RESEARCH ARTICLE

Hardware Removal Due to Infection after Open Reduction and Internal Fixation: Trends and Predictors

Mohammad R. Rasouli, MD; Jessica Viola, BS; Mitchell G. Maltenfort, PhD;
Alisina Shahi, MD; Javad Parvizi, MD, FRCS; James C. Krieg, MD

Research performed at Rothman Institute of Orthopaedics, Thomas Jefferson University, Philadelphia, PA, USA

Received: 21 February 2015 *Accepted: 29 April 2015*

Abstract

Background: Little is known about trends and predictors of hardware related infection following open reduction and internal fixation (ORIF) of extremity fractures, one of the major causes of failure following ORIF. The present study was designed and conducted to determine trends and predictors of infection-related hardware removal following ORIF of extremities using a nationally representative database.

Methods: We used Nationwide Inpatient Sample data from 2002 to 2011 to identify cases of ORIF following upper and lower extremity fractures, as well as cases that underwent infection-related hardware removal following ORIF. Multivariate analysis was performed to identify independent predictors of infection-related hardware removal, controlling for patient demographics and comorbidities, hospital characteristics, site of fracture, and year.

Results: For all ORIF procedures, the highest rate of hardware removal related to infection was observed in tarsal fractures (5.56%), followed by tibial (3.65%) and carpal (3.37%) fractures. Hardware removal rates due to infection increased in all fractures except radial/ulnar fractures. Tarsal fractures(odds ratio (OR)=1.06, 95% confidence interval (CI): 1.04-1.09, *P*<0.001), tibial fractures (OR=1.04, 95% CI: 1.03-1.06, *P*<0.001) and those patients with diabetes mellitus (OR=2.64, 95% CI: 2.46-2.84, *P*<0.001), liver disease (OR=2.04, 95% CI: 1.84- 2.26, *P*<0.001), and rheumatoid arthritis (OR=2.06, 95% CI:1.88-2.25 *P*<0.001) were the main predictors of infection-related removals; females were less likely to undergo removal due to infection (OR= 0.61, 95% CI: 0.59-0.63 *P*<0.001).

Conclusions: Hardware removal rates due to infection increased in all fractures except radial/ulnar fractures. Diabetes, liver disease, and rheumatoid arthritis were important predictors of infection-related hardware removal. The study identified some risk factors for hardwarerelated infection following ORIF, such as diabetes, liver disease, and rheumatoid arthritis,that should be studied further in an attempt to implement strategies to reduce rate of infection following ORIF.

Key words: Hardware Removal, Infection, NIS, ORIF

Introduction

As operative techniques and implant device designs improve, open reduction with internal fixation (ORIF) is evolving as the preferred method of treatment for many fractures (1-7). Internal fixation has been shown to maintain reduction, provide stability that predictably allows for bony union, and lead to earlier return to function after injury (1,8). Devices used for internal fixation of fractures include intramedullary nails, plates, and screws (9). In spite of the success and increased use of internal fixation, postoperative infection remains a significant problem. Postoperative infections

Corresponding Author: James C. Krieg, The Rothman Institute, 925 Chestnut St., Philadelphia, PA 19107
E-mail: kriegj@mac.com

THE ONLINE VERSION OF THIS ARTICLE
ABJS.MUMS.AC.IR

associated with internal fixation devices can lead to delayed union, prolonged recovery, increased morbidity, and increased expense (10.11). Most infections are acquired at the time of trauma or during the subsequent fracture fixation procedure, and staphylococcus is the most frequent organism causing infection in these cases (9). It is estimated that there are 2,000,000 fracture fixation devices inserted in the US annually and about 100,000 of those cases become infected (12). Hardware removal is commonly performed. However, this may or may not eradicate the problem, may leads to a prolonged recovery, andplaces a significant economic burden on healthcare systems, due to the cost of treatment as well as the potential time lost (10).

Considering the relatively high prevalence of infection after ORIF, it is important to determine the nationwide epidemiologic profile and predictors of hardware related infection following ORIF. Previous studies have mainly focused on the prevalence of hardware removal after fracture fixation procedures in the femur and the humerus (13,14). However, the trends and predictors of hardware removal exclusively due to infection remain undetermined. The purpose of this study was to identify the trends and predictors of hardware removal due to infection following ORIF using a nationally representative database.

Materials and methods

Data for this study were obtained from the Nationwide Inpatient Sample (NIS) database from 2002 to 2011. The Association of Healthcare and Research Quality provided the data in the NIS. The NIS is the largest database in the United States that collects all-payer inpatient care data, representing approximately 20% of hospital stays from over 1,051 hospitals in 45 states (15). This study was exempt from review by the institutional review board because the NIS database is adequately de-identified.

