Perioperative morbidity and mortality after lumbar trauma in the elderly

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OBJECT Traumatic fractures of the thoracolumbar spine are common injuries, accounting for approximately 90% of all spinal trauma. Lumbar spine trauma in the elderly is a growing public health problem with relatively little evidence to guide clinical management. The authors sought to characterize the complications, morbidity, and mortality associated with surgical and nonsurgical management in elderly patients with traumatic fractures of the lumbar spine.

METHODS Using the National Sample Program of the National Trauma Data Bank, the authors performed a retrospective analysis of patients ≥ 55 years of age who had traumatic fracture to the lumbar spine. This group was divided into middle-aged (55–69 years) and elderly (≥ 70 years) cohorts. Cohorts were subdivided into nonoperative, vertebroplasty or kyphoplasty, noninstrumented surgery, and instrumented surgery. Univariate and multivariable analyses were used to characterize and identify predictors of medical and surgical complications, mortality, hospital length of stay, ICU length of stay, number of days on ventilator, and hospital discharge in each subgroup. Adjusted odds ratios, mean differences, and associated 95% CIs were reported. Statistical significance was assessed at $p < 0.05$, and the Bonferroni correction for multiple comparisons was applied for each outcome analysis.

RESULTS Between 2003 and 2012, 22,835 people met the inclusion criteria, which represents 94,103 incidents nationally. Analyses revealed a similar medical and surgical complication profile between age groups. The most prevalent medical complications were pneumonia (7.0%), acute respiratory distress syndrome (3.6%), and deep venous thrombosis (3%). Surgical site infections occurred in 6.3% of cases. Instrumented surgery was associated with the highest odds of each complication ($p < 0.001$). The inpatient mortality rate was 6.8% for all subjects. Multivariable analyses demonstrated that age ≥ 70 years was an independent predictor of mortality (OR 3.16, 95% CI 2.77–3.60), whereas instrumented surgery (multivariable OR 0.38, 95% CI 0.28–0.52) and vertebroplasty or kyphoplasty (OR 0.27, 95% CI 0.17–0.45) were associated with decreased odds of death. In surviving patients, both older age (OR 0.32, 95% CI 0.30–0.34) and instrumented fusion (OR 0.37, 95% CI 0.33–0.41) were associated with decreased odds of discharge to home.

CONCLUSIONS The present study confirms that lumbar surgery in the elderly is associated with increased morbidity. In particular, instrumented fusion is associated with perioperative complications, prolonged hospitalization, and a decreased likelihood of being discharged home. However, fusion surgery is also associated with reduced mortality. Age alone should not be an exclusionary factor in identifying surgical candidates for instrumented lumbar spinal fusion. Future studies are needed to confirm these findings.

<http://thejns.org/doi/abs/10.3171/2015.7.FOCUS15270>

KEY WORDS trauma; lumbar spine fracture; elderly; mortality; morbidity

TRAUMATIC thoracolumbar fractures account for roughly 90% of all spinal fractures,^{7,29} with an estimated 160,000 occurring annually in North America alone.²⁹ Across published reports, the annual fracture incidence ranges from 23 to 90 per 100,000 people, and the age distribution is bimodal, with the first peak being

found in young adults between 15 and 29 years of age and the second peak in adults older than 65 years.^{3,4,10,12,23–25,34,40} Factors that make the elderly more susceptible to these fractures include lower bone density,^{20,43} alterations in vertebral biomechanics,^{11,21} and more frequent falls.³⁸ In individuals ≥ 70 years, the annual fracture incidence ex-

ABBREVIATIONS ARDS = acute respiratory distress syndrome; CCI = Charlson Comorbidity Index; ED = emergency department; GCS = Glasgow Coma Scale; HR = hazard ratio; ISS = Injury Severity Score; LOS = length of stay; NSP = National Sample Program; NTDB = National Trauma Data Bank; SBP = systolic blood pressure.

SUBMITTED May 31, 2015. **ACCEPTED** July 14, 2015.

INCLUDE WHEN CITING DOI: 10.3171/2015.7.FOCUS15270.

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ceeds 100 per 100,000 and increases exponentially with each decade thereafter.^{23,42} When trended over time, the incidence of these fractures in the elderly is increasing at a rate that outstrips that which is predicted solely by the aging of the population.^{25,42}

Despite its high incidence and prevalence in the elderly population, little is known about the morbidity, mortality, and complications associated with various management strategies for spinal trauma in this group. Much of the literature for elderly traumatic spine fractures has been confined to the cervical spine. Independent reports have demonstrated a higher rate of medical complications and worse prognosis following traumatic cervical spine injury in the elderly.^{14,32} In the lumbar spine, a single report has identified age < 80 years as a predictor of the level of functioning following thoracolumbar spine fracture.⁴⁴ Bone healing following thoracolumbar compression and/or burst fracture appears to be reduced in the elderly³³ but has yet to be systematically studied.¹⁹ However, the consequences of such findings remain unclear, and the risk profile associated with managing lumbar spine trauma in the elderly has yet to be systematically studied.

Without this evidence, practitioners must base their decisions on a body of literature that pertains to a younger population, since studies of this kind constitute the majority of studies to date. As with all spinal fractures, those within the lumbar spine can take on a variety of patterns¹⁵ and can range from stable to unstable; most fractures therefore have both operative and nonoperative management options.^{1,7,41} The decision to operate is traditionally based on such factors as fracture morphology, integrity of the posterior ligamentous complex, and neurological presentation.^{16,39} For the elderly, however, there must also be a careful consideration of perioperative risk (including preexisting comorbidities, premorbid quality of life, and goals of care) versus potential benefit. This study, the largest of its kind to date, seeks to shed light on the risk and complication profile of this population, thereby informing and optimizing the clinical decision-making process.

To this end, we use the National Sample Program (NSP) of the National Trauma Data Bank (NTDB). The NTDB is a prospective, curated trauma registry with the primary mission of tracking and providing information about trauma care and outcomes. Using these data from the NSP, we performed a retrospective analysis of demographic data, risk factors, management strategies, complications, disposition, and mortality in the elderly population following traumatic lumbar spine fractures that were treated nonoperatively and operatively. For this study, the elderly population was defined as age ≥ 70 years; a second cohort, ages 55–69 years, was also identified for comparative analysis. It is our goal, with this study, to define more clearly the complications, morbidity, and mortality that are associated with lumbar spine fractures and their surgical management in the elderly population.

Methods

In this study, we used the NSP of the NTDB from arrival years 2003 to 2012, obtained through application to the NTDB. The NSP for each year consists of a stratified

sample of 100 NTDB participating hospitals based on US census region, trauma care designation, and NTDB reporting status (<https://www.facs.org/quality-programs/trauma/ntdb/nsp>). Hospitals were drawn by the NTDB from the sampling universe of 453 Level I or II trauma centers by using the probability-proportional-to-size sampling without replacement method of Levy and Lemeshow. The sample size of 100 hospitals was determined in a prior review to represent the national patient distribution. Detailed data qualification, selection, cleaning, and standardization algorithms have been previously reported.³⁷ Because the NTDB sample is a deidentified data set without the 18 Federal Health Insurance Portability and Accountability Act (HIPAA) identifiers, the current study was classified as exempt from institutional review board review.

