


Comparative Propensity-Weighted Mortality After Isolated Acute Traumatic Axis Fractures in Older Adults

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Michael P. Catalino, MD, MSc¹ , Virginia Pate, MS²,
Til Stürmer, MD, PhD², and Deb A. Bhowmick, MD¹

Abstract

Introduction: In older patients with axis fractures, the survival benefit from surgery is unclear due to high baseline mortality. Comparative effectiveness research can provide evidence from population level cohorts. Propensity weighting is the preferred methodology for reducing bias when analyzing national administrative cohort data for these purposes but has not yet been utilized for this important surgical conundrum. We estimate the effect of surgery on mortality after isolated acute traumatic axis fracture in older adults. **Materials and Methods:** We used a retrospective population-based cohort of Medicare patients and generated a propensity score-weighted nonsurgical cohort and compared mortality with and without surgery. This balanced the comorbid conditions of the treatment groups. Incident fractures were defined using a predetermined algorithm based on enrollment, code timing, and billing location. The primary outcome was adjusted all-cause 1-year mortality. **Results:** From 12 372 beneficiaries with 1-year continuous enrollment and a coded axis fracture, 2676 patients met final inclusion/exclusion criteria. Estimated incidence was 16.5 per 100 000 person-years overall in 2014 (95% confidence interval [CI]: 15.0-18.0) and was stable from 2008 through 2014. Patients with axis fracture had a mean age of 82.8 years, 30.2% were male, and 91.9% were Caucasian. Mortality was 3.8 times higher (CI 3.6-4.1) compared with the general population of older US adults. Propensity-weighted mortality at 1 year for nonsurgical patients was 26.7 of 100 (CI: 24.5-29.0). Mortality for surgical patients was significantly lower (19.7/100; CI 14.5-25.0). Risk difference was 7.0 fewer surgical deaths per 100 patients (CI: 1.3-12.7). Surgical patients aged 65 to 74 years had the largest difference in mortality with 11.2 fewer deaths per 100 (CI: 1.1-21.3). **Discussion:** Patients with axis fractures are predominantly older Caucasian women and have a higher mortality rate than the general population. Propensity-weighted mortality at 1-year was lower in the surgical patients with the largest risk difference occurring in patients 65 to 74 years old. **Conclusions:** Surgery may provide an independent survival benefit in patients aged 65 to 75 years, and the mortality difference diminishes thereafter.

Keywords

axis fracture, surgery, mortality, propensity methods, Medicare

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Introduction

Axis fractures are the most commonly fractured cervical vertebra in the elderly individuals and are associated with significant morbidity, mortality, and up to US\$1.5 billion in medical costs annually in the United States.¹⁻⁸ Most axis fractures are amenable to external immobilization without surgery, but odontoid fractures, which may represent over 89% of axis fractures, are prone to nonunion and unresolved atlantoaxial instability with nonsurgical management.⁹ Stability can be achieved surgically by a number of techniques depending on the location and morphology of the fracture.¹⁰ According to current guidelines, nonsurgical treatment for axis fractures constitutes a reasonable initial course of management, apart from

cases with severe comminution, displacement, angulation, inability to align with external immobilization, disc injury, or severe ligamentous injury.^{10,11} A Level II recommendation advises surgical consideration for patients older than 50 years with certain

¹ Department of Neurosurgery, UNC School of Medicine, NC, USA

² Department of Epidemiology, UNC Gillings School of Global Public Health, NC, USA

Corresponding Author:

Michael P. Catalino, Department of Neurosurgery, University of North Carolina School of Medicine, 170 Manning Drive, CB 7060, Chapel Hill, NC 27599, USA.

Email: mcatalino@bwh.harvard.edu



odontoid fractures, due to high rates of nonunion with increased age.¹⁰⁻¹⁵ However, fusion is not always required for stability because stable fibrous nonunion may provide adequate biomechanical support in the elderly individuals.^{13,16} Thus, rigid collar use leading to stable nonunion in elderly patients is a reasonable outcome.^{13,17-20} A rigid collar is the preferred surgical alternative in the elderly patients because it is relatively effective and rigid external immobilization with a halo device carries disproportionate risks in the older adults.^{14,21-23}

Outcomes after surgical stabilization²⁴⁻²⁷ and nonsurgical management²⁸ of odontoid fractures in the elderly patients suggest higher fracture union rates with surgery. Over the past decade, a number of published reviews^{10,17,18,20,29-33} and guidelines^{11,34} show nonunion rates ranging from 1% to 80% without surgery depending on fracture type, gender, and age.^{12,15,17} Unfortunately, surgery also associates with significant perioperative morbidity and mortality in elderly patients, regardless of fusion success.^{26,35-37} Conflicting and inconclusive data on the survival advantage of surgery in older adults make it difficult to determine if perioperative mortality in elderly patients outweighs the risk of mortality associated with nonunion.^{21,38-40} Therefore, even if surgery is indicated based on fracture morphology, it is unclear whether or not surgery should be recommended.

