Race and gender influence management of humerus shaft fractures.

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INTRODUCTION

Racial, gender, and insurance disparities have been discovered in access to, treatments, and outcomes within several fields of medicine and surgery. Studies have concluded that blacks have worse outcomes than whites, including survival rates in endometrial cancer (1), risk of death from end-stage renal disease in lupus nephritis (2), and risk of in-hospital mortality after lobectomy for lung cancer (3). Additional studies (4,5) have reported a racial disparity in accessing healthcare, including lower rates of shoulder and knee arthroplasty in blacks compared to whites. Access and outcomes have been reported to be worse for uninsured patients as well: in one study, uninsured status was independently associated with advanced stage cancer and the risk of death from cancer (6). Gender biases have also been shown to exist in multiple settings, including the observations that pediatric females are half as likely as males to receive growth hormone treatment for short stature, and females are less likely than men to be recommended physiotherapy and radiographs for chronic musculoskeletal pain (7,8).

Disparities exist in the trauma setting as well. A recent study showed that blacks are at greater odds of receiving an amputation after lower extremity fracture than whites (9). Being uninsured is an independent risk factor for mortality after trauma (10), and uninsured trauma patients receive fewer diagnostic tests and procedures (11).

One specific orthopaedic injury that often generates debate and research around its management is a humerus shaft fracture (HSF), corresponding to OTA/AO fracture classification 12-A, 12-B, and 12-C (12). Non-operative treatment options include immobilization with a sling, coaptation splint, hanging arm cast, or functional bracing (13,14). Sarmiento, et al. (15) have demonstrated excellent outcomes in HSFs managed non-operatively with functional bracing. Operative treatment can consist of external fixation, or internal fixation via plating or intramedullary nailing (16,17). Surgical treatment allows immediate weight bearing through the operative arm. Therefore, polytrauma has been proposed as a relative indication for surgical management of HSFs (16, 18-21).

A HSF requires acute attention, and multiple management options without clearly defined surgical indications create a confluence of factors that ultimately are subject to potential biases in decision making. The primary purpose of this study was to identify how race, gender, and insurance status affect management of HSFs in the adult trauma population. This population, which gains access to healthcare via the trauma system, was selected because it eliminates access to care as a confounding variable contributing to a potential treatment disparity. It consists of polytraumatized patients and does not reflect the typical population that suffers a HSF as an isolated injury that is managed either non-operatively or with outpatient surgery. Our hypothesis was that black patients, females, and the uninsured receive surgery less often than their white, male, and insured counterparts.

MATERIALS AND METHODS

The National Trauma Data Bank (NTDB) (22), years 2007-2012, was used for this retrospective cross-sectional study. Maintained by the American College of Surgeons, it is the largest aggregation of United States trauma registry data, containing standardized data from each trauma patient admission (demographics, diagnoses, procedures, outcomes, etc.) submitted from over 900 U.S. trauma centers of all levels of designation. The NTDB is compliant with the Health Insurance and Portability Accountability Act and contains only de-identified patient information. An IRB waiver was obtained for this study. There was no external source of funding.

The NTDB was queried and statistical analysis was performed with SPSS (IBM SPSS Statistics for Windows, Version 22.0; Armonk, NY). Race was reported as white, black, Asian, American Indian, Hawaiian, or other. Diagnoses and procedures were identified using International Classification of Diseases, 9^{th} revision, diagnosis codes and procedure codes (Table 1). Nine fracture types (hip, femoral shaft, distal femur, patella, proximal tibia, tibia shaft, ankle, talus, and calcaneus) were included as lower extremity fractures because, as prior literature has established (16, 18-21), they are fractures that would most likely prompt restrictions in weight bearing or range of motion, and thus affect mobilization and rehabilitation potential so as to influence a surgeon's decision to treat a HSF surgically. Patients were defined as insured if they had private or government insurance (Medicaid, Medicare, private/commercial insurance, Blue Cross/Blue Shield, no fault automobile, workers' compensation), and patients were defined as uninsured if they were classified as self-pay or uninsured. Patients aged <18 years were excluded due to differing considerations for fracture management in this age group.

An *a priori* list of baseline covariates (age, gender, Injury Severity Score [ISS], length of stay, facility factors, etc. (Table 2)) was created based on clinical suspicion as potential confounders of the relationship between race, insurance status, presence of lower extremity fracture, and fixation of HSF.