Data Extraction

Among the 1,499,239 incidents contained in the overall NSP sample, a total of 76,386 patients who sustained a traumatic lumbar spine fracture were extracted using ICD-9 diagnosis codes 805.4 (fracture, lumbar vertebra, closed); 805.5 (fracture, lumbar vertebra, open); 806.4 (closed lumbar fracture, with cord injury); and 806.5 (open lumbar fracture, with cord injury). Patients with age > 89 years (NTDB “AGE” variable coded as “–1”) were recoded as 90 years of age. Patients with age ≥ 55 years with complete gender information were extracted to yield a final sample of 22,835 patients. Demographic and clinical variables of interest were extracted and include race, insurance status, medical history, mechanism of injury, emergency department (ED) systolic blood pressure (SBP), ED Glasgow Coma Scale (GCS) score, Injury Severity Score (ISS), ED disposition, medical complications, operative management, hospital discharge status, hospital length of stay (LOS), days in the ICU, and days on ventilator.³⁷ Medical comorbidities and complications were coded as present/absent, and the Charlson Comorbidity Index (CCI) was calculated using the standard comorbidity weights as previously described.^{8,35,36} For patients undergoing operative management the procedure codes were trichotomized to represent vertebroplasty or kyphoplasty, noninstrumented surgery, and instrumented surgery. Please refer to Table 1 for summary of extracted variables and procedure codes used for subclassification of operative management.

For all outcomes, data that were missing and/or marked as not known or not recorded from the NSP were coded as “unknown.” For the outcome variables, analysis of mortality included all patients with known hospital discharge status ($n = 21,583$). “Hospital discharge to home” analysis was completed in all patients with known hospital discharge status, excluding death ($n = 20,115$). The hospital LOS analysis was completed using all patients with known LOS values ($n = 22,010$). Analysis of ICU days ($n = 8428$) and ventilator days ($n = 7129$) included all patients triaged to ICU or operating room from the ED with non-missing data.

Statistical Analysis

Descriptive variables that are continuous are presented as the mean $\pm$ SD; categorical variables are presented as

TABLE 1. Summary of extracted variables and procedure codes for operative management of traumatic lumbar spine fracture

Variables extracted from the NTDB
Age
Race
Insurance status
Medical history, itemized
Mechanism of injury
ED SBP
ED GCS score
ISS
ED disposition
Medical complications, itemized
Operative management, by procedure code
Hospital LOS
Days in ICU
Days on ventilator
Hospital discharge status
Operative management classification & procedure codes
VP or KP
3.53; repair of vertebral fracture
81.65; percutaneous VP
81.66; KP
Noninstrumented surgery
3.09; other exploration & decompression of spinal canal
3.99; other operation on spinal cord & spinal canal structures
80.5; excision or destruction of intervertebral disc, unspecified
80.51; excision of intervertebral disc
Instrumented surgery
81.04; dorsal & dorsolumbar fusion of the anterior column, anterior technique
81.05; dorsal & dorsolumbar fusion of the posterior column, posterior technique
81.06; lumbar & lumbosacral fusion of the anterior column, anterior technique
81.07; lumbar & lumbosacral fusion of the posterior column, posterior technique
81.08; lumbar & lumbosacral fusion of the anterior column, posterior technique
81.3; refusion of spine, not otherwise specified
81.34; refusion of dorsal & dorsolumbar spine, anterior column, anterior technique
81.35; refusion of dorsal & dorsolumbar spine, posterior column, posterior technique
81.36; refusion of lumbar & lumbosacral spine, anterior column, anterior technique
81.37; refusion of lumbar & lumbosacral spine, posterior column, posterior technique
81.38; refusion of lumbar & lumbosacral spine, anterior column, posterior technique
81.39; refusion of spine, not elsewhere classified
81.62; fusion or refusion of 2–3 vertebrae
81.63; fusion or refusion of 4–8 vertebrae
84.51; insertion of interbody spinal fusion device

KP = kyphoplasty; VP = vertebroplasty.

proportions. Group differences by age cohort (55–69 years or ≥ 70 years) were assessed using ANOVA for continuous variables and Pearson's chi-square test for categorical variables. Univariate analyses were dichotomized by age cohort. Categorical outcomes (complications, mortality, and hospital discharge) were assessed using binary logistic regression; operative management was used as the

predictor. Continuous outcomes (hospital LOS, ICU days, ventilator days) were assessed using linear regression. Univariate analyses with statistically significant associations between operative management and outcome were subsequently corrected for demographic and clinical variables (sex, race, insurance status, mechanism of injury, ED SBP, ED GCS category, ISS stratification, and the CCI)

using multivariable regression. Outcome analyses that survived correction were then entered into a singular multivariable model with age cohort, operative management, and the 8 demographic and clinical variables. For in-hospital complications and each of the 5 outcomes, univariate analyses are reported in text only; multivariable analyses are reported in text and in tabular form. Odds ratios with 95% CIs were reported for all regression models, and the mean increase or decrease in values with 95% CI was reported for all linear regression models. Statistical significance was assessed at $p < 0.05$. The Bonferroni correction for multiple comparisons was applied for each respective analysis, with the threshold p value reported. All analyses were performed using the Statistical Package for Social Sciences (SPSS) software, version 22 (IBM Corp.).

Results

Patient Demographic Data and Injury Characteristics

The NSP contained 1,499,239 patient incidents recorded between 2003 and 2012. Of these, traumatic fracture of the lumbar spine occurred in 76,386 cases, which correspond to roughly 5% of all incidents. Data on individuals ≥ 55 years of age were extracted for the analysis. In total, there were 22,835 patient incidents involving traumatic fracture to the lumbar spine in that age group. After sample weighing to facilitate national estimation, the data were found to represent 305,706 incidents nationally over this 10-year period, and 94,103 incidents nationally in patients ≥ 55 years. The average age of the elderly cohort was 68.1 ± 10.1 years. The group was further subdivided into groups with ages 55–69 years ($n = 13,151$, mean age 61.1 ± 4.3 years; henceforth referred to as the middle-aged cohort) and age ≥ 70 years ($n = 9684$, mean age 78.9 ± 5.7 years; henceforth referred to as the elderly cohort). The patients' race in the study sample was predominately Caucasian (80.4%), and the majority of patients were male (58.3%). Additional descriptive statistics pertaining to the demographic information can be found in Table 1. Statistically significant differences were appreciated among age, sex, race, and insurance status between the middle-aged and elderly cohorts (Table 2).

The studied sample was relatively healthy, with a mean CCI of 0.32 ± 0.86 in the overall population. On average, the elderly cohort had a statistically significantly higher CCI (mean CCI 0.27 ± 0.78 for the middle-aged cohort vs 0.38 ± 0.95 for the elderly cohort, $p < 0.001$). Similarly, the elderly cohort had a statistically higher percentage of patients with osteoporosis and pathological vertebral fracture, but the overall prevalence remained low, as evidenced by 2.3% and 0.4% of patients with osteoporosis and pathological vertebral fracture, respectively. The mean initial GCS score was 14.0 ± 2.9 , while the mean ISS was 14.4 ± 10.5 and the mean SBP was 137.2 ± 32.7 mm Hg, with only 5.5% of patients having hypotension on initial presentation (Table 2). In patients with recorded data, the elderly cohort had a higher mean initial GCS score than the middle-aged cohort (14.2 ± 2.6 vs 13.9 ± 3.1 , $p < 0.001$), attributable to a lower incidence of patients classified in the most severe GCS category (GCS 3–8: 7.4% in the middle-aged cohort, 5.0% in the elderly cohort; $p < 0.001$). On average the $\geq$

70-year-old cohort had a statistically significantly lower ISS when compared with the 55- to 69-year-old cohort, with a greater proportion of individuals with ISS values ranging from 0 to 8 (mean ISS: 15.3 ± 10.4 for patients 55–69 years old vs 13.3 ± 10.1 for those ≥ 70 years old, $p < 0.001$; percentage ISS 0–8: 29.4% for patients 55–69 years old vs 40.8% for those ≥ 70 years old, $p < 0.001$). This may in part be explained by differences in the mechanism of injury between the two cohorts, which demonstrates a larger proportion of falls for those ≥ 70 years old (percentage of falls in 55- to 69-year-old group 31.2% vs 52.9% for those ≥ 70 years).

