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A retrospective analysis of functional and radiographic outcomes of humeral shaft fractures treated operatively versus nonoperatively

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A R T I C L E I N F O

Keywords:
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Level of Evidence: Level III; Retrospective Cohort Comparison; Treatment Study

Background: To determine differences in functional outcomes, return to work, and complications, in operatively vs. nonoperatively treated diaphyseal humeral shaft fractures.
Methods: 150 patients who presented to our center with a diaphyseal humeral shaft fracture (Orthopedic Trauma Association type 12) treated by open reduction internal fixation or closed reduction with bracing were retrospectively reviewed. Data collected included patient demographics, injury information, surgical details, and employment data. Clinical, radiographic, and patient-reported functional outcomes were recorded at routine standard-of-care follow-ups. Complications were recorded. Outcomes were analyzed using standard statistical methods and compared.
Results: 150 patients with a mean 24.4 months of follow-up (12 to 60 months) were included for analysis. 83 (55.3%) patients were treated with nonoperative care in a functional brace. The rest were treated surgically. The mean time to healing did not differ between the cohorts ($P > .05$). Patients treated operatively recovered faster with regards to functional elbow range of motion by 6 weeks ($P = .039$), were more likely to be back at work by 8 weeks after injury ($P = .001$), and demonstrated earlier mean time to return-to-daily activities ($P = .005$). Incidence of nonunion was higher in the nonoperative cohort (10.84% vs. 0%, $P = .031$). Three (4.5%) patients in the operative group developed iatrogenic, postoperative nerve palsy. Two patients in the operative group (4%) had a superficial surgical site infection.
Conclusion: More patients treated surgically had functional range of motion by 6 weeks. Functional gains should be weighed by the patient and surgeon against risk of surgery, nonunion, nerve injury, and infection when considering various treatment options to better accommodate patients' needs.

Diaphyseal humeral fractures account for 1-3% of all fractures, occurring at a rate of 14.5-19 per 100,000 person-years.[1,10,27] Epidemiological studies have demonstrated a bimodal age distribution of these fractures with the first peak in the third decade of life, which are typically high-energy injuries. The second, larger peak is in the seventh decade and most commonly results from low-energy mechanisms in osteoporotic bone.[1]

Historically the majority of humeral shaft fractures have been treated nonoperatively by immobilization in a cast or functional brace.[1,30] In recent years, changing practice patterns, possibly due to patients' desires for quicker recovery and return to preinjury level of function have led to a dramatic rise in the rates of operative management of these fractures.[32] Currently, approximately 50-60% of diaphyseal humerus fractures are treated surgically.[27,32]

The optimal treatment strategy for humeral shaft fractures continues to be debated. Although the vast majority of humeral shaft fractures treated nonoperatively heal uneventfully, successful treatment requires activity restrictions and immobilization in a brace for up to 12 weeks until fracture union.[22] Even though functional bracing allows for an unrestricted range of motion (ROM) of the shoulder and elbow, many patients treated nonoperatively initially have limited mobility secondary to pain and fracture motion. As a result of prolonged bracing, many patients initially experience some degree of functional impairment, particularly loss of shoulder ROM, which can delay recovery of their functional status.[11,25,31] In contrast, operative management enables immediate unrestricted shoulder and elbow ROM as well as earlier progression to full weight bearing. In some cases, immediate weight-bearing may be allowed after surgery. Additionally, the risk of nonunion is higher for fractures treated nonoperatively with rates typically reported between 10-13%; however, rates above 20%

NYU Langone Health Institutioanl Review Board approved this study; Study Number: 06-580.

