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Comparison of direct surgical cost for humeral shaft fracture fixation: open reduction internal fixation versus intramedullary nailing



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Background and/or Hypothesis: Prior literature has supported similar complication rates and outcomes for humeral shaft fractures treated with open reduction internal fixation (ORIF) with a plate/screw construct versus intramedullary nailing (IMN). The purpose of this study is to determine whether surgical encounter total direct costs (SETDCs) differ between ORIF and IMN for these fractures.

Methods: Adult patients (≥ 18 years) treated for isolated humeral shaft fractures by ORIF or IMN between June 18, 2014 and June 17, 2019 at a single tertiary academic center were available for inclusion. SETDCs for ORIF and IMN groups, obtained through our institution's information technology value tool, were adjusted to 2019 US dollars and converted to relative costs per institutional policy. SETDCs for ORIF and IMN were compared using the Wilcoxon rank-sum test.

Results: Demographic factors did not differ between ORIF and IMN cohorts with the exception of age (mean of 18.6 years older for IMN; $P < .001$) and American Society of Anesthesiologist class (higher for IMN; $P < .029$). Substantial cost variation was observed among the 39 included ORIF and 21 IMN cases. Costs pertaining to operating room utilization ($P = .77$), implants ($P = .64$), and the recovery room ($P = .27$) were similar for ORIF and IMN, whereas supply costs were significantly greater for IMN with a median (interquartile range) of 0.21 (0.17 ~ 0.28), more than twice the supply costs of ORIF (0.09 [0.05 ~ 0.13], $P < .001$). The SETDC of IMN was significantly greater than that of ORIF (median [interquartile range]: 1.00 [0.9 to 1.13] vs. 0.83 [0.71–1.05], respectively; $P = .047$).

Discussion and/or Conclusion: Our study found that the SETDC for humeral shaft fracture fixation was greater for IMN than for ORIF, although patient cohorts differed significantly with respect to age and the American Society of Anesthesiologist class. Surgeons should take these findings into consideration when consenting patients with humeral shaft fractures for the appropriate fixation type.

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Humeral shaft fractures account for approximately 3% of all fractures, with an incidence of 13 per 10,000 per year.⁷ The incidence follows a bimodal age distribution, with a peak between 20 and 30 for men and between 60 and 70 for women.³⁰ The incidence rate of humeral shaft fractures has steadily increased and is predicted to continue to increase.²⁰ In addition, surgical management of these fractures has increased over the past several decades.²⁷ Surgical treatment options include plating (open reduction

internal fixation [ORIF]) and intramedullary nailing (IMN).⁹ Previous literature has demonstrated similar complication and union rates between ORIF and IMN for operative management of humeral shaft fractures.^{6,15,34} The literature also supports similar clinical and functional outcomes.^{5,34} What is unclear, however, is how these two fixation methods compare in terms of surgical costs. Given the rise in surgical management of humeral shaft fractures and similar outcomes between the two fixation methods, an analysis of surgical encounter total direct costs (SETDCs) between ORIF and IMN may offer an opportunity for healthcare cost savings in orthopedic surgery.

The primary aim of this study is to determine whether SETDCs differ between ORIF and IMN for the treatment of operative humeral shaft fractures. Our primary null hypothesis is that there is no difference in SETDCs between these fixation types. Our secondary

This work was performed at the University of Utah, Department of Orthopaedics. This study was approved by the Institutional Review Board of the University of Utah.

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aim was to evaluate variation in surgical costs for the treatment of humeral shaft fractures.

Materials and methods

This study was approved by our institutional review board. All adult patients (age ≥ 18 years) undergoing surgical management for humeral shaft fractures by ORIF (CPT 25415) or IMN (Current Procedural Terminology [CPT] 24516) between June 2014 and June 2019 at a single tertiary academic institution were retrospectively reviewed. Patients were identified by CPT code through an electronic search of our institution's electronic data warehouse. Injury and postoperative radiographs were reviewed to ensure the fracture was a displaced humeral diaphyseal fracture with no intra-articular extension (Orthopaedic Trauma Association classification 12A-C including all subgroups).²⁴ Exclusion criteria included patients who underwent any additional simultaneous orthopedic procedure at the time of humeral shaft ORIF or IMN, as this would confound the cost analysis. Patients undergoing prophylactic fixation of impending pathologic fractures were also excluded, but those undergoing fixation of displaced pathologic fractures were not excluded.