To identify cases which underwent ORIF or hardware removal each year, we used the method that has been previously described by Levold et al. (13,14). The NIS database was queried based on the Ninth Revision of the International Classification of Diseases (ICD-9 codes) to identify ORIF following humeral, radial/ulnar, carpal/metacarpal, femoral, tibial/fibula, tarsal/metatarsal fractures. Patients who underwent hardware removal and those who developed infection following hardware implantation were identified as well. The ICD-9 code 79.8x was used to identify those patients who underwent ORIF for the fractures of the aforementioned bones, and ICD-9 code 78.6x was used to identify hardware removals. Infections related to hardware implants were identified with diagnostic codes 996.66 and 996.67.

Data collected included patient's age, gender, race, hospital size (small, medium, or large), hospital type (rural, private urban, or academic urban), comorbidities, indications for hardware removal, length of stay (LOS), and hospital charges. The comorbidities included were peripheral vascular disease, chronic pulmonary disease, diabetes, renal failure, solid organ tumor, lymphoma, obesity, blood loss anemia, deficiency anemia, AIDS, liver disease, rheumatoid arthritis/collagen, alcohol abuse, drug abuse, and depression. Reasons for hardware removal were broadly classified as septic (ICD-9 codes of 996.66 and 996.67) or not.

US population data were extracted from the census.gov website. National estimates of implant and removal rates were based on the population weights provided by the NIS. Logistic regression was used to estimate the contribution of patient and hospital factors to the probability that a patient visit was for the removal of hardware. The regressions included interaction terms between calendar year and site of implant/removal so that statistical comparisons could be made between different bones and the femur (used as reference due to its relatively high rate of fracture).

Of the removals, the effect of infection onLOS and charges was estimated using the Wilcoxon test. Total hospital charges, not including professionals' fees, were provided by the NIS data. These charges were adjusted to 2011 dollars using the inflation calculator available at http://www.bls.gov/data/inflation_calculator.htm.

The rate of ORIF in each year was determined using the ICD-9 coding system and calculated based on infection per 100,000 the national population.Hardware removal rates for each year were determined by dividing the number of hardware removals in a particular body region by the total number of ORIF procedures for that corresponding region. The rate of hardware removal related to infection was calculated by dividing the number of cases that had been coded for both hardware removal and infection (996.66 or 996.67) by the number of ORIF in the corresponding year. Both of these rates were also calculated by infection per 100,000 of the national population. Additionally, the rate of infection-related removal within removals was determined by dividing the rate of infection-related removal by number of removals.

Logistic regression analysis was performed, controlling for age, gender, ethnicity, the aforementioned comorbidities, hospital type and size, and fracture

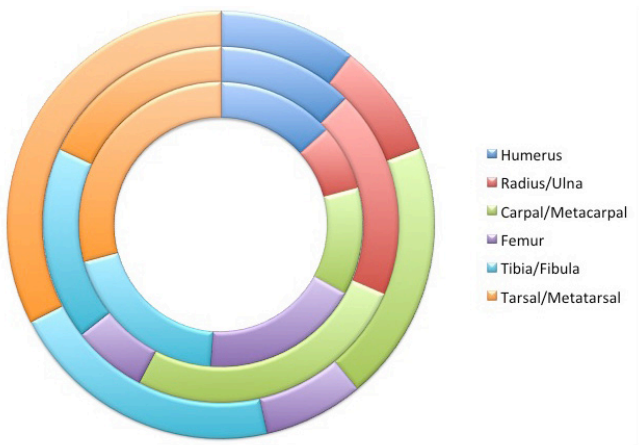

Figure 1. Average rates of hardware removals out of all open reduction and internal fixation (ORIF) procedures (outer layer), infected hardware out of all ORIF procedures (middle layer), and infected hardware within the removal group (inner layer).

location to identify independent predictors of hardware removal due to infection. LOS and hospital charges were compared between septic and aseptic groups using Wilcoxon Rank-Sum Test. We used R 2.15.1 (R Foundation for Statistical Computing, Vienna, Austria) for all analyses and the 'rms'package within R for the logistic regression. In all analyses, p-valuesless than 0.05 were considered to be statistically significant.

Results

ORIF procedures, hardware removals, and infection rates were identified in the NIS database from 2002 to 2011. Figure 1 depicts the average rate of hardware removals, the rate of hardware related infection relative to all ORIF procedures and the rate of hardware related infection relative to the hardware removal group. For all ORIF procedures, the highest rate of hardware removal related to infection was observed in tarsal fractures (5.56%), followed by tibial (3.65%) and carpal (3.37%) fractures.