In the overall study sample, traumatic lumbar spine fractures were managed nonoperatively in 87.2% of cases. A statistically significant higher number of patients were managed nonoperatively in the older cohort (86.5% for the middle-aged cohort vs 88.1% for the elderly cohort, $p < 0.001$) (Table 2, Fig. 1 upper). Of those undergoing operative management, the breakdown by operative techniques was significantly different in the two cohorts. In the middle-aged cohort who underwent operative management, the majority (69.1%) underwent instrumented surgery. In the elderly cohort, the majority (58.5%) were treated with vertebroplasty or kyphoplasty (Fig. 1 lower).

Rates of Medical and Surgical Complications

We next sought to characterize the rates of medical and surgical complications following nonoperative and operative management of traumatic lumbar spine fractures in our two cohorts. The rate of complications was 16.2% and 21.9% for those undergoing nonoperative and operative management, respectively. Overall, the most prevalent medical complications were pneumonia (7.0%), acute respiratory distress syndrome (ARDS) (3.6%), and deep venous thrombosis (3%) (Fig. 2). All additional documented medical complications occurred at a rate less than 1%. In the elderly cohort, a 2-fold increase in the rate of cardiac arrest (0.1% for the middle-aged cohort vs 0.2% for the elderly cohort, $p = 0.003$) and myocardial infarction (0.6% for the middle-aged cohort vs 1.2% for the elderly cohort, $p < 0.001$) was observed when compared with the younger cohort. A similar 1.6-fold increase in the rate of urinary tract infection was observed in those ≥ 70 years of age (1.7% for the middle-aged cohort vs 2.8% for the elderly cohort, $p < 0.001$). A nonstatistically significant trend was observed for a higher rate of unplanned intubations (0.9% for the middle-aged cohort vs 1.2% for the elderly cohort, $p = 0.032$) and a lower rate of deep venous thrombosis (3.3% for the middle-aged cohort vs 2.7% for the elderly cohort, $p = 0.012$) in the elderly cohort, but failed to reach statistical significance after Bonferroni correction. For surgical complications, the rate of surgical site infection and unplanned return to the operating room was 1.5% and 0.2%, respectively. However, the incidence of surgical site infection ranged from 0% to 8% depending on age and operative technique used.

To better understand how operative intervention may influence medical and surgical risk in our population, we examined the influence of operation type on the complication profile. A total of 14 complications were examined for each age cohort, and the Bonferroni threshold was

TABLE 2. Demographic data, injury characteristics, and operations in 22,835 patients ≥ 55 years old with traumatic lumbar spine fracture

Factor	Overall, n = 22,835	Age 55–69 Yrs, n = 13,151	Age ≥ 70 Yrs, n = 9684	p Value
Mean age in yrs (SD)	68.6 (10.1)	61.1 (4.3)	78.9 (5.7)*	<0.001
Sex				
Male	13,316 (58.3%)	8653 (65.8%)	4663 (48.2%)*	<0.001
Female	9519 (41.7%)	4498 (34.2%)	5021 (51.8%)*	
Race				
Caucasian	18,358 (80.4%)	10,452 (79.5%)	8086 (83.5%)*	<0.001
African American/African	1435 (6.3%)	997 (7.6%)	438 (4.5%)*	
Asian	554 (2.4%)	307 (2.3%)	247 (2.6%)	
Other	1178 (5.2%)	779 (5.9%)	399 (4.1%)*	
Unknown	1130 (4.9%)	616 (4.7%)	514 (5.3%)*	
Insurance status				
Self-pay	1111 (4.9%)	941 (7.2%)	170 (1.8%)*	<0.001
Private/commercial	5954 (26.1%)	4576 (34.8%)	1378 (14.2%)*	
Medicare/Medicaid	6682 (29.3%)	2324 (17.7%)	4358 (45.0%)*	
Government/other	1431 (6.3%)	911 (6.9%)	520 (5.4%)*	
Unknown	7657 (33.5%)	4399 (33.4%)	3258 (33.6%)	
Medical comorbidities				
Cardiac	9143 (40.0%)	4505 (34.3%)	4638 (47.9%)	<0.001
CHF	83 (0.4%)	22 (0.2%)	61 (0.6%)	<0.001
Hypertension	8934 (39.1%)	4421 (33.6%)	4513 (46.6%)	<0.001
Myocardial infarction	535 (2.3%)	252 (1.9%)	283 (2.9%)	<0.001
PVD	37 (0.2%)	20 (0.2%)	17 (0.2%)	0.663
Pulmonary				
COPD	132 (0.6%)	52 (0.4%)	80 (0.8%)	<0.001
FEN/GI	3720 (16.3%)	2032 (15.5%)	1688 (17.4%)	<0.001
Diabetes mellitus	3661 (16.0%)	1992 (15.1%)	1669 (17.2%)	<0.001
Chronic renal failure	42 (0.2%)	19 (0.1%)	23 (0.2%)	0.105
Liver cirrhosis	54 (0.2%)	43 (0.3%)	11 (0.1%)	0.001
Neurological	793 (3.5%)	245 (1.9%)	548 (5.7%)	<0.001
CVA	641 (2.8%)	234 (1.8%)	407 (4.2%)	<0.001
Dementia	165 (0.7%)	15 (0.1%)	150 (1.5%)	<0.001
Oncological	279 (1.2%)	121 (0.9%)	158 (1.6%)	<0.001
Chemotherapy	31 (0.1%)	22 (0.2%)	9 (0.1%)	<0.001
Disseminated cancer	279 (1.2%)	121 (0.9%)	158 (1.6%)	<0.001
Coagulopathy				
Bleeding disorder	1268 (5.6%)	423 (3.2%)	845 (8.7%)	<0.001
Bone density				
Osteoporosis	278 (1.2%)	57 (0.4%)	221 (2.3%)	<0.001
Pathological vertebral fracture	45 (0.2%)	10 (0.1%)	35 (0.4%)	<0.001
Social history				
Tobacco use	1331 (5.8%)	1074 (8.2%)	257 (2.7%)	<0.001
Comorbidity burden				
CCI (SD)	0.32 (0.86)	0.27 (0.78)	0.38 (0.95)	<0.001
Injury characteristics				
Mechanism				<0.001
Motor vehicle accident	6834 (29.9%)	4419 (33.6%)	2415 (24.9%)*	
Pedestrian vs auto	1267 (5.5%)	868 (6.6%)	399 (4.1%)*	
Other vehicle accident	1126 (4.9%)	875 (6.7%)	251 (2.6%)*	

(continued)

TABLE 2. Demographic data, injury characteristics, and operations in 22,835 patients ≥ 55 years old with traumatic lumbar spine fracture (continued)