Our institution has previously developed a "value-driven outcomes" (VDO) tool that encompasses an item-level database and information technology tools in an effort to collect specific costs and payments of healthcare services.²² Prospectively collected cost and payment data are linked to specific patient encounters including surgical encounters. Cost data can also be broken down into several subcategories: pharmacy, implant, supply, imaging, facility utilization, operating room (OR) utilization, postanesthesia care unit (PACU) utilization, and laboratories. Pharmacy, imaging, and laboratory costs are associated with the hospital stay as a whole with the VDO tool, whereas OR utilization, implant, and supply costs can be linked to the specific surgical encounter. SETDCs do not take into account professional payment costs attributed to the surgical encounter or indirect costs related to time off of work. Given these limitations and the inpatient status of most of our patients, SETDCs were composed of only OR and PACU utilization, imaging, and supply costs. This tool has previously been used to evaluate variation in costs for multiple orthopedic surgeries in which the combination of laboratory, pharmacy, and imaging costs has comprised a relatively small portion of the surgical encounter cost ($< 5\%$).^{16,17,19} Owing to contractual agreements and institutional policies, raw cost data are not permitted to be made public. Therefore, reported costs are relative to the mean SETDC (ie, divided by the mean total direct cost of the entire cohort).

Patient characteristics were summarized, stratified by surgery types (ORIF vs. IMN). Categorical variables were summarized as count (%), and continuous variables were summarized as mean (standard deviation) if normally distributed or median (interquartile range [IQR]) for skewed distributions. We compared categorical variables with surgery types using chi-squared or Fisher's exact tests if any expected counts were less than five and continuous variables using a t-test for normally distributed variables or a Wilcoxon rank-sum test otherwise. We adjusted cost data for inflation using the Personal Consumption Expenditure-Health Price Index to 2019 dollars. Because price index data were not yet available for 2019, we used linear regression with price index data from 2012 to 2018 to impute a value for 2019.² The SETDC of the study cohort was then scaled to have a mean of 1, and the cost of subcategories (OR utilization, supply, implant, and PACU) was also scaled proportionally. We compared SETDCs and subcategory costs between surgery types (IMN vs. ORIF) using Wilcoxon rank-sum tests. We also assessed each demographic and clinical variable for the associated SETDCs, using Spearman's correlation for continuous

variables and Wilcoxon rank-sum tests or Kruskal-Wallis tests for categorical variables. Statistical significance was assessed at the 0.05 level, and all tests were two-tailed.

Results

Of the 377 patients identified by CPT codes 24515 (N = 286) and 24516 (N = 91), 60 patients met inclusion criteria (39 ORIF and 21 IMN). The average age of the patients treated with IMN was significantly greater than those treated with plating (65.6 vs. 47.0, respectively; $P < .0001$). No statistically significant difference was seen between the two fixation methods for sex, body mass index, race, and insurance status (Table I). Surgical encounter data were compared between groups, with differences in surgeon preference for ORIF versus IMN being noted and differences in American Society of Anesthesiologist class with less healthy patients in the IMN group (Table II). However, no differences in distributions of operative or anesthesia times were observed ($P > .99$ and $P = .44$, respectively).

Considerable variation was observed for the SETDCs for treatment of humeral shaft fractures. The relative total cost ranged from 0.38 to 3.82, with a standard deviation of 0.56 and an IQR of 0.74 to 1.11.

Supply costs were significantly greater for IMN with a median (IQR) of 0.21 (0.17 ~ 0.28), more than twice the cost of ORIF 0.09 (0.05 ~ 0.13), $P < .001$. The SETDC of IMN was 20% greater than that of ORIF 1.00 (0.9 ~ 1.13) versus 0.83 (0.71 ~ 1.05), respectively; $P = .047$. The two fixation types did not affect the OR utilization costs, PACU utilization costs, and implant cost subcategories (Table III).

Univariate analysis of the impact of patient and surgical demographics on cost is reported in Table IV. Increased surgical and anesthesia times, as well as inpatient status, were associated with significantly greater costs. Compared with commercial insurance, univariate analysis revealed that surgical encounters associated with Medicare and Medicaid insurance status had statistically significant greater SETDCs, with no observed differences for self-pay, workers' compensation, and other government-sponsored insurance types. Patient demographics (age, sex, body mass index, and race), site location, and pathologic fracture diagnoses did not significantly impact costs.