During the period of data collection, 2002-2011, the overall rate of ORIF as it relates to the 100,000national population as a whole, decreased in all regions except for humeral (from 10 in 2002 to 11.58 in 2011) and radial/ulnar (from 13.05 in 2002 to 13.55 in 2011) fractures. However, as the Figure 2 demonstrates, all changes were slight except for the femur. The overall rate of hardware removal and hardware removal related to infection, as it relates to the population as a whole, increased in humerous, tibia/fibula, and tarsal/metatarsal regions. Figure 2 summarizes the rates of ORIF, hardware removal, and infection-related hardware removal in upper and lower extremity fractures per 100,000 national populationduring the study period.

Considering number of ORIFs as the denominator, rate of hardware removal increased over the study period in carpal/metacarpal, tibia/fibula and tarsal/metatarsal fractures. Radial/Ulnar fractures were the only fractures showed a decrease in the percent of hardware removals due to infection in 2011 at 1.64% compared to 2002 at 1.76% [Figure 3].

Using logistic regression analysis, tarsal fractures (odds

Table 1. Predicators of hardware removal after open reduction and internal fixation of fracture

		Odds Ratio	95% CI	p-value
	Female	0.61	0.59-0.63	<0.001
Ethnicity	Asian	0.75	0.64-0.88	<0.001
	Native American	1.43	1.19-1.72	<0.001
	Other	0.77	0.69-0.86	<0.001
Type and Size of Hospital	Large Hospitals	1.1	1.04-1.17	<0.001
	Rural hospitals	0.78	0.72-0.83	<0.001
	Urban Private Hospitals	1.5	1.45-1.56	<0.001
Geographic Region	Midwest	0.92	0.86-0.97	0.004
	South	1.2	1.15-1.25	<0.001
	West	1.14	1.09-1.21	<0.001
Comorbidities	AIDS	1.46	1.05-2.02	0.02
	Alcohol Abuse	0.62	0.57-0.67	<0.001
	Deficiency Anemia	1.53	1.46-1.61	<0.001
	Rheumatoid Arthritis	2.06	1.88-2.25	<0.001
	Chronic Lung Disease	1.06	1.01-1.12	0.01
	Depression	1.27	1.20-1.34	<0.001
	Diabetes Mellitus	2.64	2.46-2.84	<0.001
	Drug Abuse	1.26	1.15-1.39	<0.001
	Liver Disease	2.04	1.84-2.26	<0.001
	Peripheral Vascular Disease	1.37	1.25-1.50	<0.001
	Renal Failure	1.1	1.02-1.19	0.02
	Year of Surgery	0.99	0.98-1.00	0.04
Fracture	Tarsal/Metatarsal	1.06	1.04-1.09	<0.001
	Tibia/Fibula	1.04	1.03-1.06	<0.001

