Mortality Rates Associated With Odontoid and Subaxial Cervical Spine Fractures

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Abstract

Cervical spine fractures can lead to many devastating consequences. However, mortality rates of older individuals with odontoid or subaxial spine fractures have not been definitively established.

We conducted a retrospective review of all patients who underwent computed tomography of the cervical spine in the emergency department of a level I trauma center over 9 years to compare mortality rates after odontoid and subaxial fractures in elderly persons with those of the general population. We searched the National Death Index for patient death records, and compared mortality rates at 3 months, 1 year, and 2 years to sex- and age-matched data from the general population.

Odontoid fracture survival was 84.4% at 3 months, 82.2% at 1 year, and 72.9% at 2 years. Male survival was significantly worse compared with age- and sex-matched counterparts ($P < .001$), but female survival was not ($P = .568$). In subaxial fractures, survival was 87.9% at 3 months and 85.7% at 1 and 2 years. Male survival was decreased compared with age- and sex-matched counterparts ($P < .0001$), whereas female survival was not ($P = .554$).

In conclusion, the mortality of men with either fracture was greater compared with age-matched men initially, but this normalized. Female survival was not affected by either fracture.

Mortality rate is an important indicator of the severity of traumatic injuries, and these values have been described for different orthopedic injuries and fractures. Studies have identified 3 distinct trends in patient survival when compared with the age- and sex-matched uninjured population:

1. Hip fractures bring about a transient increase in mortality relative to age-matched controls that normalizes after a few months to 1 year.[1-10]
2. Thoracic and lumbar compression fractures are associated with an ongoing, lifelong increase in mortality rate relative to age-matched controls without an initial marked upswing.[11-15]
3. Certain injuries such as isolated rib or wrist fractures do not adversely affect survival relative to age-matched controls.[12,16-18]

Understanding the mortality patterns after these injuries can help guide management and even facilitate the development of appropriate treatment algorithms.[19-21] While studies have examined mortality in specific odontoid fracture types,[22] such mortality trends have not been broadly established in persons with cervical spine fractures.

Cervical spine fractures are common: 60% of spine fractures localize to this region,[23-26] and this equates to 2% to 3% of all blunt-trauma patients.[27,28] These injuries can lead to devastating consequences, including neurologic compromise, permanent disability, and death.[29-31]

Studies have estimated that up to 20% of cervical fractures involve the odontoid process.[23-26] These injuries are more common among the elderly population because of their greater prevalence of osteoporosis and likelihood of falling.[32] Because of demographic similarities to those of the hip fracture population, a survival analysis of all odontoid fractures is particularly interesting. Published odontoid mortality rates vary significantly, with reports ranging from 13% to 44%.[22,33-35] Unfortunately, these studies largely evaluated survival rates specific to an individual treatment modality, such as nonoperative compared with operative, or specific to certain odontoid fracture types (eg, type II). Additionally, studies have generally only considered survivorship during initial hospitalization, have been specific to a constrained age group, or have been based solely on inpatient records that do not permit the longer-term follow-up critical to determining the effect of odontoid fractures on overall mortality.[36-39]

Likewise, mortality rates after fractures of the subaxial spine (ie, the motion segments between C3 and C7) have yet to be established. In 1 study, the mortality risk of a cohort of elderly patients with cervical fractures appeared to be elevated for the first 6 to 12 months after the traumatic event.[40] However, the sample size was too small to examine mortality beyond 1 year.

In this context, the purpose of the current study was to

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determine the mortality rates at several time points (3 months, 1 year, and 2 years) of patients 50 years or older (start of the second mode of the bimodal age distribution of odontoid fractures[41-44]) with fractures of the odontoid and subaxial cervical spine. A secondary purpose of this study was to compare survival rates of these 2 cohorts relative to each other and to the general population.

