Early post-operative outcomes of plate versus nail fixation for humeral shaft fractures

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A B S T R A C T

Introduction: This study was designed to measure early postoperative outcomes of plate vs. nail fixation for humeral shaft fractures.

Patients and methods: Patients ≥ 18 years who underwent plate or nail fixation for low-energy humeral shaft fractures between 2005–2016 were identified from the National Surgical Quality Improvement Program (NSQIP). Multivariable regression was used to compare postoperative outcomes using propensity score adjustment to account for differences between fixation groups. Variables included in the propensity score were age, American Society of Anesthesiologists (ASA) class, hypertension, steroid use, cancer, functional status, chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), and sex.

Results: Plate fixation was used in 1418 patients (70.6%), while nail fixation was used in 591 (29.4%). Patients undergoing nail fixation were more likely to be older, have a higher American Society of Anesthesiologists (ASA) class, and have comorbidities. Mean operative time was statistically longer in the plate fixation group (130 +/− 62 min vs. 102 +/− 54 min). After propensity score adjustment, type of fixation was not a significant predictor of major or minor complications, length of stay, or readmission. However, nail fixation was a significant predictor of mortality following propensity score adjustment (OR 3.15, 95% Confidence interval 1.26–7.85).

Conclusion: Patients undergoing intramedullary nail fixation tended to be older patients with more comorbidities, suggesting that surgeons are selecting nail fixation in patients who may not be ideal surgical candidates. Although LOS, complications, and readmission rates were higher in the nail group, this difference was not statistically significant following propensity score adjustment. However, nail fixation remained an independent predictor of 30-day mortality following adjustment. This suggests that nail fixation may not be a safer surgical option in patients with multiple medical co-morbidities and low-energy humeral shaft fractures.

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Introduction

Humeral shaft fractures account for up to 3% of all fractures and approximately 70,000 fractures annually in North America [1–3]. These fractures are most commonly sustained in low-energy ground level falls in the elderly population, but may also occur as a result of higher energy trauma, especially in motor vehicle collisions [1,2]. Humeral shaft fractures are typically closed; previous literature reports that 2–25% present as open fractures [2,4], and approximately 6–8% are pathologic [2,5]. Midshaft and proximal shaft fractures make up about 45% and 40% of humeral shaft fractures, respectively [2].

The majority of humeral shaft fractures can be successfully managed non-operatively with functional bracing [4,6–9]. Surgical management is recommended for fractures that are open or have associated neurovascular injuries, articular involvement, or unacceptable alignment following functional bracing [1,6]. Surgery merits consideration in polytrauma patients and patients at a higher risk of nonunion, including proximal shaft fractures, or certain fracture patterns [7,8,10–12].

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Compared to non-operative management, plate fixation has been shown to decrease the rates of malunion and nonunion, and reported union rates range from 91%–100% [13,14]. The primary disadvantage of plate fixation is soft tissue disruption [1]. Intramedullary nailing has been introduced as an alternative to plate fixation, with proposed benefits including preservation of fracture biology, faster time to union, decreased soft tissue trauma, decreased blood loss, and decreased operative time [15–18]. However, this technique has been associated with rotator cuff injury, subsequent shoulder pain and impingement, and a higher rate of secondary operations [18–24]. Reported union rates range from 87 to 97% [25]. While certain patient or injury characteristics may suggest one treatment over another, there is no definitive consensus regarding which patients will have superior outcomes with plate or nail fixation [16,21,26].

Given the conflicting nature of the literature regarding humeral shaft fracture management with plate and nail fixation, the purpose of this study was to examine the patient characteristics and early post-operative outcomes associated with each method of fixation.

Patients and methods

A retrospective analysis was conducted using the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP). Patients ≥18 years who underwent plate or nail fixation for humeral shaft fractures between 2005–2016 were identified from the National Surgical Quality Improvement Program (NSQIP) database. The data available in NSQIP has been collected prospectively from over 500 participating U.S. hospitals from 2005 to 2016 [27]. This information specifically includes clinical outcomes such as perioperative morbidity and mortality within a 30-day postoperative period. This database excludes high-energy trauma patients and polytrauma patients.