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have been reported in some case series.[9,17] Nevertheless, operative management carries risks of complications such as fracture-related infection (FRI), implant failure, and radial nerve injury, which may require additional surgery or have drastic long-term deficits.[1,27] Reported rates of iatrogenic radial nerve injury and infection following operative management each approach 3%.[2,29]

Multiple studies, including a meta-analysis, have demonstrated that one-year outcomes are equivalent for operative and nonoperative management in terms of patient-reported outcomes and upper extremity function.[7,8,18,19,27,34] However, operative treatment has been found to be associated with a more rapid recovery compared to functional bracing, with superior functional outcomes until 6 months as well as a lower risk of nonunion.[7,14,19,21] Several studies reported that patients with nonoperatively treated fractures who eventually undergo surgery tend to have worse functional scores compared to patients initially treated surgically.[24,27,28]

Despite the lack of significant long-term functional benefit to date, surgery may result in a more predictable recovery course and faster functional gain compared to nonoperative treatment.[21,27] The potential of early mobilization and quicker return to function could be a tremendous benefit for certain patient populations such as elderly patients who require assistive devices to ambulate, as well as younger patients to enable earlier return to work. Therefore, it is essential to understand how operative fixation may impact a patient's unique recovery course and goals when counseling them in the office regarding management strategies.

The purpose of this study was to determine the differences in short-term functional outcomes, return to work, and complications, in two cohorts of patients with humeral shaft fractures (Orthopedic Trauma Association [OTA] type 12), who underwent operative versus nonoperative treatment.

Methods

This was an institutional review board approved review of a consecutive series of patients with diaphyseal humeral shaft (OTA type 12) fractures presenting to a multicenter academic medical system between January 1, 2010, and July 1, 2022. Inclusion criteria were: (1) open or closed OTA type 12 diaphyseal humeral shaft fracture, (2) treated conservatively with bracing/splinting or an internal fixation implant construct, (3) age 18 years or older. All patients were treated for their fractures by the same team of fellowship-trained traumatologists (n = 7). Patients who had undergone treatment for a humeral shaft fracture at another institution and presented at our outpatient clinics for follow-up were excluded (n = 19). Additionally, patients with incomplete electronic medical records (n = 12) or who did not have a minimum of 12 months follow-up (n = 120) were not included in the study (Fig. 1).

Data extracted included: demographic and baseline health data including age at the time of admission, race, sex, marital status, employment status (including type of work), body mass index, and significant past medical history. Patient injury information was collected including injury laterality, hand dominance, mechanism of injury, and initial soft tissue status (open vs. closed). Radiographs were reviewed and injuries were classified using the OTA fracture system (12A1-3, 12B1-3, or 12C1-3).[20] Surgical data (if applicable) collected included date of operation, type of implant construct, preoperative and postoperative nerve status, American Society of Anesthesiologists score class, and intraoperative complications. For all post-treatment encounters in the outpatient clinic, elbow and shoulder ranges of motion and incidence of complications including nerve palsy, joint contracture, and FRI were recorded. Additionally, the date of return to employment, date of return to full activities, and date of physician-approved lifting of weight-bearing restrictions were also recorded. Radiographs were reviewed to determine the time to radiographic healing utilizing the radiographic humerus union measurement score and development of nonunion.[5] Nonunion was defined as a radiographic humerus union measurement score <10 after 6 months of treatment.

Due to the retrospective nature of the study, nonoperative and postoperative protocols were not standardized. In general, patients were treated on initial presentation with a coaptation splint or immediate Sarmiento brace. If they were managed nonoperatively, patients were placed in a Sarmiento brace to be worn at all times for 2 weeks postinjury (Fig. 2). They were counseled to perform shoulder and elbow ROM as tolerated with formalized PT for the elbow and shoulder and biceps and triceps activation prescribed. The Sarmiento brace was worn continuously for at least 6 weeks, or until the fracture moved as a unit and there was evidence of ongoing healing on radiographs. After 6 weeks, if the fracture moved as a unit, treatment varied by surgeon, but most maintained the Sarmiento brace at least part-time until 3 months postinjury. At all standard follow-up visits (2 and 6 weeks, 3, 6, and 12 months, and any subsequent visits), skin condition and brace compliance were assessed in addition to radiographs and ROM checks, if appropriate. For patients treated operatively (Fig. 3); most patients were placed in a soft dressing and allowed to perform immediate ROM, although some were splinted for two weeks for soft tissue rest before transitioning to ROM of the elbow and shoulder and strengthening as tolerated. Weight-bearing and lifting restrictions were at the treating Orthopedist's discretion, but generally followed radiographic evidence of healing.