The NTDB contains 4,146,428 unique trauma admissions from years 2007-2012. Of these, 3,468,261 were age ≥18 years. In this age group, 28,020 had a HSF. This original sample was further refined by eliminating patients with missing data to yield a dataset of 20,483 patients with complete data which underwent statistical analysis. The continuous variables length of ICU stay, ISS, and Glasgow Coma Scale (GCS) were first grouped into level, and then separated into corresponding binary variables. ISS was subgrouped into five categories: mild (0-8), moderate

(9-14), serious (15-24), severe (25-39), and critical (40-75). GCS was subgrouped into three categories: mild (13-15), moderate (9-12), and severe (3-8). Shock was defined as presenting systolic blood pressure ≤90 mmHg.

HSF patients in the dataset were cared for at 735 different trauma hospitals ("facilities"), which were subgrouped into 4 volume quartiles. The lowest volume facilities' cumulative coverage amassed approximately 25% of the 20,483 sample patients (5,107 HSFs at 479 facilities that treated ≤11 HSFs/year), and the highest volume facilities' cumulative coverage amassed approximately 25% of the dataset (5,113 HSFs at 23 facilities that treated ≥21.6 HSF/year). The middle 50% was comprised of 10,263 patients (5,119 and 5,144 per quartile) with HSFs (52 and 48 facilities, respectively, that treated between 11 and 21.6 HSFs/year).

Multivariate logistic regression models were built using various groups of the factors identified in Table 2 using SAS (23). The fraction of patients identified as belonging to races "Asian", "Native Hawaiian or Other Pacific Islander", "American Indian", and "Other" was small: 19,818 patients (97%) identified their race as black ("Black or African American") or white ("White"). Hence, the models were built on the subset of these patients, with the focus on differences between black and white races and other covariates. A variable of ethnicity, separate from race, included values of "Hispanic or Latino" or "Not Hispanic or Latino" and was not included in the analysis. Independent of the logistic regression models, each variable was also analyzed with respect to race. The p-value was derived from a standard chi-squared test for difference in proportions, with $p < 0.05$ considered significant.

RESULTS

The overall chi-squared p-value of the logistic regression model was significant with an Area Under the Curve (AUC, c-statistic) of 0.662, indicating there was a significant relationship between surgical management of HSFs and the group of variables included in the model (Table 3) (24).

As indicated by the variables with zeroed entries for estimates of the regression coefficients, we chose the most common effects to set the base patient for this model as an insured, white male treated at a low volume, Level 1 facility in the South, with a mild ISS and GCS, along with all other binary variables set to their zero values and continuous variables set to their respective medians. Of particular interest was the significant nature of the Race Black variable, the term capturing its interaction with gender, and the associated conditional effects in the presence of the other significant confounding factors. This is evidence that race was a statistically significant variable in the prediction of surgical management of HSFs.

As we found the variable of race significant, we then analyzed the racial disparity by gender with incorporation of the variable "Gender by Race Black" into the model. Its significant nature suggests that the variable of gender interacts with race when predicting surgical management of HSFs. Turning then to the conditional terms, we found that the data did not support a statistically significant difference between treatment of white versus black females or between female and male blacks. However, there was a significant difference between treatment of black versus white males (OR 0.73, 95% CI 0.66-0.81, $p<0.001$), and female and male whites (OR 0.85, 95% CI 0.80-0.91, $p<0.001$). Amongst blacks, there was no significant gender disparity. There was no evidence to support a significant difference in treatment between insured and uninsured patients.

Of secondary interest, the regression analysis found other negative predictors of surgical management of HSFs: ISS critical (OR 0.43, 95% CI 0.36-0.52, $p<0.001$), ISS severe (OR 0.76, 95% CI 0.67-0.86, $p<0.001$), and GCS severe (OR 0.47, 95% CI 0.41-0.53, $p<0.001$). Positive predictors of surgical management of HSFs included length of stay (OR 1.04, 95% CI 1.04-1.04, $p<0.001$), ICU admission (OR 1.36, 95% CI 1.25-1.48, $p<0.001$), and presence of concomitant lower extremity fracture (OR 1.61, 95% CI 1.49-1.74, $p<0.001$).

DISCUSSION

Equal and equitable delivery of healthcare for all is an important societal goal. This is true for elective and nonurgent medical treatment and certainly true for delivering care to trauma patients. Using a large national database, we examined three factors that often are associated with disparity in healthcare delivery: race, gender, and insurance.

We found that blacks and females has lower odds of receiving surgical treatment than white males, whereas insurance status was not significant. Because black patients on average sustained a higher ISS score and higher rates of concomitant lower extremity fracture, their expected rate of fracture fixation would be higher than the absolute difference of 3% compared to white patients. Multivariate analysis demonstrated that there was indeed a large difference, with odds ratio of 0.73 for black male patients compared to their white male counterparts. Similarly, amongst white patients, the odds ratio for females receiving surgical treatment was 0.85 compared to males.