For this study, outcomes for surgically managed humeral shaft fractures were obtained by searching for the following Current Procedural Terminology (CPT) codes: "open treatment of humeral shaft fracture with plate and screws" (24515) and "treatment of humeral shaft fracture with intramedullary implant" (24516). The International Classification of Diseases, Ninth Revision (ICD9) codes included 812.21 and 812.31, which both represent humeral shaft fractures. Fixation of pathologic fractures, osteotomies for malunion, and nonunion repairs were excluded.

Demographic information, including patient medical history and comorbidities, was catalogued. The primary patient-based predictors included age, sex, American Society of Anesthesia (ASA) classification, and comorbidities. The primary surgical risk factor evaluated was operative time. The primary patient outcome measures assessed were mortality, systemic and local postoperative complications, and length of stay (LOS). Systemic and local post-operative complications were further divided into major and minor complications based on previously published criteria [28–30]. Major systemic complications included myocardial infarction, septic shock, cerebrovascular accident, and pulmonary embolus. Minor systemic complications included pneumonia, urinary tract infection (UTI), and postoperative transfusion for anemia. Major local complications included deep wound infections and peripheral nerve injuries. Minor local complications included superficial surgical site infections and wound dehiscence.

Statistical analysis

Bivariate testing was performed for unadjusted differences between groups using Chi square or Fisher exact tests for categorical variables, and t-tests for continuous variables. Propensity scores were calculated using multivariable logistic regression,

with treatment via nail fixation (vs. plate fixation) as the dependent variable. Variables included in the propensity score were age, ASA class, hypertension, steroid use, cancer, functional status, chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), and sex. Multivariable regression was then applied to assess for between-group differences while adjusting for the propensity score. Logistic regression was used for binary outcomes, negative binomial regression was used for LOS, and linear regression was used for operation length. As readmission was only included in the NSQIP database from 2011 on, for all readmission models, only patients from 2011 to 2016 were included. A sensitivity analysis was performed to see if the results changed depending on patient age (patients aged ≤50 years vs. patients aged ≥70 years).

Results

Of the 2009 patients included in this study, plate fixation was used in 1418 patients (70.6%), while nail fixation was used in 591 (29.4%). Patients undergoing nail fixation were more likely to be older and have a higher ASA class (Table 1). Patients in the nail fixation group were also more likely to have more comorbidities. Patients receiving plate fixation were more likely to live independently (p < 0.01). Mean operative time was statistically longer in the plate fixation group (130 +/−62 min versus 102 +/−54 min in the nail group, p < 0.0001). Average LOS was greater in the nail fixation group (4 +/−6 days, versus 3 +/−5 days, p < 0.001).

Transfusions were performed more frequently in the nail fixation group (Table 2). Unadjusted major systemic complications were more common in the nail fixation group (4.3% versus 1.8%, p < 0.01, Table 3). Conversely, unadjusted major local complications including peripheral nerve injury and deep infections were more common in the plate fixation group (1.4% versus 0.2%, p < 0.01).

Table 1
Patient demographic and perioperative characteristics, per fixation method.

Characteristic	Plate Fixation	Nail Fixation	P-value
Age (years)			<0.0001
18–59	723 (51.0%)	190 (32.2%)	
60–69	273 (19.3%)	138 (23.4%)	
70–79	232 (6.4%)	143 (24.2%)	
80–89	190 (13.4%)	120 (20.3%)	
Number (%) Female	880 (62.0%)	367 (62.1%)	0.98
ASA classification			<0.0001
1	198 (14.0%)	23 (4.0%)	
2	582 (41.0%)	145 (24.5%)	
3	565 (39.8%)	342 (58.0%)	
4	72 (5.1%)	80 (13.5%)	
Medical Comorbidities			
Hypertension	628 (44.3%)	334 (56.5%)	<0.0001
Steroid use	47 (3.3%)	45 (7.6%)	<0.0001
Insulin-dependent diabetes	104 (7.3%)	53 (9.0%)	0.44
Smoking	304 (21.4%)	118 (20.0%)	0.46
COPD	63 (4.4%)	42 (7.1%)	0.0015
Disseminated cancer	25 (1.8%)	67 (11.3%)	<0.001
CHF	15 (1.1%)	8 (1.4%)	0.57
0–1 comorbidities	746 (52.6%)	189 (32.1%)	<0.001
2 comorbidity	648 (45.7%)	371 (62.8%)	
≥ 3 comorbidities	24 (1.7%)	30 (5.1%)	
Independently Living	1296 (91.4%)	509 (86.1%)	0.004
Operative time (minutes)	129.7 +/−62.5	102.2 +/−54.1	<0.0001
Length of hospital stay (days)	2.9 +/−4.8	4.2 +/−6.3	<0.0001
Time to surgery (days)	0.8 +/−2.0	1.5 +/−4.6	<0.0001
Readmissions[*]	55 (4.5%)	31 (7.0%)	0.04

