0.4
Outpatient	76397	87.6
Unknown	180	0.3

Results

The database included 87,169 patients who underwent distal radius fracture fixation (Table 1); of these, 75,139 (86.2%) underwent open fixation and 12,029 (13.8%) underwent percutaneous fixation. The majority of patients were female (76.7%) and were adults between 18 and 64 years of age (50.6%) or were 65 years of age or older (41.3%). Treatment was predominantly in the outpatient setting (87.6%) versus the inpatient setting (11.7%).

Table 2
Logistic Regression Analysis of Risk Factors for Infection After Distal Radius Fracture Fixation

Variable	Odds Ratio	95% Confidence Interval	*P* Value
Age >65	0.62	0.52–0.73	<.005
Male gender	1.60	1.37–1.87	<.005
Chronic lung disease/chronic obstructive pulmonary disease	1.26	1.08–1.47	.003
History of cancer	1.05	0.86–1.27	.628
History of cerebrovascular disease	1.18	0.99–1.40	.067
History of chronic kidney disease	1.28	1.05–1.55	.014
History of coronary artery disease	0.99	0.83–1.19	.933
History of diabetes	1.24	1.06–1.46	.008
History of hypertension	1.35	1.12–1.62	.002
History of liver disease	1.20	1.00–1.43	.005
History of obesity	1.28	1.10–1.50	.002
Tobacco use	1.55	1.33–1.81	<.005
Open fracture	2.54	2.03–3.14	<.005

Approximately 4.9% (4294) of patients undergoing distal radius fracture fixation had an open fracture. Of the studied population, 24% of patients were tobacco users and nearly a third (30.4%) were diabetic. Demographic characteristics are summarized in Table 1.

Postoperative infections were identified in 781 patients (0.9%). An analysis of a 2-sample *t* test demonstrated a statistically significant difference in postoperative infections with percutaneous fixation (1.3%) versus open fixation (0.8%; $P < .005$).

A logistic regression analysis identified male gender, open fracture, lung disease, chronic kidney disease, diabetes, hypertension, liver disease, obesity, and tobacco used to be independent risk factors for developing a postoperative infection (Table 2); an age greater than 65 appeared to be protective against a postoperative infection. Histories of cancer, cerebrovascular disease, or coronary artery disease did not have statistically significant impacts on postoperative infections after distal radius fracture fixation (Table 2). Propensity-matched cohorts comparing patients with and without infection based on age, gender, and open versus closed fracture yielded 1,562 total patients in a 1:1 match (781 infected and 781 controls). A logistic regression analysis of these cohorts demonstrated that tobacco use was the only statistically significant risk factor within this subgroup (Table 3).

The average direct cost of care for open reduction and internal fixation with and without infection was $9,917 (SD $19,192). The average direct cost of care for percutaneous fixation with and without infection was $7,531 (SD $23,692). There was a significant difference between these 2 costs (t[87694] = −12.69; $P < .005$). The average cost of care for patients undergoing distal radius fracture fixation, both open and percutaneous, without an infection was $6,383 (SD $13,903). The average cost of care for patients who developed a postoperative infection was $23,355 (SD $40,412). A Mann-Whitney-Wilcoxon test demonstrated a significant difference in these costs ($P \leq .005$; difference 5,543; 95% confidence interval, 4,899–6,234).

Discussion

This study used a national database to examine risk factors for infection after distal radius fracture fixation and to assess the impact of an infection on costs. Despite a postoperative infection appearing to be a relatively rare complication, occurring in only 0.9% of patients studied, the significant cost difference experienced by this population likely signifies a cascade of costly clinical events. Although limited in the setting of an acute trauma like a distal radius fracture, there appear to be both modifiable and nonmodifiable risk factors for infection after fracture fixation.

Open reduction and internal fixation for distal radius fractures has become increasingly more common than percutaneous techniques over the past 2 decades.[3,9] This trend is mirrored in our study, as over 86% of patients underwent internal fixation. While volar locking plates have been demonstrated to have earlier short-term recovery of function, recent studies within the literature suggest that there is no significant difference in radiological or patient-reported outcomes between surgical fixation techniques in the long term.[10,11] Our study demonstrated a significant cost difference between percutaneous fixation and open reduction and internal fixation, as percutaneous methods were overall less expensive in terms of direct costs. These results are similar to those previously reported in the literature, with percutaneous methods being a lower-cost methodology.[12,13] This study, however, demonstrates that there is a significant difference in the rates of postoperative infection between open reduction and internal fixation and percutaneous pinning; the significant, 4-fold increase in cost of care as a result of these infections is another potential reason for the evolving trend in fracture fixation. Prior cost analyses comparing percutaneous fixation to open reduction and internal fixation have demonstrated a substantial cost difference between the 2 methodologies.[6] These cost savings, however, are theoretically diminished given the significantly higher rate of infection and the significant cost difference associated with a postoperative infection. Previous studies have identified external fixation as conferring a higher infection risk compared to internal fixation, with a meta-analysis identifying rates of infection of 11% in external fixation and 0.8% in open reduction.[5] While rates of infection within our studied cohort appear to be similar to those of previous studies for open reduction, our rates of infection for percutaneous pinning are lower than those previously reported. This may be due to a lack of billing and coding for superficial infections.[14] Although current evidence-based guidelines indicate no need for perioperative antibiotics for soft tissue operations on the hand and wrist, there is no consensus guideline on the use of perioperative antibiotics for bony fixation.[15,16] Current recommendations do suggest the utility of perioperative antibiotics in the setting of a distal radius fracture fixation.[17]