CI: Confidence Interval, AIDS: Acquired Immunodeficiency Syndrome

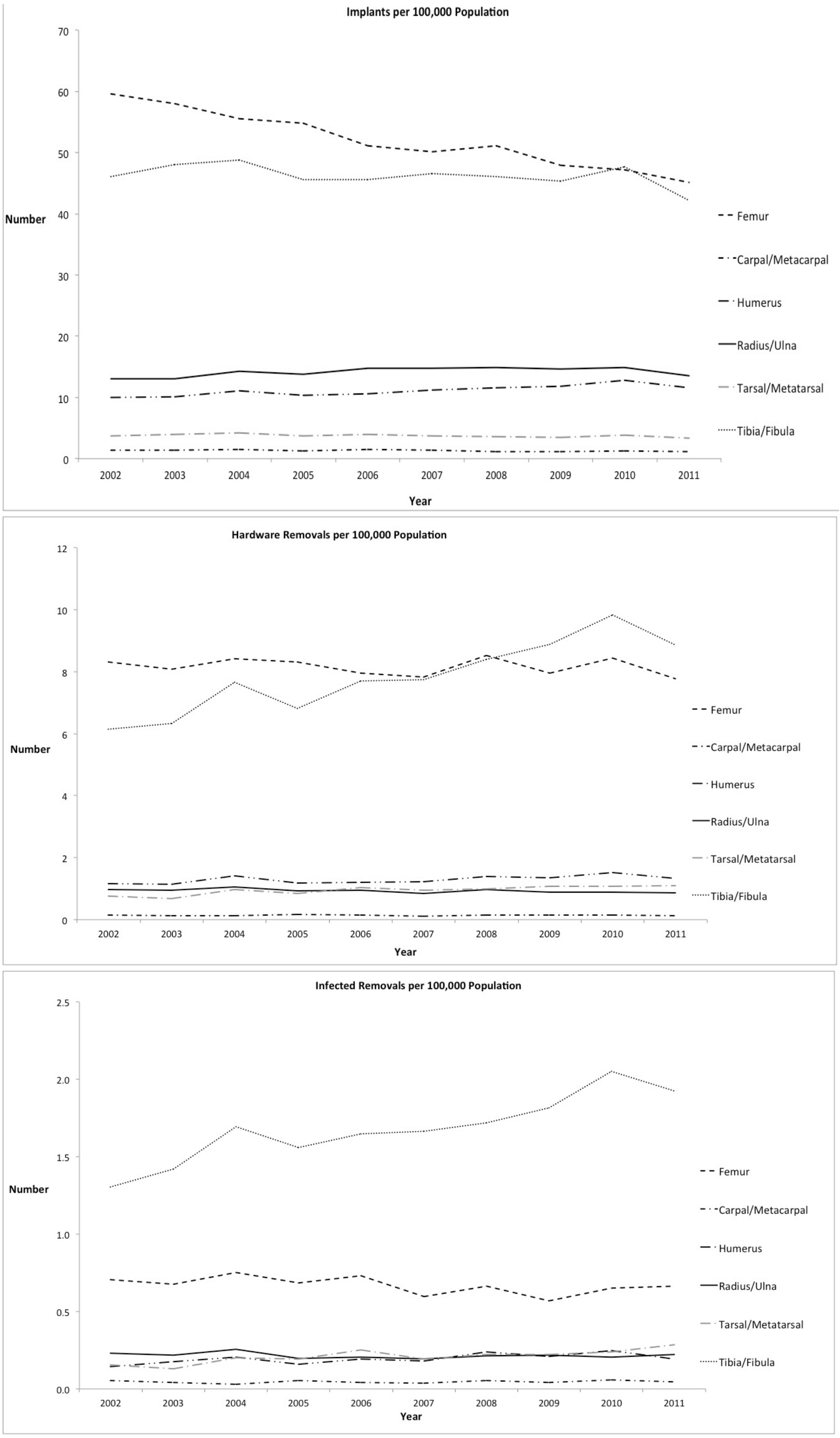

Figure 2. Trends of open reduction and internal fixation (ORIF), hardware removals, and infection-related hardware removals in upper and lower extremity fractures during 2002-2011 per 100000 national population.