Table V demonstrates that the SETDC of locking plates was 54% higher than the SETDC of nonlocking plates (median [IQR] 0.88 [0.8, ~ 1.14] vs. 0.57 [0.39 ~ 0.76], respectively; $P = .005$).

Discussion

The main finding of our study is that the SETDC was significantly greater for IMN than for ORIF for the treatment of operative humeral shaft fractures. The importance of determining opportunities for cost savings in orthopedics has increased over the last several decades. Multiple studies have evaluated cost differences between surgical techniques and fixation types for various orthopedic diseases or injuries.^{16-19,23,32} Hageman et al¹³ demonstrated that most surgeons described cost as a very important or somewhat important factor when deciding between two surgeries with equivalent outcomes. Previous literature has also indicated that physician awareness of cost differences for humeral shaft fracture and other fractures significantly impacts the choice of surgical technique and implants used.³³ Our findings demonstrate that the cost of IMN was significantly greater than the cost of ORIF for our study population.

These findings are important in light of previous literature indicating similar outcomes between ORIF and IMN for these fractures. In a randomized controlled trial by Changulani et al,⁵ no significant difference in functional outcomes was observed on the American Shoulder and Elbow Surgeons score between patients treated with ORIF and IMN. In addition, the union rate was similar

Table I
Patient demographics.

Variable	Levels	Open reduction internal fixation (N = 39) (%)	Intramedullary nailing (N = 21) (%)	P value
Age*	Median (IQR)	47.0 (26.8, 57.1)	65.6 (59.3, 69.9)	<.001
Sex†	Male	24 (61.5)	11 (52.4)	.49
BMI‡	Mean (SD)	28.4 (5.1)	29.8 (7.8)	.43
Race/Ethnicity§	White	32 (82.1)	17 (85)	.28
	Hispanic	6 (15.4)	1 (5)	-
	Other	1 (2.6)	2 (10)	-
Insurance§	Commercial	17 (43.6)	10 (47.6)	.17
	Government other	4 (10.3)	1 (4.8)	-
	Medicaid	3 (7.7)	1 (4.8)	-
	Medicare	7 (17.9)	9 (42.9)	-
	Self-pay	4 (10.3)	0 (0)	-
	Workers' compensation	4 (10.3)	0 (0)	-

IQR, interquartile range; SD, standard deviation.

* Based on Kruskal-Wallis test.

† Based on chi-square test.

‡ Based on ANOVA.

§ Based on Fisher's exact test contingency table.

Table II
Surgical encounter demographics.

Variable	Levels	Open reduction internal fixation (N = 39) (%)	Intramedullary nailing (N = 21) (%)	P value
Plate type*	Locking plate	26 (66.7)	-	>.99
	Nonlocking plate	13 (33.3)	-	-
Operating time (min)†	Median (IQR)	176.0 (131.0-225.5)	184.0 (128.0-228.0)	>.99
Anesthesia time (min)†	Median (IQR)	224.0 (151.0-253.5)	186.0 (141.0-256.0)	.44
Surgeon*	A	1 (2.6)	0 (0)	.009
	B	0 (0)	1 (4.8)	-
	C	1 (2.6)	0 (0)	-
	D	1 (2.6)	0 (0)	-
	E	1 (2.6)	0 (0)	-
	F	1 (2.6)	0 (0)	-
	G	1 (2.6)	0 (0)	-
	H	1 (2.6)	0 (0)	-
	I	1 (2.6)	0 (0)	-
	J	0 (0)	2 (9.5)	-
	K	0 (0)	2 (9.5)	-
	L	2 (5.1)	1 (4.8)	-
	M	3 (7.7)	0 (0)	-
	N	0 (0)	5 (23.8)	-
	O	3 (7.7)	3 (14.3)	-
	P	8 (20.5)	1 (4.8)	-
	Q	6 (15.4)	4 (19)	-
R	9 (23.1)	2 (9.5)	-	
ASA class*	1	7 (17.9)	2 (9.5)	.029
	2	20 (51.3)	5 (23.8)	-
	3	8 (20.5)	9 (42.9)	-
	4	3 (7.7)	2 (9.5)	-
	5	1 (2.6)	0 (0)	-
	Unknown	0 (0)	3 (14.3)	-

IQR, interquartile range; ASA, American Society of Anesthesiologist.