Factor	Overall, n = 22,835	Age 55–69 Yrs, n = 13,151	Age ≥ 70 Yrs, n = 9684	p Value
Injury characteristics (continued)				
Mechanism (continued)				<0.001
Fall	9221 (40.4%)	4102 (31.2%)	5119 (52.9%)*	
Struck by or against	452 (2.0%)	333 (2.5%)	119 (1.2%)*	
Penetrating	56 (0.2%)	43 (0.3%)	13 (0.1%)*	
Other	454 (2.0%)	293 (2.2%)	161 (1.7%)*	
Unknown	3425 (15.0%)	2218 (16.9%)	1207 (12.5%)*	
ED SBP				<0.001
<90 mm Hg	1252 (5.5%)	770 (5.9%)	482 (5.0%)*	
≥ 90 mm Hg	20,755 (90.9%)	12,005 (91.3%)	8750 (90.4%)*	
Unknown	828 (3.6%)	376 (2.9%)	452 (4.7%)*	
ED SBP in mm Hg (numerical)				<0.001
Mean (SD)	137.2 (32.7)	134.3 (31.5)	141.1 (31.5)*	
ED GCS group				<0.001
3–8	1467 (6.4%)	978 (7.4%)	489 (5.0%)*	
9–12	453 (2.0%)	278 (2.1%)	175 (1.8%)	
13–15	19,531 (85.5%)	11,277 (85.8%)	8254 (85.2%)	
Unknown	1384 (6.1%)	618 (4.7%)	766 (7.9%)*	
ED GCS score (numerical)				<0.001
Mean (SD)	14.0 (2.9)	13.9 (3.1)	14.2 (2.6)*	
ISS				<0.001
0–8	7813 (34.2%)	3866 (29.4%)	3947 (40.8%)*	
9–15	5514 (24.1%)	3347 (25.5%)	2167 (22.4%)*	
16–24	5258 (23.0%)	3227 (24.5%)	2031 (21.0%)*	
25–75	2784 (12.2%)	1766 (13.4%)	1018 (10.5%)*	
Unknown	1466 (6.4%)	945 (7.2%)	521 (5.4%)*	
ISS (numerical)				<0.001
Mean (SD)	14.4 (10.5)	15.3 (10.4)	13.3 (10.1)*	
Operative management				
Nonoperative	19,913 (87.2%)	11,379 (86.5%)	8534 (88.1%)*	<0.001
VP or KP	1087 (4.8%)	415 (3.2%)	672 (6.9%)*	
Noninstrumented surgery	194 (0.8%)	133 (1.0%)	61 (0.6%)*	
Instrumented fusion	1641 (7.2%)	1224 (9.3%)	417 (4.3%)*	

CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; CVA = cerebrovascular accident; FEN/GI = fluid, electrolytes, nutrition/gastrointestinal; PVD = peripheral vascular disease.

* Statistically significant compared with the middle-aged cohort.

set at $p < 0.0017$ (reported in text only—data not shown in tabular form). In the middle-aged cohort, univariate analysis demonstrated that surgically treated patients had significantly higher odds of decubitus ulcer ($p < 0.001$), ARDS ($p < 0.001$), and pneumonia ($p < 0.001$). In the elderly cohort, univariate analysis demonstrated that surgically treated patients had significantly higher odds of ARDS ($p < 0.001$), pneumonia ($p < 0.001$), unplanned intubation ($p < 0.001$), urinary tract infection ($p < 0.001$), deep venous thrombosis ($p < 0.001$), and surgical site infection ($p < 0.001$). This association was driven largely by those patients undergoing instrumented surgery.

Given the differing demographic and injury characteristics within the middle-aged and the elderly cohorts, we next

used multivariable regression to discern whether these observed differences in medical complications persisted after correction for sex, race, insurance status, mechanism of injury, and severity of injury. A total of 7 complications met the threshold for univariate significance in at least one age cohort and were entered in multivariable analysis, and the Bonferroni threshold was set at $p < 0.0035$. After correction, we found that operative management was associated with higher odds of decubitus ulcer ($p < 0.001$), ARDS ($p < 0.001$), pneumonia ($p < 0.001$), and urinary tract infection ($p < 0.001$) in the middle-aged cohort (Table 3). Instrumented surgery was associated with higher odds of decubitus ulcer (OR 3.05, 95% CI 2.16–4.30), ARDS (OR 1.82, 95% CI 1.38–2.40), pneumonia (OR 1.82, 95% CI 1.48–2.25),

FIG. 1. Distribution of nonoperative and operative management in an older population with traumatic lumbar fracture. Graphs depicting percentage of patients managed nonoperatively versus operatively (**upper**) and distribution of operations (**lower**) in patients 55–69 and ≥ 70 years old with traumatic fracture of the lumbar spine. KP = kyphoplasty; VP = vertebroplasty.

urinary tract infection (OR 2.00, 95% CI 1.36–2.93), and surgical site infection (OR 2.54, 95% CI 1.63–3.96). In the elderly population, operative management was associated with higher odds of decubitus ulcer ($p < 0.001$), ARDS ($p < 0.001$), pneumonia ($p < 0.001$), urinary tract infection ($p < 0.001$), deep venous thrombosis ($p < 0.001$), and surgical site infection ($p < 0.001$). Instrumented surgery was associated with the highest odds of complication from decubitus

ulcer (OR 2.68, 95% CI 1.55–4.62), ARDS (OR 1.97, 95% CI 1.33–2.92), pneumonia (OR 2.72, 95% CI 2.05–3.62), urinary tract infection (OR 2.35, 95% CI 1.50–3.68), deep venous thrombosis (OR 2.98, 95% CI 2.03–4.39), and surgical site infection (OR 5.71, 95% CI 2.53–12.86). After controlling for the effects of age across both cohorts, instrumented surgery was associated with the highest odds of complication across all complication types ($p < 0.001$).

FIG. 2. Graph showing perioperative and hospital complication rates for management of traumatic lumbar fracture in patients ≥ 55 years old. The complication rate is depicted as a function of age and type of management. OR = operating room.

TABLE 3. Multivariable ORs for medical and surgical complications in patients 55–69 and ≥ 70 years old with traumatic lumbar spine fracture*

Complication	Age 55–69 Yrs, n = 13,151		Age ≥70 Yrs, n = 9684	
	OR (95% CI)	p Value	OR (95% CI)	p Value
Decubitus ulcer		<0.001		<0.001
Nonoperative	Reference	—	Reference	—
VP or KP	1.01 (0.41-2.52)	0.982	1.00 (0.40-2.52)	0.996
Noninstrumented	1.11 (0.34-3.59)	0.862	4.25 (1.27-14.21)	0.019
Instrumented	3.05 (2.16-4.30)	<0.001	2.68 (1.55-4.62)	<0.001
ARDS		<0.001		<0.001
Nonoperative	Reference	—	Reference	—
VP or KP	1.60 (0.98-2.63)	0.061	0.55 (0.24-1.27)	0.163
Noninstrumented	2.01 (1.10-3.71)	0.024	2.59 (0.98-6.89)	0.057
Instrumented	1.82 (1.38-2.40)	<0.001	1.97 (1.33-2.92)	0.001
Pneumonia		<0.001		<0.001
Nonoperative	Reference	—	Reference	—
VP or KP	0.87 (0.55-1.38)	0.556	0.85 (0.52-1.39)	0.513
Noninstrumented	0.91 (0.50-1.67)	0.760	3.07 (1.48-6.38)	0.003
Instrumented	1.82 (1.48-2.25)	<0.001	2.72 (2.05-3.62)	<0.001
Unplanned intubation		0.026		0.004
Nonoperative	Reference	—	Reference	—
VP or KP	0.35 (0.05-2.56)	0.304	0.25 (0.03-1.83)	0.172
Noninstrumented	2.91 (1.04-8.18)	0.043	1.30 (0.17-9.77)	0.798
Instrumented	1.77 (1.04-3.00)	0.034	2.65 (1.50-4.69)	0.001
Urinary tract infection		<0.001		<0.001
Nonoperative	Reference	—	Reference	—
VP or KP	0.95 (0.38-2.35)	0.910	0.87 (0.49-1.57)	0.647
Noninstrumented	2.42 (1.03-5.70)	0.043	1.75 (0.53-5.79)	0.359
Instrumented	2.00 (1.36-2.93)	<0.001	2.35 (1.50-3.68)	<0.001
Deep venous thrombosis		0.003		<0.001
Nonoperative	Reference	—	Reference	—
VP or KP	1.58 (0.95-2.64)	0.081	0.63 (0.27-1.44)	0.268
Noninstrumented	1.20 (0.55-2.63)	0.651	—†	—
Instrumented	1.67 (1.25-2.23)	0.001	2.98 (2.03-4.39)	<0.001
Surgical site infection		<0.001		<0.001
Nonoperative	Reference	—	Reference	—
VP or KP	1.38 (0.55-3.46)	0.498	0.73 (0.10-5.54)	0.761
Noninstrumented	2.23 (0.79-6.30)	0.128	—†	—
Instrumented	2.54 (1.63-3.96)	<0.001	5.71 (2.53-12.86)	<0.001