Comparative analyses were conducted between the operative and nonoperative groups using Chi-Squared Tests, Independent Sample T-Tests, dichotomous regression analyses, and nonparametric Median tests. For patients that initially were treated conservatively but at a later time point before fracture union elected for operative repair, a "crossover group" was created. The crossover group was analyzed independently from the operative and nonoperative groups using the same statistical tests. Statistical significance was defined as $P \leq .05$. Values are reported as mean ± one standard deviation value or percentages. All statistical analyses were calculated using IBM SPSS Statistics Software Version 25.6 (IBM Corp., Armonk, NY, USA).

Results

150 patients with a mean age of 52.7 year old (19 to 94) who had 24.4 months (12 to 60 months) follow-up and complete radiographic and functional data were included for analysis. Eighty-three (55.3%) patients were treated nonoperatively in a functional brace. Sixty-seven fractures were treated surgically with either a plate and screw construct (N = 60) or an intramedullary nail (IM nail) (N = 7). Mean age ($P = .074$) and body-mass index ($P = .175$) did not differ between the operative and nonoperative cohorts (Table 1). Injury laterality ($P = .282$), OTA fracture subclassification ($P = .157$), and open vs. closed fracture type ($P = .113$) did not differ between cohorts; however, patients presenting with a high energy mechanism of injury were more likely to be treated with operative treatment ($P = .007$) (Table 2). For the operative cohort, there was a mean American Society of Anesthesiologists score of 2.09 (ranging from 1-4).

The mean time to fracture healing did not differ between the operative and nonoperative cohorts (5.8 ± 3.8 months vs. 5.1 ± 2.4 months, $P = .298$). Patients treated operatively were more likely to display functional elbow arc ROM (30°-130°) ($P = .039$) earlier, but this equalized by three months (Table 3). There were 30 (44%) patients employed in the operative group and 44 (53%) patients employed in the nonoperative group. Operatively treated patients were more likely to return to work by 8 weeks than the nonoperative group ($P = .001$) and demonstrated earlier mean time to