MI, myocardial infarction; *ASA*, American Society of Anesthesiologists [*]of 1676 patients from 2011 to 2016.
Continuous outcome compared via Wilcoxon Rank Sum Test.

Table 2
Total major or minor systemic or local complications, per fixation method.

Complication	Plate Fixation	Nail Fixation	P-value
Myocardial infarction	1 (0.1%)	4 (0.7%)	0.06
Septic shock	7 (0.5%)	3 (0.5%)	0.07
Cerebrovascular accident	1 (0.1%)	1 (0.2%)	0.18
Pulmonary embolism	4 (0.3%)	4 (0.3%)	0.13
Pneumonia	13 (0.9%)	4 (0.7%)	0.19
Urinary tract infection	14 (1.0%)	10 (1.7%)	0.07
Anemia requiring transfusion	112 (7.9%)	71 (12.0%)	0.004
Deep wound infection	4 (0.3%)	0 (0%)	0.10
Peripheral nerve injury	6 (0.80%)	0 (0%)	0.22
Superficial surgical site infection	13 (0.92%)	4 (0.68%)	0.19
Wound dehiscence	4 (0.3%)	1 (0.2%)	0.37

Table 3
30-day mortality and complications, per fixation method.[a]

	Plate Fixation	Nail Fixation	P-value
Mortality	11 (0.8%)	32 (5.4%)	<0.0001
Major systemic complication	25 (1.8%)	25 (4.3%)	0.0012
Minor systemic complication	34 (2.4%)	22 (3.7)	0.10
Major local complication	20 (1.4%)	1 (0.2%)	0.005
Minor local complication	4 (0.3%)	1 (0.2%)	0.36

[a] Bivariable analysis.

When adjusting for the propensity score, type of fixation was not a predictor of major or minor complications (Table 4). Only ASA class IV (versus I) was an independent risk factor for major complications, and only age was an independent predictor of minor complications. However, following propensity score adjustment, nail fixation increased the risk of mortality by 3.15 (95% Confidence interval [95%CI] 1.26–7.85). Nail fixation was also found to be an independent predictor of a shorter operative time by −26.8 min (95%CI −33.4 to −20.1).

In patients aged ≤50 years, 16.3% were managed with nail fixation, while 32.4% of patients aged 70 and older were managed with nail fixation. Due to the number of events, we were unable to perform propensity score adjusted models for any of the outcomes in only patients aged ≤50 years. However, unadjusted rates of mortality remained higher for patients treated with nails in both age groups (p < 0.0001). Unadjusted rates of complications and readmission were not different between fixation types in either age group. Following propensity score adjustment, in patients 70 and older, major and minor complications and readmission were not significantly affected by fixation type, while nail fixation remained a significant predictor of mortality in this age group (OR 3.45, 95%CI 1.04–11.51).

Discussion

The results of this study of 2009 patients emphasize that plate fixation is still used most commonly for surgical fixation of humeral shaft fractures (70.6% of procedures). The rate of surgical

Table 4
Results of propensity score adjusted multivariable regression to evaluate the effect of fixation type on mortality, operative time, length of stay, and readmissions.

	Odds Ratio	CI	P Value
Major Complication	0.97	0.53–1.75	0.91
Minor Complication	0.88	0.49–1.56	0.65
Mortality	3.15	1.26–7.85	0.014[*]
Operative time	−26.75	−33.40 to −20.09	<0.0001[*]
Length of Stay[a]	1.03	0.87–1.08	0.55
Readmissions[*]	0.98	0.58–1.64	0.94

OR, odds ratio; CI, confidence interval.
[a] LOS compared via negative binomial regression.
[*] Data from years 2011-2016.

fixation for humeral shaft fractures is increasing, despite previous reports of good outcomes with non-operative management, and the rate of using IMN fixation is decreasing, likely due to publications reporting increased complication rates with nail fixation [31,32]. Our study adds that patients undergoing nail fixation are more likely to be older patients with more comorbidities. These patients undergoing nail fixation are also more likely to be incapable of independent living and to have a higher ASA class. It can be inferred that surgeons are electing nail fixation in patients who are at a higher than usual risk of a postoperative complication. The results of our study are consistent with previously published literature supporting a shorter operative time with nail fixation [15–17,33]. The authors suspect that nail fixation has been favored by some surgeons for these reasons, and to decrease blood loss in patients who are older or who are at a higher risk for surgical complications, especially locally at the operative site.