* Complications significant at the univariate level were corrected for sex, race, insurance status, CCI, mechanism of injury, ED SBP, ED GCS score, and ISS. The OR was used for all comparisons. The bold font denotes statistical significance. The Bonferroni threshold was set at $p < 0.0035$ for the multivariable analysis of 7 complications across 2 age cohorts.

† No patients in the older age cohort, noninstrumented group, had deep venous thrombosis or surgical site infection; dashes in these and in the reference groups denote “not applicable.”

Pooled and Multivariable Analysis of Outcomes

After describing the complication profile, we turned our attention to characterizing the mortality rate in the studied population. Overall, the in-hospital mortality rate was 6.8%. Analysis revealed a 1.8-fold relative rate of mortality in the elderly cohort as compared with the middle-aged cohort (percent mortality 9.3% for middle-aged vs 5.0% for elderly cohorts; $p < 0.001$). To describe further the association of mortality with operative management, univar-

iate analysis was conducted (reported in text only—data not shown in tabular form). A total of 5 outcome measures (mortality, hospital LOS, days in ICU, days on ventilator, and discharge disposition to home) were examined for each age cohort, and the Bonferroni threshold was set at $p < 0.005$ for all subsequent analyses. This analysis revealed a significantly higher OR with noninstrumented surgery (OR 2.76, 95% CI 1.67–4.57, $p < 0.001$), a significantly lower OR with instrumented surgery (OR 0.25, 95% CI

0.15–0.40, $p < 0.001$), as well as a statistical trend of lower odds with vertebroplasty or kyphoplasty (OR 0.35, 95% CI 0.17–0.70, $p = 0.003$) in the middle-aged cohort. In the elderly cohort, similar analysis demonstrated significantly lower odds for mortality in individuals undergoing vertebroplasty or kyphoplasty (OR 0.14, 95% CI 0.07–0.26, $p < 0.001$), but no statistically significant changes in OR with noninstrumented surgery (OR 1.18, 95% CI 0.53–2.60, $p = 0.686$) or instrumented surgery (OR 0.84, 95% CI 0.69–1.19, $p = 0.322$).

Inpatient Mortality

Multivariable correction for the aforementioned demographic and injury characteristics demonstrated that in both cohorts, statistically significant reductions in odds of mortality were observed with vertebroplasty or kyphoplasty (middle-aged cohort: OR 0.28, 95% CI 0.13–0.60, $p = 0.001$; elderly cohort: OR 0.25, 95% CI 0.13–0.49, $p < 0.001$) (Table 4). Instrumented surgery was associated with a significant reduction in odds of mortality in the middle-aged cohort (OR 0.20, 95% CI 0.12–0.34, $p < 0.001$), whereas a nonsignificant statistical trend was ob-

served in the elderly cohort (OR 0.64, 95% CI 0.43–0.94, $p = 0.022$). Noninstrumented surgery did not show statistically significant changes in higher odds of mortality in the middle-aged cohort (OR 1.65, 95% CI 0.91–2.98, $p = 0.098$) or the elderly cohort (OR 1.12, 95% CI 0.46–2.72, $p = 0.799$).

Multivariable analysis with age cohort and operation type in the same model demonstrated independent effects of both age and operation type on mortality (Table 5). Compared with the middle-aged cohort, the elderly cohort demonstrated an OR of 3.16 for mortality (95% CI 2.77–3.60, $p < 0.001$). Instrumented surgery (OR 0.38, 95% CI 0.28–0.52, $p < 0.001$) and vertebroplasty or kyphoplasty (OR 0.27, 95% CI 0.17–0.45, $p < 0.001$) were associated with decreased odds of death compared with nonoperative management, whereas no statistically significant changes in the ORs for mortality was observed in patients who underwent noninstrumented surgery (OR 1.51, 95% CI 0.93–2.44, $p = 0.094$).

Length of Stay

The overall mean hospital LOS was 10.3 ± 12.7 days.

TABLE 4. Multivariable analysis of outcome measures in patients 55–69 and ≥ 70 years old with traumatic lumbar fracture*

Outcome	Age 55–69 Yrs		Age ≥ 70 Yrs	
	OR or B (95% CI)	p Value	OR or B (95% CI)	p Value
Mortality	n = 12,409	<0.001	n = 9174	<0.001
Nonoperative	Reference	—	Reference	—
VP or KP	0.28 (0.13–0.60)	0.001	0.25 (0.13–0.49)	<0.001
Noninstrumented	1.65 (0.91–2.98)	0.098	1.12 (0.46–2.72)	0.799
Instrumented	0.20 (0.12–0.34)	<0.001	0.64 (0.43–0.94)	0.022
Hospital LOS	n = 12,661	<0.001	n = 9349	<0.001
Nonoperative	Reference	—	Reference	—
VP or KP	3.44 (2.17–4.70)	<0.001	1.63 (0.84–2.42)	<0.001
Noninstrumented	6.22 (4.03–8.41)	<0.001	6.74 (4.27–9.21)	<0.001
Instrumented	6.19 (5.43–6.94)	<0.001	8.50 (7.53–9.46)	<0.001
ICU days	n = 5222	<0.001	n = 3206	<0.001
Nonoperative	Reference	—	Reference	—
VP or KP	−0.01 (−1.73, 1.72)	0.994	−0.46 (−2.74, 1.81)	0.690
Noninstrumented	3.25 (1.02–5.48)	0.004	4.87 (0.73–9.02)	0.021
Instrumented	3.34 (2.43–4.24)	<0.001	6.82 (5.31–8.34)	<0.001
Days on ventilator	n = 4410	<0.001	n = 2719	<0.001
Nonoperative	Reference	—	Reference	—
VP or KP	−1.09 (−3.12, 0.93)	0.290	−0.43 (−2.82, 1.97)	0.890
Noninstrumented	3.36 (0.68–6.04)	0.014	4.91 (0.62–9.20)	0.143
Instrumented	2.54 (1.52–3.56)	<0.001	5.96 (4.35–7.58)	<0.001
Discharge home	n = 11,263	<0.001	n = 7897	<0.001
Nonoperative	Reference	—	Reference	—
VP or KP	0.76 (0.61–0.94)	0.012	0.91 (0.76–1.09)	0.292
Noninstrumented	0.48 (0.32–0.74)	0.001	0.47 (0.24–0.92)	0.029
Instrumented	0.36 (0.31–0.41)	<0.001	0.34 (0.26–0.46)	<0.001

* Univariate outcomes were corrected for sex, race, insurance status, CCI, mechanism of injury, ED SBP, EC GCS score, and ISS. The OR was used for categorical variables, and the mean difference (B) was used for continuous variables. The bold font denotes statistical significance. The Bonferroni threshold was set at $p < 0.005$ for the multivariable analysis of 5 outcomes across 2 age cohorts. Totals vary because some data were missing or not recorded in the NSP; see *Data Extraction* section in text.