Materials and Methods

Identification of Cervical Fractures and Collection of Demographic Information

This protocol was approved by the human investigation committee of our institution. Every computed tomography (CT) scan of the cervical spine performed in the emergency department (ED) of an academic hospital between November 27, 1997, and December 31, 2006, was identified. Since the threshold for obtaining a CT scan of a patient with suspected cervical spine trauma is relatively low, it was assumed that virtually all acute cervical spine fractures during this time period would be successfully identified through this approach.

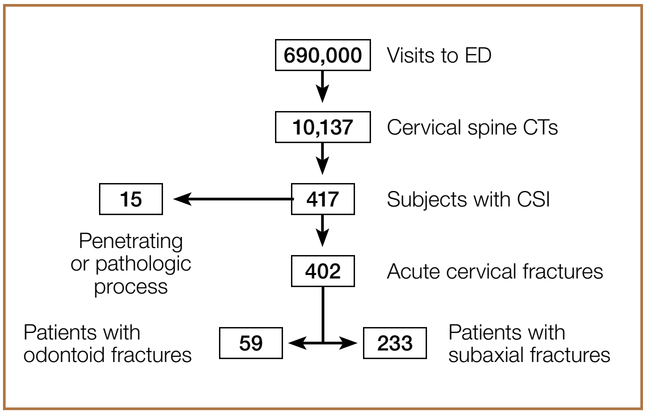

Figure 1. Flowchart depicting the study design and the manner in which the final cohorts were identified. Abbreviations: ED, emergency department; CT, computed tomography; CSI, cervical spine injury.

Radiology reports for all identified CT scans were reviewed for any findings consistent with acute fractures and/or dislocations of the cervical spine (**Figure 1**). Every study noted to be positive or equivocal for cervical trauma was directly visualized, including those that did not specifically mention the presence or absence of an injury. Scans with no signs of acute trauma or that showed fractures caused by a pathologic process or penetrating mechanism (eg, metastatic lesions or gunshot wounds) were omitted from this series. Finally, relevant demographic information, such as the medical record number, age, gender, and date of study, was recorded for every subject in this group.

Fracture Classification

Next, the level and the type of cervical injury were documented for each patient. Fractures were segregated according to their involvement with the odontoid or the subaxial vertebrae.

Odontoid fractures were categorized into type I (limited to the tip), type II (across the base of the process) and type III (through the base with extension into the C2 vertebral body).[45,46] Since many systems for classifying subaxial cervical spine trauma require a subjective inference of the injury mechanism, which is difficult to ascertain from imaging studies alone, all of these fractures were pooled together.

A preliminary survey of the data indicated that the odontoid fractures appeared to exhibit a bimodal age distribution, with the beginning of the second cluster occurring around age 50 years (**Figure 2**). As noted above, this has been shown in previous studies.[41-44] As a consequence, the mortalities of those older than 50 years became the focus of this study. To control for comorbid conditions, mechanism of injury, and to allow for more direct comparison with the odontoid fractures in this study, the same age demarcation was used for subaxial cervical fractures.

Mortality Data

The mortality status of every patient diagnosed with an acute cervical injury at our institution between November 27, 1997,