HSFs are an ideal fracture to examine when looking for possible disparity in treatment as they account for 1–3% of all fractures (25), thus allowing for large sample sizes. Our study group included more than 20,000 patients with HSF. Additionally, the fracture is amenable to many options of treatment, both surgical and nonsurgical. Therefore, decision to treat surgically is not uniformly applied.

One limitation of this study was that the cohort was not the standard humeral diaphyseal fracture population, which consists of patients who don't enter the trauma system and are managed non-operatively as outpatients. As such, the conclusions are not generalizable to that typical HSF population. This study's purpose was to examine differences in management of patients whose care is not dictated by access and who have an injury with arguable indications for surgical treatment. Whereas this study's conclusions do not apply to management of HSF in all patients, they do apply to the adult trauma population in a setting where several factors of the patient, surgeon, facility, region, or injury type, including unconscious or unrecognized biases, influence treatment decisions.

This study is subject to the usual limitations of database analyses. Selection bias exists because NTDB data are submitted voluntarily from hospitals that may not be representative of all hospitals. Trauma cases not admitted to the hospital (i.e., patients who die prior to arrival) may skew the selection of data that is reported, though this number is likely small. Analyses are subject to bias when missing data are ignored. Information bias exists, and though data is reported from hospitals in a standardized fashion, there may be differences in the way that data is collected, interpreted, coded, and reported to the NTDB. However, the methods of data filtering we used, as described above, resulted in our ability to use only cases with complete and explicit data, which comprised 73% of all available patients with HSFs. The NTDB is not a population-based dataset and is not representative of all trauma hospitals in the U.S. However, this is the largest trauma database available and thus the most generalizable to the U.S. population.

Other limitations result from the interpretation of the data itself. This database only collects data during initial hospitalization and will miss all HSF surgeries that were performed after discharge. It is unknown how frequently HSFs are treated surgically post-hospitalization, though the authors hypothesize the rate is low in the polytraumatized patient. Length of stay may be affected by surgical management of HSFs, as patients who are hospitalized longer may have higher rates of surgery during initial hospitalization and not during a subsequent outpatient surgery. Conversely, surgery may affect length of stay, as those receiving surgery may require longer hospitalization due to post-surgical needs. The higher levels of polytrauma as indicated by the variables ISS, GCS, shock, ICU admission, and lower extremity fracture may skew the treatment decision of HSFs in a negative direction, as increasingly severe or unstable injuries may be a factor in the surgeon's decision-making towards non-operative management. However, given that critical ISS (40-75) and severe GCS (3-8) represented a minority of patients (4% and 8%, respectively), this group of critically polytraumatized patients is not felt to meaningfully impact overall treatment trends. Additionally, the database does not capture the fracture type or severity (i.e. simple transverse, long oblique, comminution) of the HSF, which is an important factor in the treatment algorithm. Finally, the database poorly reports patient comorbidities, which are important considerations when considering any surgery. We were unable to control for this potentially confounding factor, though given that the median age in years for blacks was 37 and for whites was 51, it can be reasonably assumed that if medical comorbidities were to negatively influence decision for surgery in any group, it would likely be the cohort of older patients (whites) which, in fact, still had higher odds of surgery.

A 2016 poll (26) demonstrated the existence of biases within Orthopaedic Surgery: 50% of orthopaedic surgeons admitted biases towards specific groups of patients, and of those, 16% of males and 14% of females admitted race was a patient factor that triggered bias. Furthermore, 11% of all orthopaedic surgeons indicated bias affects their treatment of patients. Researchers have increasingly attempted to understand the complex relationship between disparities and biases, and quantify their manifestations within healthcare. Whereas prior studies reported worse outcomes and diminished access to healthcare for blacks compared to whites, this study eliminates access as an issue as the patients are trauma patients who have entered the system. Rather, the issue is solely the management of an acute orthopaedic injury with wide and varied indications for operative and non-operative management. This study demonstrates that disparity related to race and gender exists in orthopaedic care of HSFs. Given the variable indications, and paucity of cases with absolute indications for surgery (i.e., associated vascular injury, floating elbow, etc.), a surgeon can make arguments for or against operative treatment in a majority of cases. Therefore, the disparity may reflect bias in the decision-making process within the treating team.