TABLE 5. Multivariable analysis demonstrating independent effects of age and operation type on outcomes following traumatic lumbar fracture*

Outcome	Value	
	OR or B (95% CI)	p Value
Mortality		
Age group		<0.001
55–69 yrs	Reference	—
≥70 yrs	3.16 (2.77–3.60)	
Operation		<0.001
Nonoperative	Reference	—
VP or KP	0.27 (0.17–0.45)	<0.001
Noninstrumented	1.51 (0.93–2.44)	0.094
Instrumented	0.38 (0.28–0.52)	<0.001
Hospital LOS		
Age group		0.255
55–69 yrs	Reference	—
≥70 yrs	–0.20 (–0.55, 0.15)	
Operation		<0.001
Nonoperative	Reference	—
VP or KP	2.53 (1.80–3.26)	<0.001
Noninstrumented	6.66 (5.00–8.31)	<0.001
Instrumented	6.71 (6.12–7.30)	<0.001
ICU days		
Age group		0.034
55–69 yrs	Reference	—
≥70 yrs	0.55 (0.04–1.06)	
Operation		<0.001
Nonoperative	Reference	—
VP or KP	–0.11 (–1.49, 1.27)	0.874
Noninstrumented	3.84 (1.86–5.82)	<0.001
Instrumented	4.28 (3.50–5.06)	<0.001
Days on ventilator		
Age group		0.092
55–69 yrs	Reference	—
≥70 yrs	0.48 (–0.09, 1.04)	
Operation		<0.001
Nonoperative	Reference	—
VP or KP	–0.78 (–2.33, 0.77)	0.323
Noninstrumented	3.82 (1.57–6.09)	0.001
Instrumented	3.47 (2.61–4.34)	<0.001
Discharge home		
Age group		<0.001
55–69 yrs	Reference	—
≥70 yrs	0.32 (0.30–0.34)	
Operation		<0.001
Nonoperative	Reference	—
VP or KP	0.83 (0.72–0.95)	0.007
Noninstrumented	0.47 (0.33–0.67)	<0.001
Instrumented	0.37 (0.33–0.41)	<0.001

(continued)

TABLE 5. Multivariable analysis demonstrating independent effects of age and operation type on outcomes following traumatic lumbar fracture* (continued)

* Age and operation type are entered onto the same multivariable model and corrected for sex, race, insurance status, CCI, mechanism of injury, ED SBP, ED GCS score, and ISS. The OR was used for categorical variables, and the mean difference (B) was used for continuous variables. The bold font denotes statistical significance. The Bonferroni threshold was set at $p < 0.005$ for the multivariable analysis of 5 outcomes across 2 age cohorts.

For those undergoing operative management, a significantly longer mean LOS ($p < 0.001$) was observed for noninstrumented surgery (12.3 ± 11.7 days) and instrumented surgery (16.5 ± 14.8 days) compared with nonoperative management (9.7 ± 12.5 days) and vertebroplasty or kyphoplasty (10.1 ± 10.7 days). A significant decrease in hospital LOS was observed in the elderly cohort compared with the middle-aged cohort (mean LOS: 10.9 ± 14.1 days for the middle-aged cohort vs 9.4 ± 10.6 days for the elderly cohort; $p < 0.001$). Univariate analyses (reported in text only—data not shown in tabular form) showed a significant mean increase in hospital LOS in the middle-aged cohort for noninstrumented surgery (9.0 days, 95% CI 6.6–11.4, $p < 0.001$) and instrumented surgery (5.7 days, 95% CI 4.8–6.5, $p < 0.001$) compared with nonoperative management; a trend was observed for vertebroplasty or kyphoplasty (2.2 days, 95% CI 0.8–3.6, $p = 0.002$). In the elderly cohort, similar increases in LOS were observed with noninstrumented surgery (6.8 days, 95% CI 4.2–9.4, $p < 0.001$) and instrumented surgery (9.2 days, 95% CI 8.2–10.3, $p < 0.001$) compared with nonoperative management, but not in the vertebroplasty or kyphoplasty group (mean decrease 0.8 days, 95% CI –1.7 to 0, $p = 0.048$).

These results persisted after multivariable correction for demographic and injury characteristics, with an additional statistically significant mean increase observed in vertebroplasty or kyphoplasty in the elderly cohort (1.6 days, 95% CI 0.8–2.4, $p < 0.001$) (Table 4). Multivariable statistics showed an association of all types of operative management with increased mean LOS independent of age cohort. Vertebroplasty or kyphoplasty was associated with the lowest mean increase in LOS (2.5 days, 95% CI 1.8–3.3, $p < 0.001$) compared with nonoperative management, whereas the mean increase for noninstrumented surgery (6.7 days, 95% CI 5.0–8.3, $p < 0.001$) and instrumented surgery (6.7 days, 95% CI 6.1–7.3, $p < 0.001$) were comparable (Table 5). After normalizing to hospital LOS, Cox regression analysis showed an independent hazard ratio (HR) of 2.65 (95% CI 2.37–2.97, $p < 0.001$) for mortality associated with the elderly cohort compared with the middle-aged cohort, when adjusted for demographic and clinical variables. Independently lower risks of mortality were observed in patients with instrumented surgery (HR 0.31, 95% CI 0.24–0.42, $p < 0.001$) and vertebroplasty or kyphoplasty (HR 0.27, 95% CI 0.17–0.44, $p < 0.001$) compared with nonoperative management, whereas no effects were seen for noninstrumented surgery (OR 1.02, 95% CI 0.68–1.52, $p = 0.925$).

Number of Days in ICU

For patients triaged to the ICU or the operating room

from the ED, we performed an analysis of the number of days spent in ICU-level care. Overall, 36.9% of patients were directly admitted to the ICU or operating room. The mean number of ICU days was 8.8 ± 11.4 , and no differences were observed between age cohorts (middle-aged: 8.7 ± 11.2 days, elderly: 8.9 ± 11.6 days; $p = 0.451$). Univariate analyses (reported in text only—data not shown in tabular form) showed a statistically significant difference in number of ICU days in both age cohorts for operative management, with an increased mean number of ICU days driven by instrumented surgery ($p < 0.001$). Additionally, a statistically significant mean increase in ICU days was seen in patients with noninstrumented surgery in the middle-aged cohort ($p = 0.001$), whereas no such association was seen in the elderly cohort. After adjusting for demographic and injury differences, the association between ICU days and operative management was shown to be driven by instrumented surgery in both age cohorts (middle-aged: 3.3 days, 95% CI 2.4–4.2, $p < 0.001$; elderly: 6.8 days, 95% CI 5.3–8.3, $p < 0.001$), with a more than 2-fold increase in length of ICU stay for patients in the elderly cohort (Table 4).

Multivariable analysis confirmed the independent effect of operative management on increased mean ICU days in both instrumented surgery (4.3 days, 95% CI 3.5–5.1, $p < 0.001$) and noninstrumented surgery (3.8 days, 95% CI 1.9–5.8, $p < 0.001$) compared with nonoperative management, but independent age effects were not observed in this case (Table 5). After normalizing to number of ICU days, Cox regression analysis showed an independent HR of 2.16 (95% CI 1.91–2.45, $p < 0.001$) for mortality associated with the elderly cohort compared with the middle-aged cohort, when adjusted for demographic and clinical variables. Independently lower risks of mortality were observed in patients with instrumented surgery (HR 0.26, 95% CI 0.19–0.36, $p < 0.001$) and vertebroplasty or kyphoplasty (HR 0.28, 95% CI 0.15–0.53, $p < 0.001$) compared with nonoperative management, whereas no effects were seen for noninstrumented surgery (OR 0.88, 95% CI 0.56–1.36, $p = 0.556$).