Publicly available databases constructed with the *International Classification of Diseases, Ninth Revision, Clinical Modification* or *International Classification of Diseases, Ninth Revision (ICD-9)* codes are frequently used to support practice changes based on highly generalizable actual patient-oriented outcomes.^{6,8,36,39,41} Over the last 2 decades, propensity scores have emerged as the preferred method for generating causal inference in comparative effectiveness research using administrative databases.⁴²⁻⁴⁶ In 2016, Pearson et al³⁹ used Medicare claims and regression analyses to estimate survival and compare surgical and nonsurgical management of axis fractures, but given the nuances of incidence and prevalence cross-over with International Classification of Diseases-based sampling, broad inclusion criteria, and insufficient control of confounding (eg, selection bias) we felt more rigid methods were required to adequately assess outcomes in this cohort of patients. The current study utilizes a random sample of the US Medicare population to identify isolated acute traumatic axis fractures in older US adults. We exercise a strict incidence definition algorithm to compare surgical and nonsurgical mortality and exploit a robust propensity score-weighted methodology. Our null hypothesis was that patients treated with surgery have equal mortality rate at 1 year compared to nonsurgical patients; our alternative hypothesis was that surgical mortality would be lower.

Methods

Study Population

We used a 20% random sample of US fee-for-service Medicare beneficiaries with concurrent Medicare Parts A (inpatient),

B (outpatient), and D (dispensed drugs) coverage in at least 1 month between 2007 and 2014. Medicare is the US national health insurance program and provides medical coverage for citizens aged 65 years and older. Once selected into our sample, we receive all data from beneficiaries until death or disenrollment from fee-for-service Medicare. The institutional review board at the University of North Carolina, Chapel Hill, approved the study (IRB #16-0533).

Identification of Incident Fractures

We required beneficiaries to be continuously enrolled in fee-for-service Medicare Parts, A, B, and D for 12 months in order to be eligible for our cohort. Among eligible beneficiaries, we identified incident axis fractures by requiring an inpatient hospitalization with a primary, secondary, or tertiary discharge diagnosis code for an axis fracture (*ICD-9* diagnosis codes 805.02) or a physician claim with a primary diagnosis code for an axis fracture during a hospitalization. We excluded patients with any inpatient or outpatient cervical fracture diagnosis code (*ICD-9* diagnosis code 805.0x or 806.0x) during the prior 12 months, except for outpatient cervical fracture codes in 30 days prior to the hospitalization. This ensured patients diagnosed as outpatients with subsequent hospitalization were not missed, but also that only patients requiring hospitalization within 30 days of their fracture were included in order to prevent cohort contamination with chronic fractures. We also excluded patients with severe brain injury, skull fracture, coma, and concurrent or historical pathological vertebrae fracture (*ICD-9* diagnosis code 733.13). Fractured vertebrae were identified using the fifth digit of the *ICD-9* diagnosis code. All diagnosis codes during initial hospitalization were used to exclude patients with concurrent atlas and axis fractures and concurrent axis and subaxial or multiple cervical fractures. The final cohort was our isolated acute traumatic axis fractures group and the hospitalization associated with the fracture was the index hospitalization.

Treatment Identification

We identified whether patients received surgical treatment based on current procedural terminology (CPT) codes preselected by authors (MPC and DAB) representing surgical procedures used to treat axis fractures. The surgery must have been performed during the index hospitalization or else the patient was placed in the nonsurgical group. Delayed surgery was not accounted for. Only CPT codes during initial hospitalization qualified. Patients without a surgery code were grouped as nonsurgical, irrespective of whether they received a halo or not.