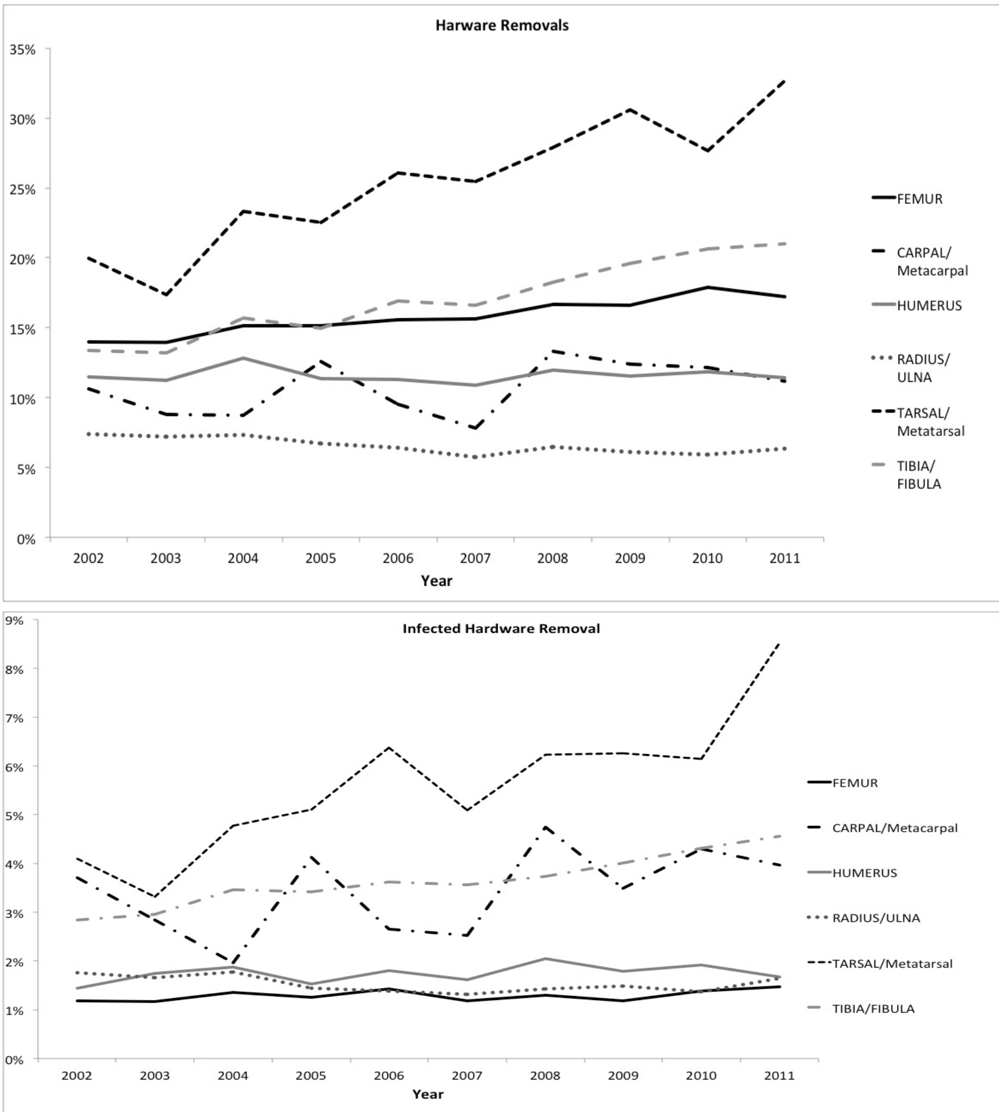

Figure 3. Rate of hardware removal and hardware removal related to infection in different type of fractures.

ratio(OR)=1.06, 95% confidence interval (CI): 1.04-1.09, *P*<0.001) and tibial fractures (OR=1.04, 95% CI: 1.03-1.06, *P*<0.001) were the main independent predictors of infection-related removals. Patients with diabetes mellitus (OR=2.64, 95% CI: 2.46-2.84, *P*<0.001), liver disease (OR=2.04, 95% CI: 1.84- 2.26, *P*<0.001), and rheumatoid arthritis (OR=2.06, 95% CI: 1.88-2.26 *P*<0.001) were also more likely to undergo infection-related removal.Females were less likely than men to have infection related hardware removal. (OR=0.61, 95% CI: 0.59-0.63 *P*<0.001). Table1 summarizes these findings.

Length of stay (LOS) was significantly higher (*P*< 0.001) in the infection-related hardware removal group (median: 6 days; interquartile range (IQR): 3-10 days) compared to the aseptic hardware removal group (median: 3 days; IQR: 2-6 days). Figure 4 demonstrates LOS in the septic and aseptic groups for several fracture locations. Despite an increase in the LOS in the infection group, there was not a statistically significant difference (*P*<0.001)between the infected (median: $35,310; IQR: $20,630-$64,660) and non-infected (median: $38,200; IQR: $23,300-$62,200) hardware removal groups [Figure 4, 5].

Discussion

Postoperative infection remains a significant problem after fracture fixation. It is relatively frequent, and has been reportedly associated with serious disability, increased morbidity and mortality, and an increase in healthcare costs (10-12). In spite of this, national epidemiologic data, including trends and predictors for

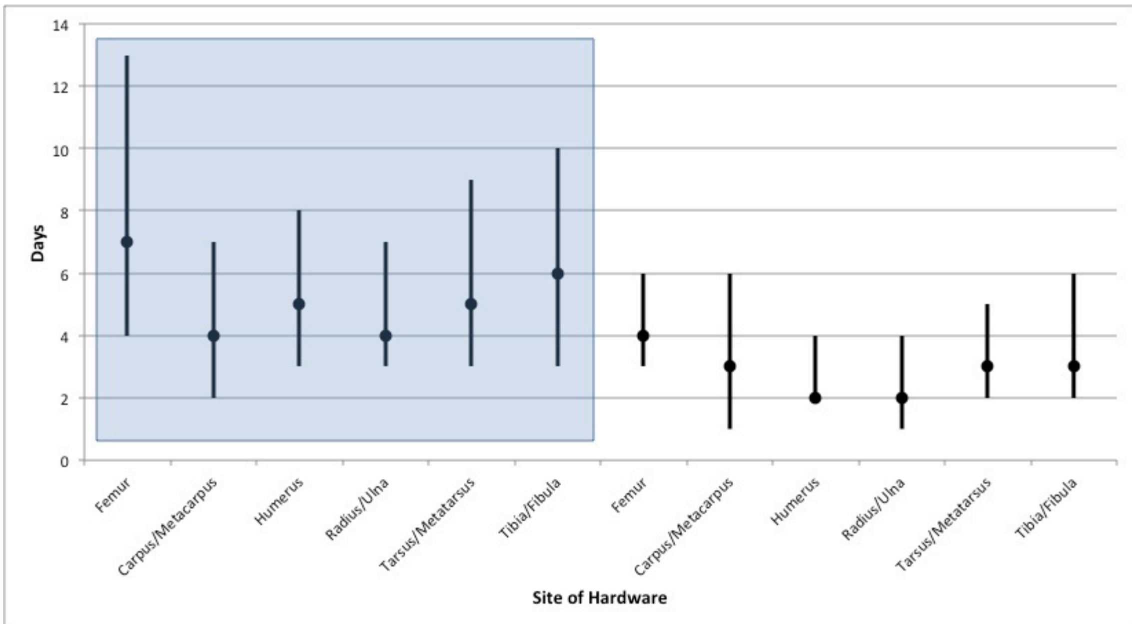

Figure 4. Length of stay for hardware removals in various fracture regions.
Left and right panels respectively depict length of stay for infected and non-infected hardware removals based on the site of the fracture.

hardware removal in the face of infection, have not been well defined. Successful treatment of hardware related infection is important, both for the benefit of individual patients, and to minimize costs for healthcare (11). Using nationally representative data, wedeterminedthe epidemiologic profiles and predictors of subsequent hardware infection following ORIF.