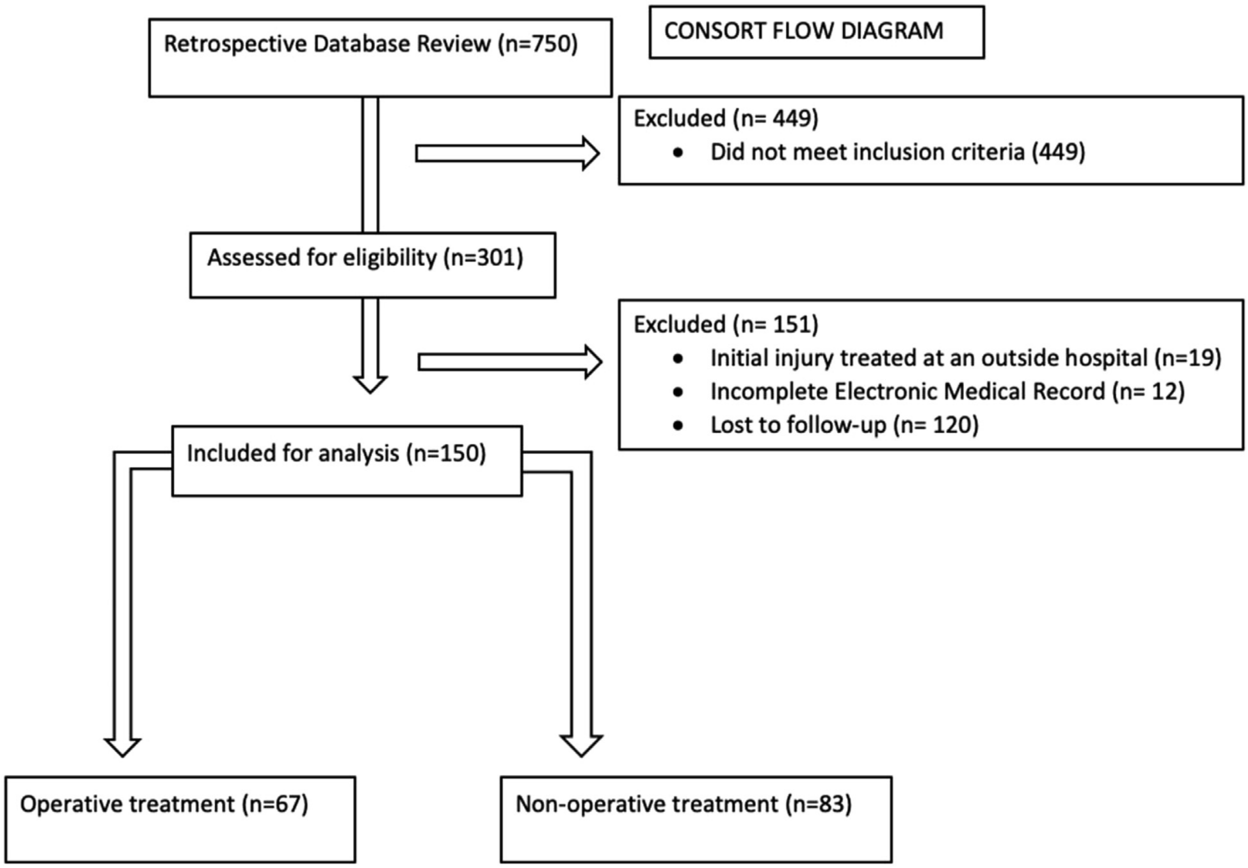

Figure 1 CONSORT Flow Diagram displaying the inclusion and exclusion process.

return-to-daily activities (P = .005) (Table 3). The mean time to return to work was shorter for the operative cohort (7.16 ± 2.97 weeks vs. 10.98 ± 6.39 weeks, P = .033). Additionally, significantly more operative patients demonstrated a return-to-work time (in weeks) below the median than nonoperative patients (Median 7.71, P = .003) The time to lifting of weight-bearing restrictions as directed by the physician did not differ between groups (P = .153) (Table 3). Eight patients (4 operative and 4 nonoperative) filed Workers' Compensation suits; all (100%) of these patients had not returned to work by the 8-week time point. Two patients filed for No-Fault (one op, one nonop) and the operative patient had not returned to work by 8 weeks. Patients that filed Workers' Compensation suits or No Fault were not included in the return-to-work analysis. Employment data was available for 77 patients (Table 1). Of these, 18 patients (23.4%) were employed in jobs that required heavy physical labor and 59 (76.6%) were office workers. There was no significant difference in the proportion of patients treated operatively between the physical labor and office worker groups (38.9% vs. 39.0%, P = .904). However, office workers returned to work significantly earlier compared to the physical labor group (8.8 weeks vs. 15.0 weeks, P = .020)

Incidence of nonunion was higher in the nonoperative cohort (10.84% vs. 0%, P = .031). In a subanalysis of the nonunion patients, the mean time to healing after nonunion surgery was 5.49 ± 2.30 months. Two patients elected nonoperative treatment of their nonunion. Additionally, no patients in the nonoperative cohort developed any skin issues from the bracing protocol.