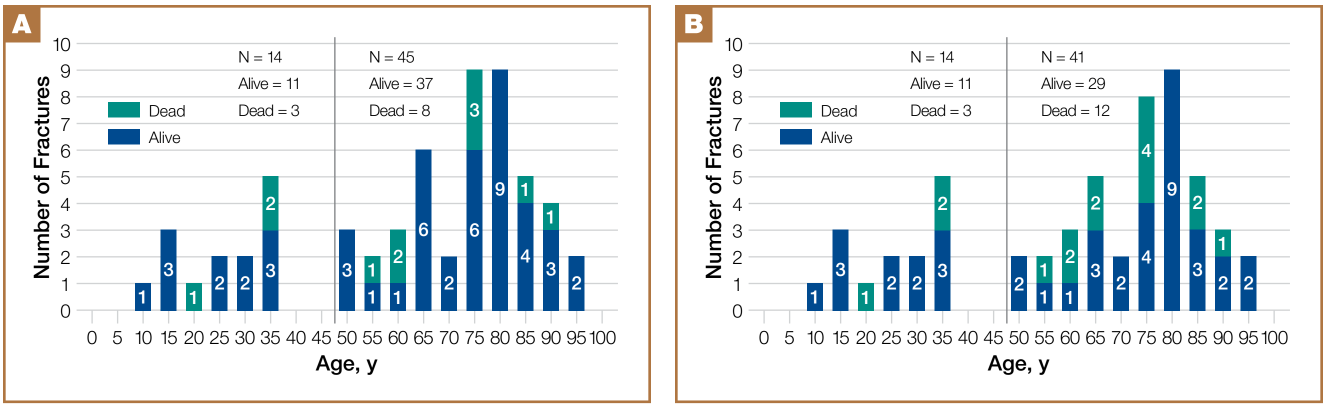

Figure 2. Incidence and survival data of patients with odontoid fractures at (A) 1 and (B) 2 years after the time of injury. These fractures are divided into 2 distinct populations based on the bimodal age distribution that was evident for this specific fracture type. Subjects with less than 2-year follow-up are not included in Figure 2B.

and December 31, 2006, was determined by referencing the National Death Index (NDI). The NDI is a computerized database of death records maintained by the National Center for Health Statistics (NCHS). The time window for the current study was selected because we had access to NDI information only through 2007 at the time of this study. Social Security numbers (SSNs), which were available for approximately half of the subjects, were used to search the NDI catalog. For individuals whose SSNs were unavailable, patient names and birthdates were considered to be sufficient to confirm a true match. Our center's medical records of this cohort were also examined to verify whether any had died during their initial hospitalizations and to substantiate the NDI data. Finally, patient deaths were categorized as trauma (eg, motor vehicle accident, fall from a height) or medical comorbidity (eg, diabetes mellitus, cancer, congestive heart failure), based on information in the NDI listing.

Age- and Sex-Matched Controls

Age- and sex-matched controls were determined from the Wide-ranging Online Data for Epidemiologic Research (WONDER) application distributed by the Centers for Disease Control and Prevention (http://wonder.cdc.gov). Composite mortality data from the state in which the study was performed was obtained for the years between 1999 and 2007, and this information was further stratified according to gender and age to estimate the mortality rates and construct survival curves for each group. Controls were used to establish a standardized mortality ratio (SMR) for subjects 50 years and older, a value that compares the number of observed deaths with the figure expected for matched populations from the general population.

Statistical Methods

Statistical analyses were performed by using both SAS 9.2 (SAS Institute Inc., Cary, North Carolina) and R (version 2.9; www.r-project.org, Auckland, New Zealand). Relevant comparisons were planned, and all tests were 2-sided. The Wilcoxon rank sum test was applied to compare the survival times of patients with odontoid fractures with different documented causes of death, and Pearson χ^2 test was used to compare the age distributions of odontoid and subaxial fractures. Survival rates at 3 months, 1 year, and 2 years were estimated from Kaplan-Meier curves. The relative survival of these cohorts was compared by completing a 2-sample log-rank test. In addition, a 1-sample log-rank test was implemented to compare the mortality from either odontoid or subaxial cervical spine fractures with that of the age- and gender-matched general population. Statistical significance was defined as a 2-sided α error of less than 0.05 ($P < .05$).

Results

Fifty-nine patients were diagnosed with odontoid fractures (28 men, 31 women), and 233 patients were diagnosed with subaxial cervical spine fractures (168 men, 65 women).

Odontoid Fracture Patients

Odontoid fracture patients exhibited a distinct bimodal age distribution (**Figure 2**). In the younger population, there were 14 subjects, 3 of whom died within days of the injury (mean, 12 days; 78.6% survival). At 2-year follow-up, there were no further deaths. The fractures that caused death were high-energy injuries, and only early deaths occurred in these cases.