In the present study, ORIF trends in all fractures remained relatively stable, with the exception of femoral fracture fixation, which was shown to decrease. It is not entirely clear why ORIF of femur fractures decreased, but one possible contribution may be the relative increase in arthroplasty for displaced femoral neck fractures. This trend would be expected based on evidence of better patient outcomes following hip replacement in comparison to ORIF (16,17).

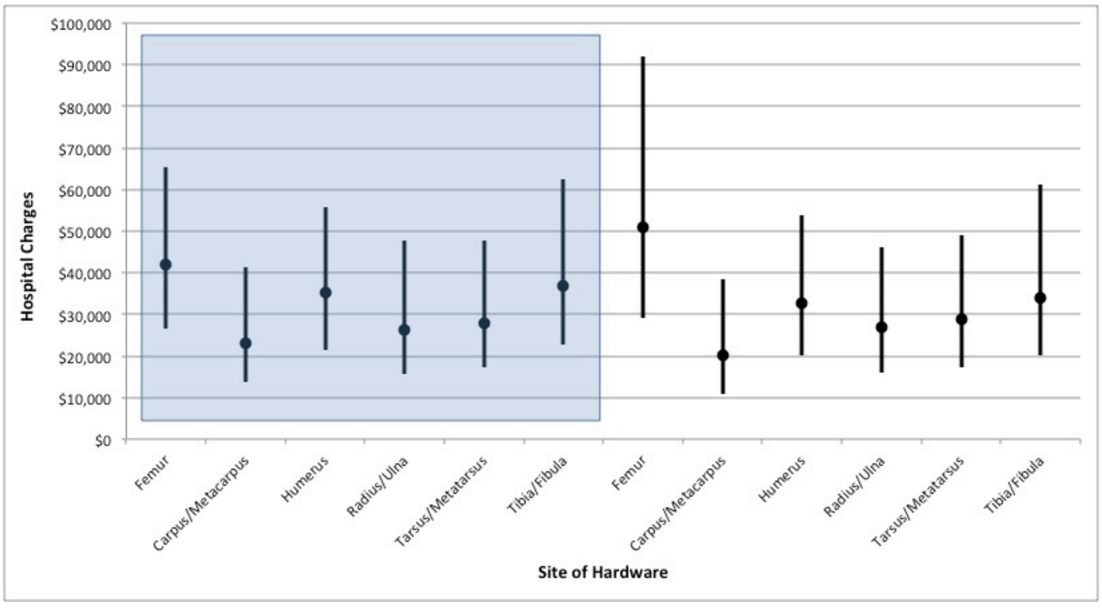

Figure 5. Comparison of hospital charges between infectedand non-infected cases of hardware removal in upper and lower extremity fractures.
Left and right panels respectively depict hospital charges for non-infected and infected hardware removals based on the site of the fracture.

The overall removal rate for radial fracture implants was found to decrease. Our results compare favorably with Rozental's evaluation of 28 patients with comminuted, dorsally displaced radial fractures, with the ORIF group experiencingexcellent early function, and a decreased rate of complications (18). Similarly, Beharrie et al. found that ORIF in patients aged 60 and older provided encouraging functional outcomes using the Gartland and Werley and Disabilities of the Arm, Shoulder and Hand scoring system with an average score of 4 out of 100, demonstrating minimal disabilities of activities of daily living (1). These encouraging results,indicating a reduction in the rate of subsequent revision following ORIF of the radial/ulnar fractures, support our findings.

Tarsal and tibial fractures were found to have increased rates ofhardware removal related to infection. Effectively managing distal lower limb fractures remains a common and challenging problem faced by orthopaedic surgeons (7,19). With improve techniques there is often an increase in the indication for ORIF. Because of the nature of the soft tissue envelope in the distal lower extremity, it seems reasonable to assume that increased use of internal fixation in the lower extremity would lead to increased incidence of hardware removal. The somewhat tenuous nature of the same soft tissue envelope also seems likely to lead to more post implant infection, and subsequent removal related to infection (7,19,20). Cheng-Yu Fan et al. add that the mechanisms resulting in distal tibial fractures frequently involve high-energy trauma that involves both the bone and the soft tissues, further compromising the management of ORIF (3).