Number of Days on Ventilator

For patients treated in the ICU or operating room, we also investigated whether age and/or operative management was associated with days on ventilator. The mean number of ventilator days was 5.4 ± 11.5 , and no differences were observed between age cohorts (middle-aged: 5.4 ± 11.7 days, elderly: 5.4 ± 11.5 days; $p = 0.652$). Univariate analyses (reported in text only—data not shown in tabular form) showed a significant difference in ventilator days associated with operative management in the middle-aged cohort for both noninstrumented (mean increase 4.3 days, 95% CI 1.5–7.1, $p = 0.003$) and instrumented operations (mean increase 1.6 days, 95% CI 0.5–2.6, $p = 0.005$), whereas no associations were seen for vertebroplasty or kyphoplasty. In the elderly cohort, only instrumented surgery showed a statistically significant mean increase in number of ventilator days (5.8 days, 95% CI 4.2–7.5, $p < 0.001$). After adjusting for demographic and clinical differences, operative management effects were driven by instrumented surgery in both cohorts (middle-aged: mean

increase 2.5 days, 95% CI 1.5–3.6, $p < 0.001$; elderly: mean increase 6.0 days, 95% CI 4.4–7.6, $p < 0.001$) with a more than 2-fold increase in time on ventilator in the elderly cohort (Table 4).

Multivariable analysis confirmed the independent effect of operative management on increased mean ventilator time for both instrumented surgery (3.5 days, 95% CI 2.6–4.3, $p < 0.001$) and noninstrumented surgery (3.8 days, 95% CI 1.6–6.1, $p = 0.001$), showing statistically significant increases compared with nonoperatively managed patients, whereas independent age effects were not observed (Table 5). After normalizing to number of ventilator days, Cox regression analysis showed an independent adjusted HR of 2.01 (95% CI 1.82–2.38, $p < 0.001$) for mortality associated with the elderly cohort compared with the middle-aged cohort. Independently lower risks of mortality were observed in patients with instrumented surgery (HR 0.27, 95% CI 0.20–0.38, $p < 0.001$) and vertebroplasty or kyphoplasty (HR 0.37, 95% CI 0.19–0.72, $p = 0.003$) compared with nonoperative management, whereas no effects were seen for noninstrumented surgery (OR 0.80, 95% CI 0.48–1.32, $p = 0.795$).

Discharge Disposition to Home

We next sought to characterize discharge disposition in surviving patients. Overall, 47.1% of patients were discharged home, including 57.1% of those in the middle-aged cohort and 33.0% of those in the elderly cohort. Univariate analyses (reported in text only—data not shown in tabular form) demonstrated that in both age cohorts, operative management was associated with statistically lower odds of return to home; this outcome was driven by instrumented surgery (middle-aged: OR 0.42, 95% CI 0.37–0.47, $p < 0.001$; elderly: OR 0.35, 95% CI 0.26–0.46, $p < 0.001$). Furthermore, in the middle-aged cohort noninstrumented surgery was associated with decreased odds of returning home (OR 0.38, 95% CI 0.26–0.56, $p < 0.001$), whereas no such association was seen in the elderly cohort. After multivariable correction, these results persisted, with instrumented surgery as the driver of decreased odds of returning home (middle-aged: OR 0.36, 95% CI 0.31–0.41, $p < 0.001$; elderly: OR 0.34, 95% CI 0.26–0.46, $p < 0.001$) (Table 4). Using multivariable analysis, we show that both age cohort and operative management are independent predictors of discharge disposition ($p < 0.001$). The complete set of results can be found in Table 5.

Influence of Osteoporosis on Outcome Following Traumatic Lumbar Fracture

Given that osteoporotic and acute traumatic fractures reflect different pathological entities, we further examined the effects of a diagnosis of osteoporosis or pathological vertebral fracture on outcome in each treatment group. As shown in Table 2, the overall prevalence of osteoporosis and pathological fractures was very low. Univariate analysis following stratification of treatment groups by the presence or absence of a diagnosis of osteoporosis or pathological fracture demonstrated a statistically significant difference in hospital discharge disposition in those managed nonoperatively (percent discharged home: 32.8% with osteoporosis-related diagnosis vs 49% without osteo-

porosis-related diagnosis; $p < 0.05$). This analysis also revealed a statistically significant difference in hospital LOS for those undergoing vertebroplasty or kyphoplasty (mean LOS: 6.1 ± 3.7 days with osteoporosis-related diagnosis vs 10.0 ± 10.7 days without osteoporosis-related diagnosis; $p < 0.05$). However, these differences did not remain statistically significant following multivariable regression. No other significant differences were observed in the other outcome measures, including inpatient complications, mortality, discharge disposition, hospital LOS, ICU LOS, or number of ventilator days, with respect to osteoporosis-related diagnosis and treatment group (data not shown).

Discussion

Lumbar spine trauma in the elderly is a growing public health problem with relatively little evidence to guide clinical management. With this analysis of more than 22,500 patients, of whom 9600 were older than 70 years, we have sought to characterize the complications, morbidity, and mortality associated with lumbar spine surgery in the elderly. In so doing, we have analyzed demographic data, comorbidities, inpatient complications, inpatient mortality, and hospital discharge disposition in both an elderly and a middle-aged cohort. To date, we are unaware of previously published studies in which these characteristics in the elderly population have been reported. When formulating our study question, our hypothesis was simple: elderly patients would have more comorbidities, worse injuries, more frequent medical complications, and worse outcomes. We predicted also that the perioperative risk profiles and surgical complications would be worse across the board in the elderly cohort. Although several of these predictions were borne out by the study, many of them were directly contradicted by our results. We will discuss some of the more notable findings in the following sections.

Inpatient Mortality

Unsurprisingly, inpatient mortality in all patients (nonoperative and operative groups) was 3-fold higher in the elderly than in the middle-aged cohort. Furthermore, advancing age was shown to be an independent predictor of mortality in the elderly cohort. However, on subanalysis of the patients undergoing surgery of any kind, the results were less clear-cut. Among the elderly group, vertebroplasty or kyphoplasty was associated with significantly improved survival, and instrumented surgery trended strongly toward the same, although the results fell just short of statistical significance. Prior reports have demonstrated a mortality benefit favoring vertebroplasty or kyphoplasty vs nonoperative management in elderly individuals with vertebral compression fractures over 3–4 years of follow-up.^{9,17} Whether a similar benefit can be observed in the acute inpatient setting as suggested by our data remains to be seen and should be systematically studied. Similarly interesting is the increased odds ratio of death with noninstrumented surgery. The source of these findings is unclear, and it is possible that patients undergoing noninstrumented surgery were also worse surgical candidates with greater injury-specific or comorbid mortality risk that was not captured in the NTDB.