Mortality

The outcome of interest was 1-year, all-cause mortality. Center of Medicare and Medicaid Services (CMS) obtains mortality data for all beneficiaries based on a linkage with the National Death Index, irrespective of enrollment status. Since we had

data on all-cause mortality for all beneficiaries, we allowed beneficiaries to disenroll from fee-for-service Medicare during mortality follow-up. For each analysis, patients were only included if there was enough follow-up time to assess their outcome within the window (eg, only patients with incident fracture dates more than 360 days prior to December 31, 2014, were included in the 360-day analysis).

Analyses

Incidence rates of axis fracture were calculated by dividing the number of incident fractures by the total eligible person-time among beneficiaries in our database. Beneficiaries were considered eligible after at least 12 months of continuous Parts A, B, and D fee-for-service enrollment with no cervical fracture diagnosis codes until either the end of their continuous enrollment or a cervical fracture diagnosis code. Rates are presented per 100 000 person-years along with 95% confidence intervals (CIs). The estimated 1-year standardized mortality ratio (SMR) for the isolated acute traumatic axis fracture cohort equaled observed mortality divided by the expected mortality based on age and sex-standardized mortality rates in the general US population.⁴⁷ We assessed all covariates based on medical claims during the 12 months prior to index hospitalization. We report baseline characteristics by fracture type (crude data from full cohort), as well as by surgery, in the isolated axis fracture cohort (crude and SMR weighted). For surgical versus nonsurgical cohorts, we calculated standardized mean differences for all covariates.

In order to balance comorbid conditions in the treatment groups, we used propensity scores to control for differences in measured covariates between surgical and nonsurgical cohorts. We estimated the probability of receiving surgery (PS) based on all variables included in Table 1 for each patient. We then weighted the nonsurgical cohort by SMR weights, defined as the odds of the estimated probability of receiving surgery ($PS/[1 - PS]$). The surgical cohort received weights of 1. This process leads to a pseudopopulation of nonsurgical patients, whose covariate distribution mimics the one observed in surgery patients. This not only removes confounding by measured covariates but also allows us to estimate the association between surgery and all-cause mortality in patients who received surgery (treatment effect in treated). We estimated in-hospital, 30-day, 180-day, and 360-day crude mortality risks per 100 patients with 95% CIs using Poisson regression and compared surgical and nonsurgical mortality at 1 year.

Results

Axis Fracture Incidence

We identified 4877 beneficiaries with an incident axis fracture and 2797 had an isolated axis fracture (Figure 1). The estimated incidence for isolated axis fractures in 2014 was 16.5 per 100 000 person-years overall (95% CI: 15.0-18.0). This remained stable from 2008 through 2014, with a peak in 2011 (Figure 2). Incidence rates strongly associated with age, with rates 10-fold

higher in those aged 85+ years compared to those aged 65 to 74 years in 2014. Between the ages of 65 to 74 years, men and women experienced similar incidence, but rates trended slightly higher in women older than 85 compared to men.

The mean age of beneficiaries with an incident isolated axis fracture was 82.8 years. Of the beneficiaries with axis fractures 68.4% were female; 92.3% were white; 36.8% were from the South, 27.6% from the Midwest, 21.0% from the Northeast, and 14.6% from the West. The mean Charlson comorbidity index among those with incident isolated axis fracture was 3.6, and mean frailty score was 0.4. The most common mechanism of injury was low energy trauma (81.6%).

Mortality

In-hospital, 30-day, 180-day, and 360-day mortality for isolated axis fractures was 5.6 (95% CI 4.8-6.5), 12.6 (11.3-14.0), 24.6 (22.8-26.6), and 32.5 (30.3-34.9) per 100 beneficiaries, respectively. The SMR was 3.8 (95% CI: 3.6-4.1) for isolated axis fractures compared to mortality in the general US population aged 65+ years in 2007. We found that mortality accelerates as age increases (Supplemental Figure).

Surgical and Nonsurgical Treatment Outcomes

We included 2320 incident fractures with at least 360 days of follow-up in our treatment analyses. Of those, 223 (9.6%) received surgical treatment. In this group, the most common surgical CPT code was 22318, "anterior odontoid fracture reduction," occurred in 50% of cases. The second most common CPT code was 22595, "posterior C1-2 fusion," and occurred in about 30% of index admissions. Compared to nonsurgical patients, surgical patients were younger, more likely to be white, had a lower baseline frailty score, and were less likely to have home health claims in the year prior to fracture (Table 1). Baseline characteristics used to estimate the propensity weights were determined a priori and included baseline prescription medications and health-care utilization variables. We present the distribution of these covariates in the nonsurgical cohort after reweighting the nonsurgical cohort based on the propensity score to mimic the distribution of covariates observed in the surgery group (Table 1). Weighted standardized differences were all <0.1, which indicates our propensity score model balances all these measured covariates.