Major predisposing factors for infection following ORIF include diabetes mellitus, liver disease, and rheumatoid arthritis.Our findings are consistent with previous studies showing diabetes mellitus is a common risk factor for postoperative infection (11,21). An increased risk of infection in patients with rheumatoid arthritis has been reported throughout the literature, related to both the disease process and the immunosuppressive nature of treatment (22). Patients on tumor necrosing factor inhibitors have been shown to have an increased risk of bone, skin, and soft tissue infection (23,24). Liver disease has been shown to be associated with a deficient immune system, predisposing end-stage liver disease patients to severe infections (25). The negative effect of liver disease on immunoglobulin and albumin production also increases a patient's risk for infection.

Females were found to be less associated with infection-related hardware removal. This discrepancy of infection-related hardware removal between sexes may partially be explained by sex hormones and their action on the immune system (15). Testosterone is known to suppress immune function, whereas estrogen increases immune function and can even result in autoimmune disorders (26,27).

This study has some limitations that need to be highlighted. While the ICD-9 coding system determines the overall region of fracture fixation, it does not differentiate the specific anatomic location of ORIF or hardware removal in forearm, hand, leg, and foot fractures. As a result, we were not able to distinguish tibial fractures from fibular fractures or tarsal from metatarsal and carpal from metacarpal fractures. Moreover, unintentional coding errors in the NIS database were inevitable and we could not completely eliminate the effect of these potential errors. However, these errors are presumed to be random and should, over the vast amount of data collected, be distributed uniformly in all study groups. Another limitation of the NIS database is that individual patients could not be followed up through the database. As a result, we calculated the rates based on the method previously described by Levold et al, which takes the rate of ORIF and hardware removal in each year, regardless of whether they occurred in the same patient, in the same year (13,14). Also it should be noted that majority of uncomplicated hardware removals are performed as an outpatients basis and since the NIS only collects inpatient data, total rate of hardware removal might be underestimated in this study. However, we believe that complicated hardware removals including infection-related ones are mainly required hospitalization and this study provides a more accurate estimation on infection-related hardware removals compared to other etiologies of hardware removals. Despite these limitations, the database should be considered as the main strength of our study, allowing us to study over 500,000 hardware removals in all types of fractures. We also examined the rate of ORIF, hardware removal, and infection-related hardware removal for nearly all extremity fractures. The comprehensiveness of this study makes it unique and a potential reference for future epidemiologic studies.

The current study analyzed six different fracture locations in a nationwide database to determine the rate of hardware removal and infection-related hardware removal. Our data and analysis suggest that tarsal and tibial fractures have the highest rates of infection related hardware removal. Radial/Ulnar fractures were the only one showed a decrease in the rate of hardware removal related to infection.The study also identified some risk factors for hardware infection following ORIF that should be studied further in an attempt to implement strategies to reduce rate of infection following ORIF.

Mohammad R. Rasouli MD
The Rothman Institute at Thomas Jefferson University, Philadelphia, PA
Sina Trauma and Surgery Research Center, Tehran University of Medical Sciences, Tehran, Iran

Jessica Viola BS
Mitchell G. Maltenfort PhD
Alisina Shahi MD
Javad Parvizi MD, FRCS
James C. Krieg MD
The Rothman Institute at Thomas Jefferson University, Philadelphia, PA