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Table 1: International Classification of Diseases, 9th revision, diagnosis and procedure codes

Humerus fracture	ICD-9 diagnosis code
Fracture of shaft of humerus, closed	812.21
Fracture of shaft of humerus, open	812.31
Humerus surgical procedure	**ICD-9 procedure code**
Application external fixator, humerus	78.12
Other repair or plastic operations on bone, humerus	78.42
Internal fixation of bone without fracture manipulation, humerus	78.52
Closed reduction of fracture with internal fixation, humerus	79.11
Open reduction internal fixation, humerus	79.31
Unspecified operation on bone injury, humerus	79.91
Hip fracture	**ICD-9 diagnosis code**
Fracture of unspecified intracapsular femoral neck, closed	820.00
Fracture of epiphysis of femoral neck, closed	820.01
Fracture of midcervical femoral neck, closed	820.02
Fracture of base of femoral neck, closed	820.03
Other transcervical femoral neck fracture, closed	820.09
Fracture of unspecified intracapsular femoral neck, open	820.10
Fracture of epiphysis of femoral neck, open	820.11
Fracture of midcervical femoral neck, open	820.12
Fracture of base of femoral neck, open	820.13
Other transcervical femoral neck fracture, open	820.19
Fracture of unspecified trochanteric section of femur, closed	820.20
Fracture of intertrochanteric section of femur, closed	820.21
Fracture of subtrochanteric section of femur, closed	820.22
Fracture of unspecified trochanteric section of femur, open	820.30
Fracture of intertrochanteric section of femur, open	820.31
Fracture of subtrochanteric section of femur, open	820.32
Fracture of unspecified part of femoral neck, closed	820.8
Fracture of unspecified part of femoral neck, open	820.9
Femur shaft fracture	**ICD-9 diagnosis code**
Fracture of shaft of femur, closed	821.01
Fracture of shaft of femur, open	821.11
Fractures about the knee	**ICD-9 diagnosis code**
Fracture of lower end of femur, unspecified part, closed	820.20
Fracture of femoral condyle, closed	821.21
Fracture of lower epiphysis of femur, closed	821.22
Supracondylar fracture of femur, closed	821.23
Other fracture of lower end of femur, closed	821.29
Fracture of lower end of femur, unspecified part, open	821.30
Fracture of femoral condyle, open	821.31
Fracture of lower epiphysis of femur, open	821.32
Supracondylar fracture of femur, open	821.33

Other fracture of lower end of femur, open	821.39
Fracture of patella, closed	822.0
Fracture of patella, open	822.1
Fracture of upper end of tibia, closed	823.00
Fracture of upper end of tibia with fibula, closed	823.02
Fracture of upper end of tibia, open	823.10
Fracture of upper end of tibia with fibula, open	823.12
Tibia shaft fracture	**ICD-9 diagnosis code**
Fracture of shaft of tibia, closed	823.20
Fracture of shaft of tibia with fibula, closed	823.22
Fracture of shaft of tibia, open	823.30
Fracture of shaft of tibia with fibula, open	823.32
Ankle fracture	**ICD-9 diagnosis code**
Fracture of medial malleolus, closed	824.0
Fracture of medial malleolus, open	824.1
Fracture of lateral malleolus, closed	824.2
Fracture of lateral malleolus, open	824.3
Fracture of bimalleolar, closed	824.4
Fracture of bimalleolar, open	824.5
Fracture of trimalleolar, closed	824.6
Fracture of trimalleolar, open	824.7
Unspecified ankle fracture, closed	824.8
Unspecified ankle fracture, open	824.9
Hindfoot fracture	**ICD-9 diagnosis code**
Fracture of calcaneus, closed	825.0
Fracture of calcaneus, open	825.1
Fracture of talus, closed	825.21
Fracture of talus, open	825.31

Table 2: Cohort of patients with humeral shaft fractures identifying as black or white