Mortality for surgical patients was 19.7 deaths per 100 beneficiaries at 1 year (95% CI: 14.5-25.0). Crude nonsurgical mortality rate was significantly higher at 33.9 (95% CI 31.8-35.9), but using our propensity weights, this rate dropped to 26.7 (95% CI: 24.5-29.0; Supplemental Table). This suggests that there was substantial confounding, which favors healthier patients for surgery, and that we were able to adjust for at least some of it. Propensity-weighted risk difference (RD) showed 7.0 fewer surgical deaths per 100 patients at 1 year (95% CI: 1.3-12.7), and a risk ratio (RR) of 0.7 favoring surgery (95% CI: 0.6-1.0). Table 2 shows in-hospital, 30-day, 180-day, and 360-day mortality for the 2 groups. There was no difference in

Table 1. Baseline Characteristics by Treatment for Isolated Axis Fractures only for Patients With at Least 1-Year Follow-Up Available Treated Operatively or Nonoperatively.^a

Characteristic	Surgery, N = 223	No Surgery, N = 2097	Unweighted Std Diff	No Surgery Weighted	Weighted Std Diff
Age group					
65-74	52 (23.3%)	356 (17.0%)	0.159	61 (27.3%)	0.091
75-84	107 (48.0%)	747 (35.6%)	0.253	92 (41.0%)	0.141
85+	64 (28.7%)	994 (47.4%)	0.393	71 (31.7%)	0.066
Age, mean (SD)	80.1 (7.19)	83.0 (7.91)	0.385	80.0 (7.79)	0.013
Sex, male	75 (33.6%)	613 (29.2%)	0.095	77 (34.6%)	0.020
Race, nonwhite	12 (5.4%)	173 (8.2%)	0.114	12 (5.4%)	0.001
Region					
Northeast	29 (13.0%)	435 (20.7%)	0.208	28 (12.5%)	0.014
Midwest	67 (30.0%)	562 (26.8%)	0.072	67 (30.1%)	0.002
South	87 (39.0%)	803 (38.3%)	0.015	88 (39.5%)	0.010
West	40 (17.9%)	297 (14.2%)	0.103	40 (17.8%)	0.002
Charlson comorbidity index, mean (SD)	3.3 (2.58)	3.7 (2.69)	0.141	3.3 (2.60)	0.011
Frailty score, mean (SD)	0.3 (0.26)	0.4 (0.30)	0.407	0.3 (0.26)	0.003
Mechanism					
High energy	22 (9.9%)	276 (13.2%)	0.103	22 (10.0%)	0.005
Low energy	179 (80.3%)	1645 (78.4%)	0.045	180 (80.2%)	0.001
No E code	22 (9.9%)	176 (8.4%)	0.051	22 (9.8%)	0.004
Baseline outpatient office visits					
0-6	75 (33.6%)	848 (40.4%)	0.141	75 (33.4%)	0.006
7-12	73 (32.7%)	572 (27.3%)	0.119	73 (32.6%)	0.002
13+	75 (33.6%)	677 (32.3%)	0.029	76 (34.0%)	0.008
Baseline home health claims					
0	176 (78.9%)	1485 (70.8%)	0.188	177 (78.9%)	0.001
1	25 (11.2%)	311 (14.8%)	0.108	25 (11.1%)	0.003
2+	22 (9.9%)	301 (14.4%)	0.138	22 (10.0%)	0.005
Days in hospital during baseline					
<1 week	174 (78.0%)	1564 (74.6%)	0.081	175 (78.0%)	0.001
1 to <2 weeks	19 (8.5%)	285 (13.6%)	0.162	19 (8.5%)	0.002
2+ weeks	30 (13.5%)	248 (11.8%)	0.049	30 (13.5%)	0.003
Any SNF stay during baseline	27 (12.1%)	387 (18.5%)	0.177	27 (11.9%)	0.006
Baseline DME claims					
0	109 (48.9%)	1088 (51.9%)	0.060	110 (49.1%)	0.004
1	39 (17.5%)	263 (12.5%)	0.139	39 (17.4%)	0.003
2+	75 (33.6%)	746 (35.6%)	0.041	75 (33.6%)	0.001
Baseline ED visits					
0-1	104 (46.6%)	769 (36.7%)	0.203	105 (46.9%)	0.005
2-5	104 (46.6%)	1124 (53.6%)	0.140	104 (46.3%)	0.007
6+	15 (6.7%)	204 (9.7%)	0.109	15 (6.8%)	0.003
Distinct generic drugs at baseline					
0-4	26 (11.7%)	239 (11.4%)	0.008	26 (11.5%)	0.006
5-9	74 (33.2%)	576 (27.5%)	0.125	75 (33.7%)	0.011
10+	123 (55.2%)	1282 (61.1%)	0.121	123 (54.8%)	0.007
ACE inhibitors	83 (37.2%)	740 (35.3%)	0.040	83 (37.2%)	0.000
Antiarrhythmics	30 (13.5%)	237 (11.3%)	0.065	30 (13.3%)	0.003
Anticoagulants	70 (31.4%)	737 (35.1%)	0.080	70 (31.3%)	0.003
β-Blockers	111 (49.8%)	1094 (52.2%)	0.048	112 (50.0%)	0.005
Bisphosphonates	36 (16.1%)	351 (16.7%)	0.016	35 (15.6%)	0.014
Calcium-channel blockers	61 (27.4%)	675 (32.2%)	0.106	60 (27.0%)	0.009
Loop diuretics	57 (25.6%)	736 (35.1%)	0.209	56 (25.2%)	0.008
NSAIDs	61 (27.4%)	457 (21.8%)	0.129	61 (27.2%)	0.002
PPI	76 (34.1%)	776 (37.0%)	0.061	76 (33.9%)	0.003
Statin	106 (47.5%)	950 (45.3%)	0.045	106 (47.5%)	0.001
Thiazides	50 (22.4%)	400 (19.1%)	0.083	49 (22.0%)	0.010