This hypothesis for selecting humeral nail fixation in elderly patients has been suggested by Chen et al in a 2013 study. The authors found that amongst 511 Medicare patients with a mean age of 74 years who were treated surgically for non-pathological humeral shaft fractures, nail fixation was used for 310 patients (61%) [17]. This study also found that nail fixation was associated with decreased operative time (165 min versus 138 min for plate versus nail fixation, p < 0.0001), which is in agreement with our study.

However, the results of our study also indicate that the mortality rate was significantly greater in the nail fixation group (5.4% versus 0.9%, p < 0.0001), even following propensity score adjustment. It is possible that another factor, for instance, failure to identify all pathologic fractures, may be responsible for this higher mortality rate in the nail fixation group. It should also be considered that despite a decreased operative time in the nail fixation group, this study cannot support the premise that nail fixation is a safer alternative to plate fixation. Although a difference in mortality rate has not been reported in previous literature, other studies are smaller than this present study and may be underpowered to detect such differences [20,21,25].

Current literature remains inconclusive in comparing surgical complications of plate and nail fixation [23,26,34]. When adjusting for the propensity score, our study found no difference in major or minor systemic or local complication rates between plate and nail fixation groups at 30 days post-operatively. Kurup et al. investigated outcomes of 260 patients undergoing either plate or nail fixation using the Cochrane Library, and found that humeral nail fixation was associated with a higher incidence of shoulder impingement and hardware removal [21]. While Changulani et al. also found restricted shoulder motion (abduction) in the nail group of their randomized study of 47 patients, they noted no difference in final American Shoulder and Elbow Surgeons' Score (ASES) after hardware removal (4/23 nail patients) [18]. The same authors also found an increased infection rate in the plate group (20.8% versus 4.5% for plate versus nail fixation, p < 0.05) [18]. In a prospective study of 44 patients randomized to plate or nail fixation, McCormack et al. found higher rates of secondary surgery and complications, especially shoulder impingement, in the nail fixation group [22]. Fan et al found a higher incidence of radial nerve palsy with plating in a study that randomized 60 humeral shaft patients to nail or plate fixation [15]. Notably, there was no difference in incidence of post-operative radial nerve palsy identified in our study, although our study and other recent investigations may be underpowered to detect differences in this complication rate and others [21]. Many studies are limited by a small cohort size or study design, and given the heterogeneity of the results, there is a need for a large, randomized control trial evaluating plate versus nail fixation. It is also probable that

complication patterns with each fixation mode will change with the increased use of minimally invasive techniques and improved methods for hardware insertion [14,35,36].

While recent studies by Zhao et al. and Fan et al. found a shorter LOS for patients managed with intramedullary nail fixation, we did not find any significant difference in LOS or hospital readmission rate between plate and nail fixation, following propensity score adjustment [15,16]. LOS and hospital readmission rate were more influenced by factors such as age, ASA class and patient functional status.

This study is limited by its retrospective nature and the potential errors associated with database studies. As previously noted, it is possible that coding errors or omissions may confound results, or that our study may be insensitive to certain complications, such as radial nerve palsies. Additionally, the data provided by NSQIP does not include any information regarding outcomes after 30 days, which limits our ability to assess union rates, certain complications, and long term functional outcomes. This database is also limited by failure to include injury characteristics, such as specific fracture location, and by inability to assess other factors that may influence surgeons' decisions, such as bone quality.

Conclusions

Despite an association with decreased operative time, nail fixation appears to be associated with a higher mortality rate than plate fixation for low-energy humeral shaft fractures. Given this finding in a large retrospective cohort, the authors suggest that nail fixation may not be the preferred surgical option in more medically complex patients. Prospective clinical studies are required to confirm these findings.

Source of funding

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