Seven patients (8.43%) in the nonoperative group elected operative intervention at a mean of 15.04 ± 3.95 weeks after initial injury, prior to fracture union. Reasoning for conversion to operative management included persistent pain and discomfort in the brace (n = 3), concern for developing nonunion (n = 3), and noncompliance with bracing and physical therapy (n = 1). This group was considered our crossover group and was analyzed independently from the operative and nonoperative groups. From time to surgery, this group displayed a mean time to healing of 5.6 ± 3.0 months.

Three (4.48%) patients in the operative group developed iatrogenic, postoperative nerve palsy, from which two (66.6%) resolved and one required a secondary operative intervention (neuroma excision with repair using a sural nerve autograft) to address function. All three patients had eventual full palsy resolution (mean of 15.86 weeks post initial operation). Two patients in the operative group (2.99%) had a suspected FRI; both developed superficial wound dehiscence that resolved with a course of cephalexin and local wound care without subsequent surgery. There were no instances of implant failure in the operative group.

Discussion

The optimal treatment for humeral shaft fractures should focus on individualized patient needs and fracture characteristics. Our goal for this study was to provide data on patient-driven outcome measures to assist surgeons in counseling patients on operative versus nonoperative treatment.

Several recent studies have utilized outcomes scores to define the differences between operative and nonoperative management in humeral shaft fractures. Hartog et al performed a multicenter prospective cohort study on humeral shaft fractures, and found that functional scores and elbow ROM were significantly better in the operative group until 3-6 months post operatively.[7] Ramo et al performed a randomized clinical trial on humeral shaft fractures and found no differences at 1 year, but statistically significant

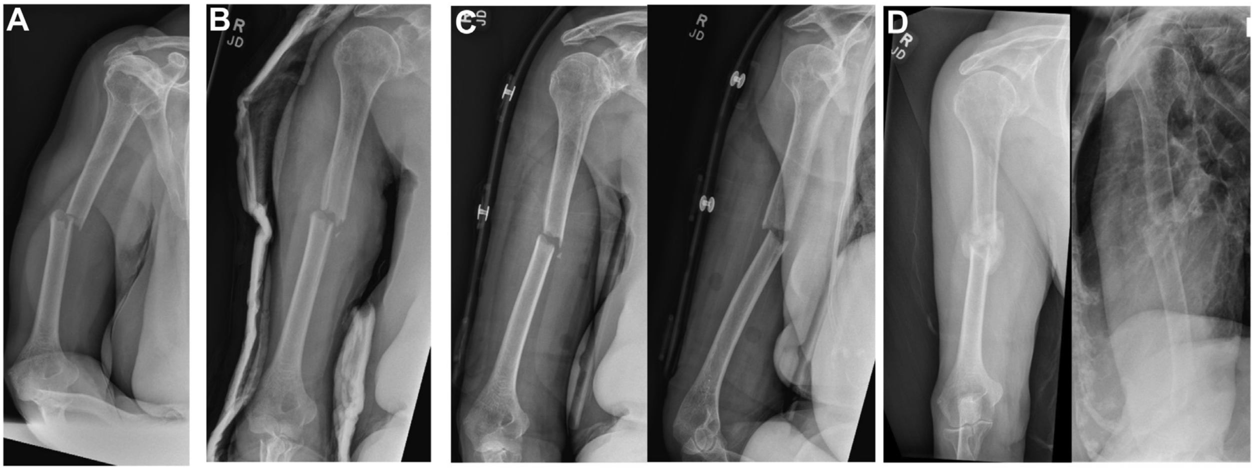

Figure 2 A case of a humeral shaft fracture treated nonoperatively. An 81-year-old female presenting after a mechanical fall found to have a right midshaft humerus fracture, elected to be treated nonoperatively. (**A**) Injury anteroposterior (AP) radiograph, (**B**) Coaptation splinting AP radiograph, (**C**) Transition to a Sarmiento brace at 2 weeks AP and lateral radiograph, (**D**) 4-month postinjury AP and lateral radiographs demonstrating bridging callus formation.