	Black		White		p-value	Odds Ratio
	n		n			
Humerus shaft fractures (HSF)	3491		16327			
Fractures treated surgically	1867	53.5%	9077	55.6%	0.011	0.92
Demographic characteristics						
Age, median		37.3 yrs		51.0 yrs	<0.001	
Sex, male	2344	67.4%	8205	50.3%	<0.001	2.02
Work Related	2853	81.7%	13877	85.0%	<0.001	0.79
Alcohol Use	457	13.1%	1656	10.1%	<0.001	1.33
Drug Use	633	18.1%	1494	9.2%	<0.001	2.20
Median Injury Severity ISS Score		10		9	<0.001	
Mild (0-8)	957	27.4%	6373	39.0%	<0.001	0.59
Moderate (9-14)	1286	36.8%	4959	30.4%	<0.001	1.34
Serious (15-24)	616	17.7%	2485	15.2%	<0.001	1.19
Severe (25-39)	467	13.4%	1814	11.1%	<0.001	1.24
Critical (40-75)	165	4.7%	696	4.3%	0.111	-
Glascow Coma Scale						
Mild (13-15)	3073	88.0%	14686	90.0%	<0.001	0.82
Moderate (9-12)	114	3.3%	347	2.1%	<0.001	1.55
Severe (3-8)	304	8.7%	1294	7.9%	0.062	-
Admitted to ICU	1361	39.0%	5383	33.0%	<0.001	1.30
ICU length of stay, median		0 days		0 days		
Length of stay, median		6 days		5 days	<0.001	
Facility trauma level designation						
I	2688	77.0%	10014	61.3%	<0.001	2.11
II	712	20.4%	5047	30.9%	<0.001	0.57
III	75	2.2%	1141	7.0%	<0.001	0.29
IV	16	0.5%	125	0.8%	0.025	0.60
Facility volume of HSF treated						
Highest quartile (>130 HSF per year)	1130	32.4%	3868	23.7%	<0.001	1.54
Middle 50% (11-130 HSF per year)	1701	48.7%	8181	50.1%	0.069	-
Lowest quartile (<11 HSF per year)	660	18.9%	4278	26.2%	<0.001	0.66
Region						
West	240	6.9%	2930	18.0%	<0.001	0.34
Midwest	894	25.6%	4774	29.2%	<0.001	0.83
North East	399	11.4%	2450	15.0%	<0.001	0.73
South	1958	56.1%	6173	37.8%	<0.001	2.10
Concomitant lower extremity fracture	879	25.2%	3426	21.0%	<0.001	1.27
Presented in shock	163	4.7%	542	3.3%	<0.001	1.43
Insured	1922	55.1%	11970	73.3%	<0.001	0.31

Table 3: Factors influencing surgical management of humeral shaft fractures

Effect	Estimate	Odds Ratio	95% Confidence Interval	p-value
Intercept	-0.8668	-	-	<0.001
Gender Female	-0.1589	0.853	0.799-0.911	<0.001
Race Black	-0.310	0.733	0.644-0.809	<0.001
Facility volume				
1 (low)	0.000	Reference	-	
2	0.333	1.396	1.276-1.527	<0.001
3	0.4660	1.594	1.443-1.760	<0.001
4 (high)	0.507	1.661	1.490-1.851	<0.001
Facility trauma level designation				
I	0.000	Reference	-	-
II	0.227	1.255	1.156-1.361	<0.001
III	-0.214	0.807	0.698-0.933	<0.001
IV	0.178	1.195	0.845-1.690	0.314
Region				
MidWest	-0.036	0.964	0.895-1.039	0.340
NorthEast	-0.120	0.887	0.807-0.975	0.013
West	-0.079	0.924	0.846-1.009	0.078
South	0.000	Reference	-	-
Median Injury Severity ISS Score				
Mild	0.000	Reference	-	-
Moderate	-0.041	0.960	0.891-1.033	0.276
Serious	-0.074	0.928	0.838-1.029	0.157
Severe	-0.027	0.760	0.670-0.862	<0.001
Critical	-0.835	0.434	0.361-0.522	<0.001
Glascow Coma Scale				
Mild	0.000	Reference	-	-
Moderate	-0.235	0.791	0.644-0.971	0.025
Severe	-0.761	0.467	0.410-0.533	<0.001
Race and gender relationships				
Gender by Race Black	0.267	-	-	0.001
Gender Female given Race is Black	-	1.115	0.961-1.293	0.151
Gender Female given Race is White	-	0.853	0.799-0.911	<0.001
Race Black given Gender is Female	-	0.958	0.841-1.092	0.522
Race Black given Gender is Male	-	0.733	0.664-0.809	<0.001
Demographic characteristics				
Work Related	0.103	1.109	1.027-1.198	0.008
Alcohol	-0.053	0.949	0.861-1.046	0.290
Drug	0.065	1.067	0.967-1.177	0.196
Insured	0.000	Reference	-	-
Uninsured	0.013	1.013	0.926-1.107	0.784
Length of Stay	0.039	1.040	1.035-1.044	<0.001
Admitted to ICU	0.305	1.357	1.245-1.479	<0.001
Concomitant lower extremity fracture	0.4759	1.609	1.486-1.743	<0.001
Shock	0.306	1.358	1.147-1.609	<0.001