* Based on Fisher's exact test contingency tables.

† Based on Kruskal-Wallis test.

Table III
Scaled average cost breakdown.

Cost type	Open reduction internal fixation median (IQR)	Intramedullary nailing median (IQR)	P value
OR utilization	0.37 (0.24-0.52)	0.35 (0.26-0.44)	.774
Supply	0.09 (0.05-0.13)	0.21 (0.17-0.28)	<.001
Implant	0.34 (0.06-0.40)	0.28 (0.10-0.49)	.641
PACU	0.03 (0.00-0.04)	0.03 (0.02-0.05)	.269
Surgical encounter total direct cost	0.83 (0.71-1.05)	1.00 (0.90-1.13)	.047

IQR, interquartile range; OR, operating room; PACU, postanesthesia care unit.

between the two cohorts. The infection rate was found to be higher in the plating group, but range of motion (ROM) restrictions were more prevalent in the IMN group. These findings are further corroborated in the meta-analysis by Kurup et al²¹ – the authors found similar American Shoulder and Elbow Surgeons scores for

both fixation types. Micic et al²⁵ also demonstrated no difference in functional outcomes as measured by the Constant-Murley score and the Disabilities of the Arm, Shoulder, and Hand questionnaire between fixation types. In the randomized controlled trial by Chapman et al⁶ comparing ORIF and IMN, similar nonunion and

Table IV
Univariate analysis of factors that effect total cost variation.

Characteristic	Median	IQR	P value
Age groups			.217*
18-35	0.8	0.8-0.9	-
35-64	0.9	0.5-1.1	-
65+	1.0	0.9-1.1	-
Gender			.244†
Female	1.0	0.8-1.2	-
Male	0.9	0.7-1.1	-
BMI	0.12‡	0.16-0.38	.393§
Race			.207*
White	0.9	0.7-1.1	-
Hispanic	1.1	0.9-1.4	-
Other	0.8	0.8-0.8	-
Insurance			.029*
Commercial	0.9	0.7-1.0	-
Government other	0.9	0.8-1.1	-
Medicaid	1.7	1.3-2.2	-
Medicare	1.0	0.9-1.2	-
Self-pay	0.7	0.5-0.8	-
Workers' compensation	0.8	0.7-0.9	-
Inpatient vs. outpatient			.067†
Outpatient	0.9	0.7-0.9	-
Inpatient	1.0	0.8-1.2	-
Pathologic fracture			.885†
No	0.9	0.7-1.2	-
Yes	0.9	0.8-1.10	-
OR time	0.49†	0.20-0.72	<.001†
Anesthesia time	0.41†	0.14-0.65	.001§
Site			.769†
Ambulatory surgery center	0.9	0.9-1.2	-
Main hospital	0.9	0.7-1.1	-
Fixation type			.047†
Open reduction internal fixation	1.0	0.9-1.1	-
Intramedullary nailing	0.8	0.7-1.1	-
ASA class			.004*
0 to 2	0.8	0.7-1.0	-
3 to 5	1.1	0.9-1.2	-

IQR, interquartile range; OR, operating room; ASA, American Society of Anesthesiologist.

* Kruskal-Wallis.

† Wilcoxon rank-sum.

‡ Spearman's correlation.

§ Spearman's rank correlation.

Table V
Scaled average cost breakdown of locking versus nonlocking plates.

Cost type	Locking median (IQR)	Nonlocking median (IQR)	P value
OR utilization	0.39 (0.28-0.49)	0.27 (0.22-0.56)	.308
Supply	0.10 (0.07-0.15)	0.06 (0.04-0.09)	.010
Implant	0.39 (0.33-0.46)	0.06 (0.06-0.09)	<.001
PACU	0.03 (0.01-0.04)	0.04 (0.00-0.05)	.988
Surgical encounter	0.88 (0.80-1.14)	0.57 (0.39-0.76)	.005
total direct cost			

IQR, interquartile range; OR, operating room; PACU, postanesthesia care unit.

malunion rates were noted. Total complications were nearly identical between the two groups. They did find, however, that patients treated with IMN could expect increased pain and decreased ROM in the shoulder, whereas patients treated with ORIF were more likely to experience increased pain and decreased ROM of the elbow. This finding has been supported by several meta analyses including that by Zhang et al which demonstrated similar infection, non-union, and radial nerve palsy rates between IMN and ORIF. However, shoulder impingement and the rate of reoperation were significantly higher for IMN than than for plating.^{15,35} Given that the literature suggests that outcomes are very similar, if not slightly better for ORIF, the differences in cost may suggest that the value of

performing ORIF is greater than treating humeral shaft fractures with IMN.