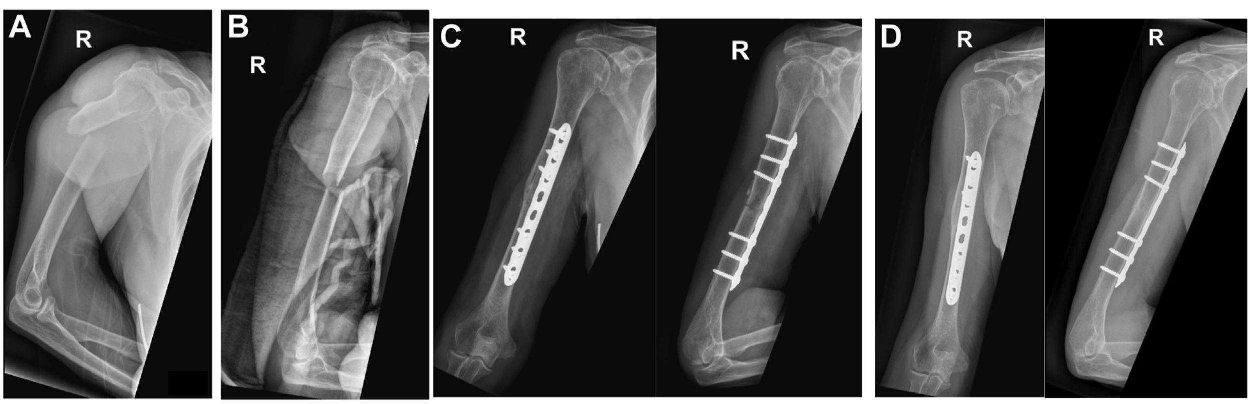

Figure 3 A case of a humeral shaft fracture treated operatively. An 82-year-old female presenting after a mechanical fall found to have a right midshaft humerus fracture, elected for operative management in order to use her walker. (**A**) Injury AP radiograph, (**B**) Coaptation splinting AP radiograph, (**C**) postoperative AP and Lateral radiographs, (**D**) 6-month AP and lateral radiographs demonstrating healed fracture. AP, anteroposterior.

improvements in disabilities of arm, shoulder and hand scores at 3 months post-treatment. They also had a high rate of crossover from bracing to surgery due to adverse events early in treatment.[27] Another prospective study comparing bridge plating to functional bracing demonstrates a significantly different disabilities of arm, shoulder and hand score at 6 months favoring surgery that equalized at 1 year.[19]

The likely reality of improved early functional outcomes with surgical intervention must be weighed against the complications of surgical intervention. It is well documented in the literature that rate of radial nerve palsy with operative intervention of humeral shaft fractures ranges from 3-32%.[3,4,6,12,15,33] Our study aligns with these findings with a radial nerve palsy incidence in our operative group of 4.48%. The rate of recovery of secondary radial nerve palsy reaches up to 93%, but spontaneous recovery can take up to 6 months.[16] In our study, two-thirds of patients had spontaneous recovery of the radial nerve, although one required revision surgery.

FRI is another postoperative consideration that should be considered when deciding between operative and nonoperative management of humeral shaft fractures. Ramo et al in their series of 38 operatively treated humeral shaft fractures, reported a rate of superficial infection of 7%, which is slightly higher than our rate of 3%. All of the patients in their study with a superficial infection were treated successfully with oral antibiotics and local wound care and no further surgical interventions.[27]

Surgical intervention is not without risk. Given the various risk tolerances of patients, it is up to the surgeon to determine how each patient defines an "acceptable risk" for undergoing surgery. The potential functional benefits of operative fixation must then be weighed against the risks of surgery in order to maximize shared decision-making.