Abbreviations: ACE, acetylcholinesterase; DME, durable medical equipment; ED, emergency department; NSAIDs, nonsteroidal anti-inflammatory drugs; PPI, proton pump inhibitor; SD, standard deviation; Std Diff, standardized absolute mean difference; SNF, skilled nursing facility.

^aWeighted standardized differences for nonsurgical cohort included for nonsurgical group.

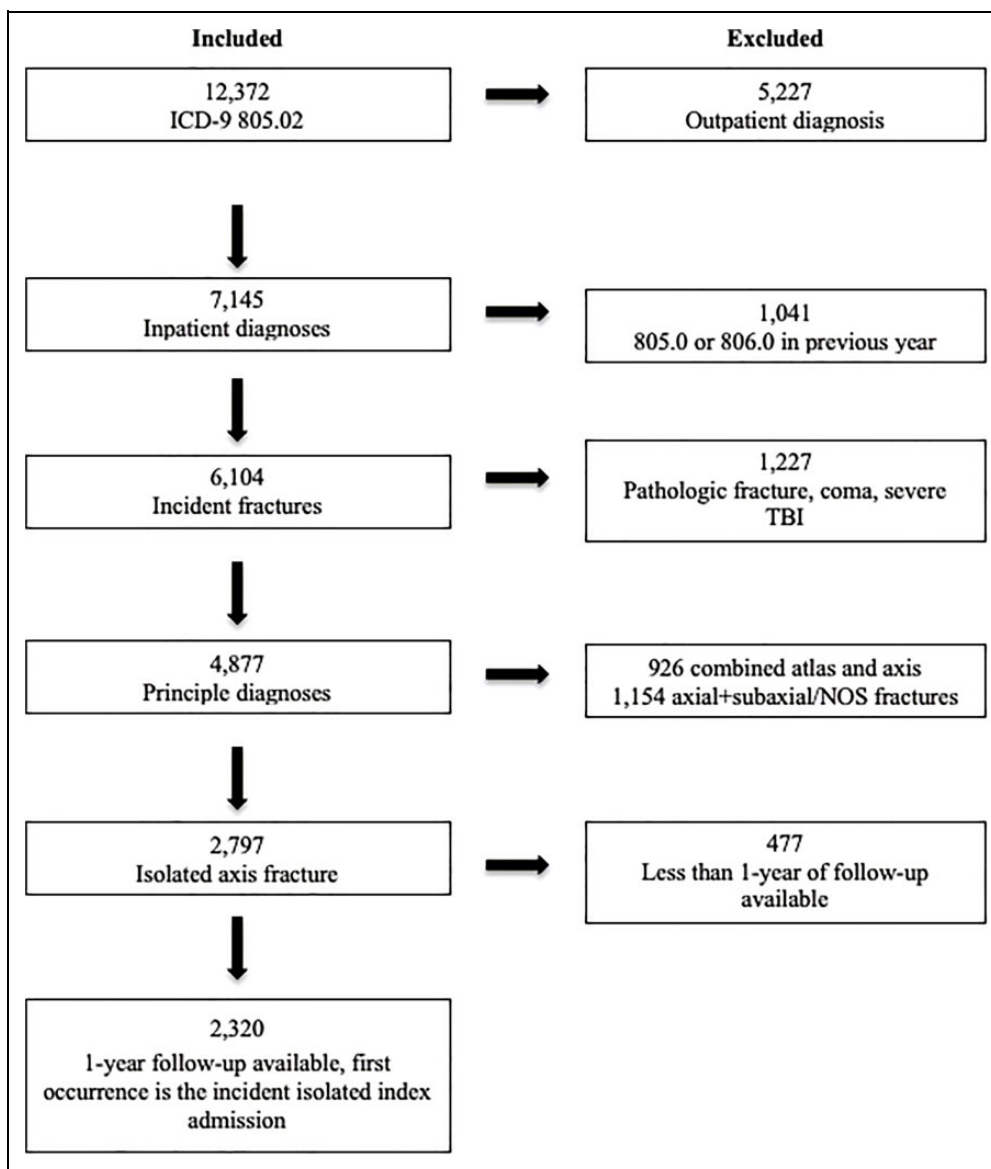


Figure 1. Flow chart for determination of isolated acute axis fractures.

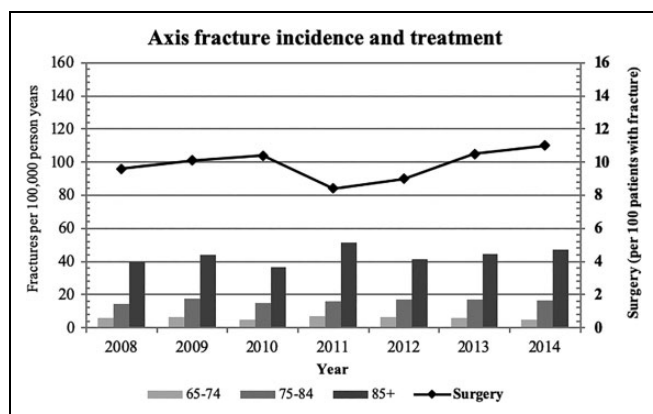


Figure 2. Bar and line graphs for age stratified fracture incidence and rate of surgical intervention during study period showing increasing incidence with age and stable rate of surgery.

in-hospital mortality, but the 2 groups diverge by 30 days and thereafter, in which the surgical group maintains a lower mortality rate. Given the impact of age on mortality, we also stratified by age. Those 65 to 74 years experienced the lowest mortality (Figure 3). Propensity-weighted mortality for this group was 7.7 (95% CI: 0.5-14.9) and 18.9 (95% CI: 11.9-26.0) deaths per 100 at 1 year for surgery and nonsurgical cohorts, respectively. This resulted in an RD of 11.2 (95% CI: 1.1-21.3) and RR of 0.4 (95% CI: 0.1-1.1). For other age-groups, weighting eliminated the difference in mortality.

Discussion

Isolated acute axis fractures in older adults was associated with a high 1-year mortality. Uniformly, there was a lower mortality among those who had surgery during the years, and both

Table 2. Crude Mortality Rate Presented as Deaths Per 100 Patients.^a

Group	Inhospital	30 Days	180 Days	360 Days
No surgery	5.8 (4.9-6.7)	13.3 (12.0-14.6)	25.7 (23.9-27.4)	33.9 (31.8-35.9)
Surgery	3.6 (1.4-5.8)	6.3 (3.4-9.1)	15.1 (10.7-19.6)	19.7 (14.5-25.0)