A secondary study finding was that substantial variation in costs exists in the surgical treatment of humeral shaft fractures. We found that relative to the mean surgical cost for all included study patients, the standard deviation for cost was substantial (0.55) and the range of surgical encounter costs was wide (0.38 to 3.82). Prior literature has demonstrated that in orthopedics, substantial variation in cost is a common concern in the context of the value of care.^{12,16} Furthermore, it has been shown that although orthopedic surgeons rate cost as an important factor in a patient's care, they have a poor understanding of the factors that affect cost variation and are more likely to underestimate these costs.^{1,26,29,33} Measures to address sources of cost variation may improve the value of treatment for patients.^{3,4,12,16,31} Such efforts could include selecting the less-expensive implant type and manufacturer when possible,^{26,29,33} avoiding unnecessary laboratory and imaging workup,^{11,14,28} preoperative optimization of patients with comorbidities,⁸ and ensuring the minimal length of hospital stay.¹⁴

Limitations of our study deserve mention. Our study is limited by a relatively small sample size. As a result, there was a difference in findings between univariable regression results and results from simple nonparametric statistical tests. Owing to the small sample size, we opted for reporting findings from statistical tests which make fewer assumptions and are likely more reliable. A consequence of this choice was that we were unable to adjust for patient characteristics in our analysis. In addition, our study included patients treated for pathologic fractures, which was exclusively seen in the IMN cohort, consistent with previous literature.^{10,25} It is possible that the treatment of pathologic humeral shaft fractures may be more technically challenging than traumatic fractures and require a longer operative time, thus leading to increased costs. Although treatment groups differed in terms of age, it is unclear how these differences would affect procedural costs. Given that the surgical technique (IMN vs. plating) was based on surgeon preference at our institution rather than fracture pattern, our study was limited in commenting on how fracture patterns would have impacted the total direct cost. It is likely that fixation of comminuted and or open fractures would have increased the operative time and therefore the overall total direct cost. Our study is also limited by differences noted in American Society of Anesthesiologist classes between the two procedures. It is likely that because patients treated with IMN were noted to have had more comorbidities, this could have required greater operative time. The retrospective design of our study makes it susceptible to selection bias. In addition, physician preference of one fixation type over the other was seen in our study, and therefore, it was not possible to statistically control for provider and fixation type. Our study only evaluated costs directly related to the surgical encounter. A comparison of the costs associated with the hospital stay as a whole was not practical given that many of the patients underwent additional procedures and treatments for injuries or complications not related to their humeral shaft fracture. We likewise were unable to evaluate the impact on the cost of factors related to imaging, laboratories, and pharmacy, given that these cost values include all charges related to the entire hospital admission and not the specific surgical encounter. It is unclear if the ability to include these factors would alter our findings significantly. Given that the VDO tool only analyzes costs connected to our institution, we were unable to account for patients who may have sought care elsewhere. Therefore, factors of the cost related to the preoperative and postoperative management were not conducted. Finally, our study is not a cost-effectiveness analysis and does not take into account factors related to long-term outcomes such as return to work and the effect of less-favorable health states attributed to complications.

Conclusion

In conclusion, our study also demonstrated that a large variation in costs exists in the operative treatment of humeral shaft fractures. Our study also demonstrated that operative humeral shaft fractures treated with IMN had a total direct cost significantly higher than patients treated with ORIF. In light of these results and prior literature demonstrating similar outcomes, ORIF may be expected to yield greater value (unit of outcome per unit of cost) than IMN for patients with operative humeral shaft fractures. Based on these results, this is an area where significant cost savings could be seen in the healthcare setting by treating operative humeral shaft fractures with ORIF rather than IMN when either procedure may be indicated. However, factors not measured by our study including surgeon familiarity with their technique of choice, and potential for decreased outcomes secondary to chronic shoulder pain, should be considered when indicating operative patients for ORIF or IMN of novel instrumentation for the preparation and insertion of bone grafts during reverse shoulder arthroplasty.

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