We identified multiple risk factors for postoperative infection, including male gender, open fracture, lung disease, chronic kidney disease, diabetes, hypertension, liver disease, obesity, and tobacco use. Open fracture was the strongest predictor for a postoperative infection. Open fracture has long been known to have an increased risk of infection, given the potential for contamination of the wound bed.[18] Treatment guidelines and quality metrics advocate for expedient administration of antibiotics in long bone fractures, as these measures have been shown to improve infections and overall outcomes.[19,20] Data for open hand and wrist fractures are limited, and no consensus guidelines exist; however, 1 meta-analysis demonstrated a significant reduction in postinjury

Table 3
Logistic Regression Analysis of Risk Factors after Propensity Matching

Variable	Odds Ratio	95% Confidence Interval	*P* Value
Age >65	0.97	0.76−1.24	.806
Male gender	1.05	0.84−1.30	.689
Chronic lung disease/chronic obstructive pulmonary disease	0.91	0.69−1.19	.390
History of cancer	1.10	0.88−1.37	.486
History of cerebrovascular disease	1.16	0.90−1.49	.242
History of chronic kidney disease	1.16	0.87−1.54	.310
History of coronary artery disease	0.99	0.76−1.29	.954
History of diabetes	0.90	0.71−1.13	.354
History of hypertension	1.21	0.94−1.56	.142
History of liver disease	1.16	0.89−1.51	.274
History of obesity	1.17	0.94−1.46	.161
Tobacco use	1.31	1.05−1.64	.017

infections, from 9.4% to 4.4%, with antibiotic prophylaxis.[21] Overall risk factors that conferred a level of immunocompromise, like chronic kidney disease, liver disease, and diabetes, seemed to incur a risk of postoperative infection. Diabetes has been well-established as conferring an increased risk of surgical site infection, and this was corroborated in our study.[22] Obesity also was an independent risk factor in our study for a postoperative infection after fracture fixation. Recent meta-analyses of the orthopedic surgery population have established obesity as a risk factor for infection.[23] Recent studies have also highlighted obesity as a risk factor for higher-complexity fractures or overall more severe fracture patterns.[24,25] Older age may serve as a protective factor against a postoperative infection, because distal radius fractures suffered in this population are more likely as a result of lower-energy mechanisms, like a fall from a standing height, compared to those suffered in younger populations.[26−29]

The most recent joint guidelines from the American Association of Orthopedic Surgeons and American Society for Surgery of the Hand delineate fracture fixation by patient age.[30] In the nongeriatric population, the guideline suggests with moderate strength evidence that operative fixation with postreduction radial shortening greater than 3 mm, dorsal tilt beyond 10°, or intraarticular displacement or step-off of 2 mm or more leads to improved radiographic and patient-reported outcomes, whereas in the geriatric population it suggests with strong evidence that operative fixation does not necessarily lead to improved outcomes. While treatment decisions, including the decision to operate, should be individualized to the patient in light of these recommendations, our study highlights multiple risk factors that may help further influence the decision on whether or not to operate in the setting of a closed fracture in a high-risk patient.

Propensity matching was used to control for age, gender, and open fracture. Regression based on

this cohort demonstrated that tobacco use conferred a significantly higher risk for a postoperative infection. Tobacco use has long been established as a significant risk factor for postoperative infections, wound healing problems, and bone-healing problems.[31] While smoking has not been identified as an independent risk factor for fracturing the distal radius itself, osteoporosis, which is strongly associated with smoking, is a strong risk factor for distal radius fracture.[32] Within hand surgery, smoking is associated with overall surgical site complications and infections, and this can be seen within the logistic regression analyses of both the overall cohort and the propensity-matched cohort.[29] Complication rates, including infectious complications, were demonstrated to be higher in current smokers in 2 recent studies.[33,34] Given the acute time frame of distal radius fracture fixation—typically within 2 weeks of injury—tobacco use and smoking cessation represent the most likely modifiable risk factor for preventing infection after distal radius fracture fixation. Smoking cessation can have demonstrable physiologic effects from 1 hour of cessation, and data indicate that cessation does have a positive impact on infectious healing complications.[31] Clinical care pathways for tobacco cessation for orthopedic trauma have been proposed, and are based on models with significant demonstrable success in other fields.[35] These pathways rely on multilevel cessation resources and therapies that trigger as soon as the patient is designated a tobacco user in the electronic medical record.

There are a number of limitations with this study. An epidemiological study indicated that distal radius fractures have a bimodal distribution, with peaks occurring in patients younger than 18 years old and those above 65 years old; however, this study focused on surgical management of these fractures, creating a bias toward the studied population that predominantly includes patients older than 18 years.[36] There is a female preponderance of distal radius fractures requiring fixation, and this is more common in patients older than 65, which has been noted in previously in analyses of a similar cohort within the PearlDiver cohort.[37] These trends have been cited as a result of a rise in the number of active advanced-age patients, and a concomitant rise in this patient population seeking a highly functioning outcome after an injury.[26]

Given that the PearlDiver software utilizes insurance claims−based data, the data are only as accurate as is allowed by International Classification of Diseases Ninth and Tenth Edition and CPT codes. Clinical nuances and data are inherently limited by this type of database, and results may be biased by improper or nonspecific coding. These codes cannot accurately account for the surgical technique or clinical context. Furthermore, coding for postoperative infections is not directly related to index procedures; thus, it is plausible that codes from other surgeries were captured within the data set. A cost analysis within the PearlDiver database only considers direct payment costs associated with fracture fixation and is unable to include indirect costs, like those due to lost time working or costs to employers.

Infection after distal radius fracture fixation is a rare complication. Given that costs are significantly increased after postoperative infection by almost 4-fold, attempts to address risk factors may lead to substantial cost savings and decreased rates of infection.

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