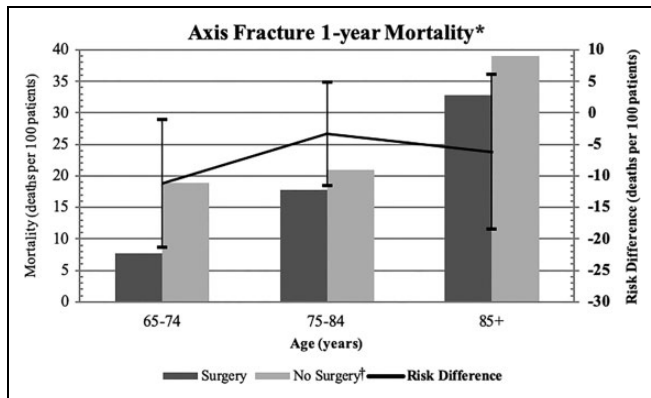
^a95% Confidence intervals.

Figure 3. Bar and line graphs showing 1-year mortality in patients with isolated acute traumatic axis fractures stratified by age as well as propensity-weighted risk difference comparing mortality in surgical patients with nonsurgical patients. Poisson regression was used to estimate the rates and risk differences. It shows 95% confidence intervals and significantly decreased mortality in the 65 to 74 age-group.

fracture and surgical treatment incidence rates were relatively stable, which is what others have found.³⁹ Overall survival data demonstrate congruence showing high 1-year mortality (32 deaths per 100 beneficiaries; SMR 3.8 compared to general population). Patients older than 85 years, who did not receive surgery, experienced the highest mortality. Using a propensity-weighted nonsurgical cohort for comparison, surgery was associated with a 20% relative risk reduction, and 7 fewer deaths per 100 at 1 year. Age profoundly impacted mortality. Surgical mortality was 7.7 for 65 to 74 age-group compared to 32.8 in the 85+ group per 100 beneficiaries at 1 year, which suggests that surgery may have provided a survival benefit, especially in the youngest patients, although considerable selection bias likely contributes to lower surgical mortality rates.

Previous work in this area includes landmark studies from the AO Spine group and the associated odontoid fracture registry analysis.^{14,21,38-40} Each of these well-constructed analyses utilizes a similar cohort of about 640 patients included in the AO Spine registry from roughly 1990 to 2010. Schoenfeld et al²¹ reported a mortality RR of 0.4 (CI: 0.1-1.5) for type 2 odontoid fractures, favoring surgery. Vaccaro et al¹⁴ also found clinically significant improvement in neck disability index and short form-36v2 as well as lower surgical mortality compared to nonsurgical management of type 2 odontoid fractures at 1 year (14% vs 26%). Chapman et al⁴⁰ calculated a mortality RR for nonsurgical management of 1.35 (CI: 0.97-1.89), also favoring surgery. These data suggest that surgical patients aged

65 to 74 years with odontoid fractures have lower mortality and better functional outcomes compared to nonsurgical patients. However, nonrandomized cohort studies of institutional data have limited generalizability with inherent selection bias, and, therefore, guidelines have been slow to recommend surgery in older patients, favoring the “consideration” of surgical stabilization in patients aged 50 years and older.^{10,11}

Over the last 2 decades, propensity score methods have been increasingly used in comparative effectiveness research, especially when the ratio of events to confounders is low.⁴²⁻⁴⁵ Ghaferi and Dimick suggested using propensity scores or instrumental variable analyses for generating causal inference from administrative databases such as Medicare.⁴⁶ Pearson et al were the first to utilize the Medicare data to analyze axis fracture outcomes and used logistic regression to control for confounding.³⁹ Analyses using propensity score weights retain more robust ability for causal inference compared to logistic regression in these data. Using propensity scores, the current study balanced 26 covariates spanning patient demographics, health-care utilization parameters, durable medical equipment claims, medication use, frailty, and geography to control for large unmeasured sources of bias. A strict definition of incidence was used to prevent cross-over with prevalent fractures and multiple counts of a single patient. Pearson et al utilized published algorithms from the spine patient outcomes research trial (SPORT) to identify those who had surgery,^{39,48} but SPORT trial validations were for the identification and classification of surgery for degenerative lumbar disease, not traumatic fractures, and no mention was made as to how the authors distinguished incident fractures from prevalent fractures. The AO Spine registry appropriately attempted to control for a few measurable covariates in patients with traumatic axis fractures receiving surgical or nonsurgical management but, unfortunately, this registry was not necessarily representative of the general US population. Therefore, from a methods perspective, propensity-weighted analyses of representative population-based databases may generate the strongest real-world observational evidence for mortality associated with surgical treatment of axis fractures. Causal inference for comparative efficacy is limited in the absence of a randomized control trial.