Overall, we saw mortality rates of 7% in the nonoperative group and 3% in the group with operative management. This discrepancy probably reflects the fact that those at greatest risk for death were likely to be poor surgical candidates. Again, however, it must be noted that our analysis did correct for multiple comorbidities including the CCI, so this effect of selection bias affecting mortality is at least somewhat mitigated. Rates of mortality in those undergoing surgical management was similar to the previously reported range of 0%–4.5% in adults requiring surgical stabilization of traumatic lumbar spine fractures.^{2,13,26–28}

Other Complications

In this analysis, the rate of complications was 16.2% and 21.9% for those undergoing nonoperative and operative management, respectively. Rates of surgical site infection were slightly lower than the reported range of 9.4%–14% within spine trauma populations.^{5,31} The most prevalent medical complications were pneumonia, ARDS, deep venous thrombosis (3%), urinary tract infection, and decubitus ulcer, and these were highest in the subgroup undergoing instrumented surgery. Multivariable analysis demonstrated that no statistically significant difference in total complication rate was observed between age groups. There were, however, age-dependent effects in specific complications, such as cardiac arrest and myocardial infarction.

Notably, there was a comparatively high prevalence of pulmonary complications in the studied population. Operative intervention was associated with greater odds of pneumonia in both the middle-aged and the elderly cohorts, whereas the rate of ARDS was only increased in the middle-aged cohort in patients undergoing an operation. On average, the patients included in the present study were intubated for 5.4 days. This number is substantially higher than previously reported; the previously reported range was 0.6–3.6 days in non-age-stratified reports in those requiring surgical intervention for traumatic lumbar spine fracture.^{2,13,26–28} Nonetheless, the reported rates of pneumonia for each subgroup were within the previously reported range of 0%–16.7% for surgical repair of traumatic lumbar spine fracture.² Rates of decubitus ulceration and urinary tract infection were also similar to those previously reported for surgically treated traumatic lumbar and thoracic spine fractures.⁴¹ In contrast, the reported rate of deep venous thrombosis is higher than the published range of 0.1%–2.4%.⁴¹ These data suggest that in the postoperative period, particularly in the elderly population, emphasis should be placed on early mobilization, aggressive weaning from mechanical ventilation, and early recognition of pneumonia to mitigate medical complications.

Discharge Disposition

When considering discharge disposition, age was shown to be an independent predictor of discharge disposition, with a smaller proportion of elderly patients returning home (OR 0.32, 95% CI 0.30–0.34). With respect to operative technique, noninstrumented surgery, vertebroplasty or kyphoplasty, and instrumented surgery were associated with lower odds of returning home in the middle-aged

cohort. For our elderly cohort, only instrumented surgery was associated with decreased odds of returning home. The source of this discrepancy is unclear, and it is likely that it reflects a smaller sample size, as evidenced by the nonsignificant trend for noninstrumented surgery and vertebroplasty or kyphoplasty in this cohort.

Public Awareness Surrounding Mechanisms of Injury

Although our analysis was largely focused on describing the complications involved in lumbar surgery, we would be remiss if we failed to discuss the implications of the mechanisms of injury in the middle-aged and elderly cohorts. The predominant mechanism of injury in this elderly cohort was falls from standing; in the middle-aged cohort falls were a close second to motor vehicle accidents. Interestingly, we found an overrepresentation of women in the elderly cohort as compared with the middle-aged one. A similar female propensity toward lumbar fractures has been reported in both Asian and Scandinavian countries.^{23,42} The female predominance, comparatively milder ISS, and increasing use of vertebroplasty or kyphoplasty with advancing age, probably implicates osteoporosis as a contributing etiological entity.^{6,30} From the public health perspective, these findings highlight the importance of ongoing primary prevention efforts to avert falls in the elderly.^{18,22} They also offer evidence that measures designed to improve bone mineral density (e.g., vitamin D and calcium supplementation, bisphosphonates, calcitonin, and so on) have the greatest potential for curbing the rapidly rising incidence of elderly traumatic lumbar spine fractures.^{23,25} Although potentially helpful in reducing the incidence of lumbar spine fracture, our subgroup analysis demonstrated that a preexisting diagnosis of osteoporosis does not influence outcome following acute traumatic fracture in the elderly. Overall, the incidence of osteoporosis was low in the studied cohort. Although we suspect that osteoporosis is underreported in the NTDB, we are unable to confirm our suspicion with the data available in the NTDB. Given that the NTDB is a curated sample that is reflective of the population overall, it is reasonable to assume that the prevalence of osteoporosis in the sample is similar to that of the population overall, underreported though it may be. Thus, if osteoporosis is in fact underreported in the NTDB, it does not invalidate the overall conclusions of our study or limit their applicability.

Limitations of the Study

Although the national sample population of the NTDB is a very large database, it is not without limitations. Patients are enrolled into the NTDB through convenience sampling, which relies on nonrandom voluntary submission and is therefore prone to bias. All analysis is retrospective and may be skewed by inaccurate and/or missing data. Fractures in the lumbar spine are heterogeneous,¹⁵ and management decisions are dependent on fracture morphology, ligamentous disruption, and neurological presentation.³⁹ None of these data are encoded in the NTDB, and despite controlling for other variables it is likely that those in different treatment groups had different levels of severity of fracture and/or neurological injury. No information is available on preinjury functional analysis, and therefore

poor surgical candidates may skew comparisons between nonoperative and operative groups. Similarly, no data on cost of care are included in the NTDB; thus analysis of cost-effectiveness cannot be performed. Finally, as previously noted, preexisting diagnoses that may influence the natural history of lumbar fracture, such as osteoporosis, are probably underreported in the data set. Despite these limitations, the NTDB has been extensively used to elucidate the epidemiology of different traumatic injuries and is the most comprehensive trauma database available.

From the perspective of our study, it must be stated explicitly that causality must not be inferred from these results. The associations, for example, between operation type and mortality are just that. We must therefore be meticulous in drawing correct conclusions from this analysis; for example, whereas it is correct to observe that patients undergoing vertebroplasty or kyphoplasty have a lower odds ratio of death than those undergoing nonoperative management, it would be wrong to infer that the intervention was the direct and proximal cause for the change in mortality rates. Selection bias undoubtedly plays a role in patient selection for surgical procedures—those elderly patients being offered an operation are probably chosen at least in part because they are better surgical candidates. That being said, our results do suggest that, when applied judiciously, instrumented surgery is well tolerated in the elderly, and should be offered with an appropriate discussion of the expected risks and benefits.

Conclusions

The present study confirms that lumbar surgery for traumatic fracture in the elderly is associated with increased morbidity. In particular, instrumented fusion is associated with periprocedural complications, prolonged hospitalization, and a decreased likelihood of being discharged to home. However, fusion surgery is also associated with reduced mortality and, when applied judiciously, is well tolerated in the elderly. Selection of the appropriate surgical technique in the elderly should place emphasis on fracture morphology, stability, neurological condition, and surgical candidacy, including consideration of both medical comorbidities and systemic injuries, as with other age groups. Age alone should not be an exclusionary factor in identifying surgical candidates for instrumented lumbar spinal fusion. Future studies in similar patient populations are needed to confirm these findings.

Acknowledgments

We thank the Committee on Trauma, American College of Surgeons, NTDB NSP 2003-12, Chicago, Illinois. The content reproduced from the NTDB NSP remains the full and exclusive copyrighted property of the American College of Surgeons. The American College of Surgeons is not responsible for any claims arising from works based on the original data, text, tables, or figures.

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Disclosure

Dr. Dhall has received speaking honoraria from Globus and DePuy.

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Conception and design: Tarapore, Winkler, Yue, Manley, Dhall. Acquisition of data: Tarapore, Winkler, Yue, Birk, Robinson. Analysis and interpretation of data: all authors. Drafting the article: Tarapore, Winkler, Yue. Critically revising the article: Tarapore, Winkler, Yue, Manley, Dhall. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Tarapore. Statistical analysis: Tarapore, Winkler, Yue. Administrative/technical/material support: Tarapore. Study supervision: Tarapore.

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