References

1. Beharrie AW, Beredjiklian PK, Bozentka DJ. Functional outcomes after open reduction and internal fixation for treatment of displaced distal radius fractures in patients over 60 years of age. J Orthop Trauma. 2004;18 (10):680–6.
2. Chirodian N, Arch B, Parker MJ. Sliding hip screw fixation of trochanteric hip fractures: Outcome of 1024 procedures. Injury. 2005; 36 (6):793–800.
3. Fan CY, Chiang CC, Chuang TY, Chiu FY, Chen TH. Interlocking nails for displaced metaphyseal fractures of the distal tibia. International Journal of the Care of the Injured. Injury. 2005; 36 (6):669–74.
4. Grawe B, Le T, Lee T, Wyrick J. Open Reduction and Internal Fixation (ORIF) of Complex 3- and 4-Part Fractures of the Proximal Humerus Does Age Really Matter? Geriatr Orthop Surg Rehabil. 2012;3 (1):27-32.
5. Orbay J, Fernandez D. Volar fixed-angle plate fixation for unstable distal radius fractures in the elderly patient. J Hand Surg. 2004;29 (1):96–102.
6. Südkamp N, Bayer J, Hepp P, Voigt C, Oestern H, Kääb M, et al. Open Reduction and Internal Fixation of Proximal Humeral Fractures with Use of the Locking Proximal Humerus Plate. J Bone Joint Surg Am. 2009; 91(6):1320-8.
7. Vaienti L, Di Matteo A, Gazzola R, Pierannunzii L, Palitta G, Marchesi A. First results with the immediate reconstructive strategy for internal hardware exposure in non-united fractures of the distal third of the leg: case series and literature review. J Orthop Surg Res. 2012;7:30.
8. Xie X, Xie X, Qin H, Shen L, Zhang C. Comparison of internal and external fixation of distal radius fractures: A meta-analysis of randomized controlled trials. Acta Orthopaedica. 2013;84(3):286-91.
9. Trampuz A, Zimmerli W. Diagnosis and treatment of infections associated with fracture-fixation devices. Injury. 2006; 37(Sup 2):59–66.
10. Duckworth AD, Phillips SA, Stone O, Moran M, Breusch SJ, Biant LC. Deep infection after hip fracture surgery: Predictors of early mortality. Injury. 2012;43 (7):1182–6.
11. Partanen J, Syrjälä H, Vähänikkilä H, Jalovaara P. Impact of deep infection after hip fracture surgery on function and mortality. J Hosp Infect. 2006;62(1):44–9.
12. Darouiche RO. Treatment of Infections Associated with Surgical Implants. N Engl J Med. 2004;350(14):1422–9.
13. Lovald S, Mercer D, Hanson J, Cowgill I, Erdman M, Robinson P, et al. Complications and Hardware Removal After Open Reduction and Internal Fixation of Humeral Fractures. J Trauma. 2011;70 (5):1273–8.
14. Lovald S, Mercer D, Hanson J, Cowgill I, Erdman M, Robinson P, et al. Hardware Removal After Fracture Fixation Procedures in the Femur. J Trauma Acute Care Surg. 2011;72 (1):1273-7.
15. Rasouli MR, Maltenfort MG, Purtill JJ, Hozack WJ, Parvizi J. Has the rate of in-hospital infections after total joint arthroplasty decreased?. Clin Orthop Relat Res. 2013;471(10):3102–11.
16. Bhandari M, Devereaux PJ, Swiontkowski MF, Tornetta P 3rd, Obremskey W, Koval KJ,et al. Internal Fixation Compared with Arthroplasty for Displaced Fractures of the Femoral Neck. J Bone Joint Surg Am. 2003;85-A (9):1673–81.
17. Gao H, Liu Z, Xing D, Gong M. Which is the Best Alternative for Displaced Femoral Neck Fractures in the Elderly?: A Meta-Analysis. Clin Orthop Relat Res. 2012;470 (6):1782–91.
18. Rozental TD, Blazar PE, Franko OI, Chacko AT, Earp BE, Day CS. Functional outcomes for unstable distal radial fractures treated with open reduction and internal fixation or closed reduction and percutaneous fixation. A prospective randomized trial. J Bone Joint Surg Am. 2009; 91(8):1837–46.
19. Ronga M, Longo UG, Maffulli N. Minimally invasive locked plating of distal tibia fractures is safe and effective. Clin Orthop Relat Res. 2010;468 (4):975–82.
20. Janssen KW, Biert J, van Kampen A. Treatment of distal tibial fractures: plate versus nail: a retrospective outcome analysis of matched pairs of patients. Int Orthop. 2007; 31(5):709–14.
21. Enstone JE, Humphreys H. Monitoring infective complications following hip fracture. J Hosp Infect. 1998;38 (1):1–9.
22. Galloway JB, Hyrich KL, Mercer LK, Dixon WG, Fu B, Ustianowski AP, et al.. Anti-TNF therapy is associated with an increased risk of serious infections in patients with rheumatoid arthritis especially in the first 6 months of treatment: updated results from the British Society for Rheumatology Biologics Register with special emphasis on risks in the elderly. Rheumatology. 2010;50 (1):124–31.
23. Listing J, Strangfeld A, Kary S, Rau R, von Hinueber U, Stoyanova-Scholz M, et al. Infections in patients with rheumatoid arthritis treated with biologic agents.

Arthritis Rheum. 2005;52 (11):3403–12.
24. Dixon WG, Watson K, Lunt M, Hyrich KL, Silman AJ, Symmons DP,et al. Rates of serious infection, including site-specific and bacterial intracellular infection, in rheumatoid arthritis patients receiving anti–tumor necrosis factor therapy: Results from the British Society for Rheumatology Biologics Register. Arthritis Rheum. 2006;54 (8):2368–76.
25. Cheruvattath R, Balan V. Infections in Patients With End-stage Liver Disease. J Clin Gatroenterol. 2007;41 (4):403–11.
26. Angele MK, Schwacha MG, Ayala A, Chaudry IH. Effect of gender and sex hormones on immune responses following shock. Shock. 2000;14 (2):81–90.
27. Beery TA. Sex differences in infection and sepsis. Crit Care Nurs Clin North Am. 2003;15(1):55–62.