Others have used inpatient claims data to estimate burden of axis fractures and effectiveness of surgery in the elderly patients.^{8,11,27,36,39,40,49} Although previous studies report a potential survival advantage for all surgical patients older than 65 years, after stratifying for age, this advantage is questioned in patients aged 75 years and older.³⁹ Regardless of age, unmeasured variables impacting a surgeon’s willingness to offer surgery likely confounds the survival advantage observed

in observational studies. The current study shows that surgeon ability to select patients who would benefit from surgery appears to be more reliable in younger patients. Surgical mortality increased with age, which shows either diminished protective effect of surgery or poor patient selection in older patients. A possible explanation for poorer surgical outcomes in the older age-groups, from a biomechanical standpoint at least, is that the risk of delayed myelopathy from nonunion eventually is balanced by lower demands on the atlantoaxial joint. Thus, a stable nonunion may be considered a safe fracture-healing outcome and thus surgical mortality would approximate nonsurgical mortality.^{11,50} It should be noted that the propensity score weights adjusted more substantially with increasing age but were still able to identify a potential treatment effect from surgery. The 64 to 74 age-group retained significant treatment effect even after adjusting for measured confounding supporting better surgeon prediction of good outcome in this age-group. A possible explanation for treatment effect in this group is that between 65 and 74 years, patients can tolerate surgery and due to poor fracture healing, surgical stabilization aids in creating a more stable union. Finally, a well-tolerated surgery may still associate with improved survival, even in the oldest patients, but the current data suggest caution as age and comorbidities increase. Only a randomized trial could balance potentially unmeasured covariates adequately.

Studies relying on large administrative databases have inherent limitations because estimates depend on accuracy of the database and coding integrity. Using linked mortality data from CMS and National Death Index increases accuracy of mortality data. Surgical decision-making has unmeasurable variables not included here, but important comorbid conditions and baseline predictors of mortality were adjusted for in this study. Despite expected selection bias, crude mortality (Table 2) shows overlapping CIs for in-hospital mortality and divergence thereafter, which supports the expected delayed benefit from surgery. Furthermore, surgical management of axis fractures depends on fracture morphology (eg, type 2 odontoid fractures are the axis fracture morphology in which surgery is most likely considered whereas fractures involving the vertebral body, pedicles, articular pillars, or lamina are less likely to require surgery).¹¹ Our analysis cannot distinguish among various morphologies of fractures due to the single *ICD-9* code for axis fracture. While most axis fractures are odontoid fractures, definitive conclusions about a specific fracture pattern cannot be directly made. Finally, the inclusion of multiple fracture types improves the sensitivity but hinders specificity of our results and makes it impossible to compare different surgical approaches for specific fracture type. Further studies using *International Classification of Diseases, 10th Revision* codes and anterior versus posterior comparisons are needed in order to draw further conclusions about comparative mortality in this cohort of patients.

The complex multifaceted nature of spine trauma in the elderly patients presents a management conundrum. This study is highly generalizable to the US population for outcomes after surgical intervention for isolated acute traumatic axis fractures

in the elderly patients. Given the rates of *stable* nonunion and high surgical mortality in patients aged 75+ years, the authors suggest a more cautious approach to surgical intervention in these patients¹³; stable nonunion may be the safest outcome. For patients aged 65 to 74 years, the authors agree with others that surgery should be strongly considered.

Conclusion

Based on a representative sample of US Medicare patients, those selected for surgery were found to have improved survival. The differences between groups were attenuated with age. Isolated acute axis fracture incidence increases with age, is highly fatal, and standardized mortality weighted survival data suggest an association between surgery and survival benefit in patients aged 65 to 74 years, which decreases with increasing age. Despite the challenges of accurately comparing the effectiveness of surgical interventions based on *ICD-9* and CPT coding methods, these generalizable and well-adjusted observational data provide meaningful evidence.

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ORCID iD

Michael P. Catalino, MD, MSc  <https://orcid.org/0000-0002-0411-6903>

Supplemental Material

Supplemental material for this article is available online.

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