Aside from early functional outcomes, the biggest difference in outcomes reported throughout the literature on humeral shaft fractures is the rate of nonunion between surgical intervention and nonoperative care. Established rates of nonunion with nonoperative management of humeral shaft fractures in the literature have been reported to be as high as 33%.[8,13,35,36] Nonunion rates of operative management range from 0-13% (inclusive of plate osteosynthesis and intramedullary nailing).[17] Nonunion with nonoperative management may result in time lost and the need for subsequent surgery. Driesman et al has previously reported gross motion at 6 weeks to be a strong predictor for the development of nonunion.[9] To be truly defined as nonunion, six months of follow-up are necessary, but some surgeons utilize the 6-week time point to begin to counsel patients about the possibility of nonunion and the need for surgery. Many comparative studies of humeral shaft fractures describe a

Table I
Patient demographics.

Demographics	Operative	Nonoperative	*P* value
	n (%)	n (%)	
N	67 (44.7%)	83 (55.3%)	
Variables			
Age (y; mean ± std)	56.40 ± 22.57	49.71 ± 22.75	.074
Body mass index	27.71 ± 7.4	26.04 ± 5.07	.175
Gender			
Male	26 (38.80%)	37 (44.58%)	
Female	41 (61.20%)	46 (55.42%)	
Race			
White	49 (73.13%)	59 (71.08%)	
Black	2 (2.99%)	2 (2.41%)	
Hispanic	1 (1.49%)	0 (0%)	
Asian	6 (8.96%)	6 (7.23%)	
Other	6 (8.96%)	10 (12.05%)	
Unknown	3 (4.47%)	6 (7.23%)	
Employment			
Employed	30 (44.78%)	44* (55.70%)	
Not employed	37 (55.22%)	35* (44.30%)	

*Employment information not provided for four patients in the nonoperative cohort.

crossover group who switch from nonsurgical to surgical treatment before the diagnosis of nonunion. Our study had a crossover group of 8.4%. The crossover group likely encompasses those who are unable to tolerate bracing due to pain or skin compromise, unacceptable fracture reduction parameters, or who have concerns about impending nonunion. For our group of seven patients, three (42.9%) underwent operative repair due to persistent pain in the brace, three (42.9%) due to concern for developing nonunion, and one (14.2%) due to noncompliance with the prescribed Sarmiento brace and physical therapy. The rate of crossover from nonoperative to operative treatment can serve as another discussion point while counseling on treatment options.

While not the primary purpose of this study, Oliver et al argued that surgical treatment of all humeral shaft fractures is a cost-effective option to prevent lost revenue and later medical cost of nonunion treatment following nonoperative care.[23] The decision to operate on humeral diaphysis fractures is likely more nuanced than this blanket statement, and each patient and surgeon needs to weigh the risks of operative management against the risks of nonoperative management in the context of the patient's occupation and medical comorbidities. Of note, Oliver's group also found that patients requiring nonunion surgery were less satisfied than their counterparts who healed with initial surgical or nonsurgical treatment.[24] Therefore, nonunion tolerance should be a critical discussion point when discussing management strategies.

Like most fractures, humeral shaft fractures occur in a bimodal distribution typically affecting a young, healthy, high-energy cohort and an older, lower-energy, osteoporotic cohort. Shared patient decision-making for these two groups may consider different factors to guide treatment. For the young, healthy patient, factors to consider include desire to return to work and lost revenue, as well as low general risk of surgery weighed against the risk of radial nerve palsy. For the geriatric patient, the conversation is more complex. Geriatric patients often have more medical comorbidities, potentially increasing surgical complication risk, and may not have the need to return to the workforce quickly or at all. However, some authors have suggested that advancing age may be an independent risk factor for nonunion, which should also factor into the discussion.[26] Especially since nonunion repair is often a more involved procedure than acute open reduction, internal fixation. Furthermore, geriatric patients may require assistive devices for ambulation, and early operative intervention may allow for earlier weight bearing and return to independence.

Table II
Injury characteristics of diaphyseal humeral shaft fractures.

Injury characteristics	Operative	Nonoperative	*P* value
	n (%)	n (%)	
N	67 (44.7%)	83 (55.3%)	
Injury laterality			.282
Left	39 (58.21%)	41 (49.40%)	
Right	28 (41.49%)	42 (50.60%)	
OA/OTA fracture classification			.157
12A	33 (49.25%)	53 (63.86%)	
12B	26 (38.81%)	25 (30.12%)	
12C	8 (11.94%)	5 (6.02%)	
Energy mechanism			**.007**
High	11 (16.42%)	3 (3.61%)	
Low	56 (83.58%)	80 (96.39%)	
Injury type			.113
Open	2 (2.99%)	0 (0%)	
Closed	65 (97.01%)	83 (100%)	

AO/OTA, Arbeitsgemeinschaft für Osteosynthesefragen/Orthopedic Trauma Association.
High energy mechanisms were more likely to be treated operatively, but otherwise, there were no significant differences between the cohorts.
Bold indicates *P* value is significant (< .05).

Table III
Outcomes comparing operative to nonoperative management of humeral shaft fractures.

Outcomes	Operative	Nonoperative	*P* value
	n (%)	n (%)	
N	67 (44.7%)	83 (55.3%)	
Events			
Fracture related infection	2 (2.99%)	0 (0%)	**.041**
Nonunion	0 (0%)	9 (10.84%)	**.031**
Postoperative nerve palsy	3 (4.48%)	N/A	
# of revisions/other procedures	0.06 ± 0.32	0.19 ± 0.42	**.041**
Healing			
Time to healing (mo)	5.8 ± 3.8	5.1 ± 2.4	.298
Functional elbow ROM by 6 weeks	17 (25.37%)	12 (14.46%)	**.039**
Functional elbow ROM by 3 mo	31 (46.27%)	44 (53.01%)	.282
# return to work by 8 weeks	14 (46.67%)*	5 (11.26%)*	**.001**
# below median return to work time	12 (40.00%)*	5 (11.26%)*	**.003**
Time to return to work (weeks)	7.16 ± 2.97	10.98 ± 6.39	**.033**
Time to restrictions lifted (weeks)	13.16 ± 7.18	16.22 ± 9.98	.153
Time to full activities (weeks)	15.25 ± 10.12	22.5 ± 14.75	**.005**

ROM, range of motion.
*Bold indicates *P* value is significant (< .05).
Percentage calculated from employed patients.

Finally, skin checks remain paramount when treating humeral shaft fractures nonoperatively in the elderly. The surgeon and patient must, therefore, weigh several critical factors when deciding on the best course of action.

Our study has several limitations, primarily related to the retrospective nature of the work. As the patients were not prospectively allocated to cohorts, there may have been several factors confounding the treatment group which were not captured in our data. Most importantly, the decision to return to work is multifactorial, and strictly comparing operative vs. nonoperative groups may be too reductive. Finally, as the study was retrospective, treatment protocols were not standardized across patients and surgeons which may lead to heterogeneity in the results. However, as our data is similar to that previously reported in the literature regarding several key outcome measures, and includes patients from multiple, fellowship-trained orthopedic traumatologists, it remains relevant to the discussion and incorporates information that may drive decision-making in a standard orthopedic practice.

Conclusion

Shared decision-making is paramount in the management of humeral shaft fractures. This study enumerates patient-driven outcomes between operative and nonoperative management of humeral shaft fractures to create a framework to guide decision-making. Operative management leads to a lower risk of nonunion, early functional gains, and ability to return to work and/or utilize assistive devices; however, these early benefits were seen only at 6 weeks and leveled out within three months of injury. These very early functional improvements must be weighed against the risks of operative management including: iatrogenic radial nerve palsy, FRI, and risks of undergoing anesthesia. Utilizing these parameters, the surgeon and patient can best determine the appropriate treatment for their unique circumstance in a “shared decision-making” paradigm.

Disclaimers:

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