Because of the significant bimodal age distribution, it was believed these cohorts could not be directly compared. As a result, the remaining analysis focused on the older age group. In the older population mode (50 years and older) were 45 patients with odontoid fractures. Of the 12 subjects who died after odontoid fracture, 5 were assigned a trauma code as the cause of death, while a medical comorbidity code was assigned for the remaining 7. Mean survival time of those who died secondary to trauma was significantly shorter than the medical comorbidity group ($P = .025$).

In the cohort of subjects older than 50 years, 3-month, 1-year, and 2-year survival rates were 84.4%, 82.2%, and 72.9%, respectively. **Figure 2** shows the 1- and 2-year follow-up data by age group.

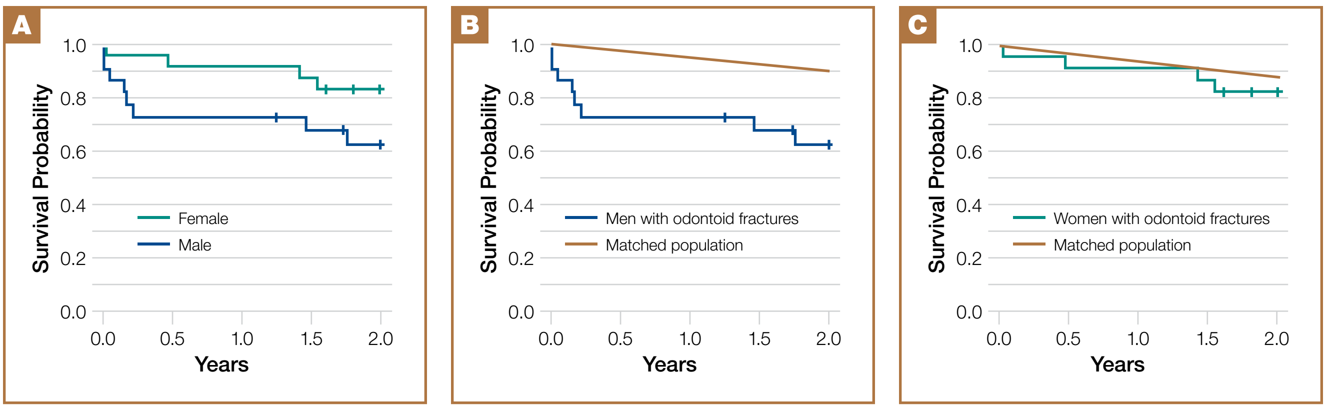

Figure 3. Comparison of the Kaplan-Meier survival curves of patients older than 50 years with odontoid fractures with those derived for the general population. (A) Survival curves of male and female subjects with odontoid fractures. (B) Survival curves of men with odontoid fractures and corresponding male controls. (C) Survival curves of women with odontoid fractures and corresponding female controls.

Analysis was performed relative to gender. Of male patients (n = 22), the 3-month, 1-year, and 2-year survival rates were 72.7%, 72.7%, and 62.7%, respectively. Among women (n = 23), the 3-month, 1-year, and 2-year survival rates were 95.7%, 91.3%, and 82.6%, respectively.

Figure 3 shows the Kaplan-Meier survival curves of the older patients with odontoid fractures. A comparison of the curves for each gender showed no significant disparities between the male and female survival (**Figure 3A**, P = .124). Compared with age-matched male counterparts, the survival of male subjects with odontoid fractures was significantly worse (**Figure 3B**, P < .001). Men experienced an initial acute decline in survival, with the remainder of the survival curve matching that of the general male population. In contrast, odontoid fractures did not adversely affect female survival compared with the matched population (**Figure 3C**, P = .568).

The 2-year SMR of 2.98 for men showed that odontoid fractures led to greater mortality compared with a sex- and age-matched population. This means that men older than 50 years who sustained an odontoid fracture had nearly 3 times the mortality rate after 2 years compared with a normal, matched population; this increase is attributed to the 3-month time point that subsequently normalized. The female rate was 1.33 times that of a matched population, a difference that is not statistically significant.

Subaxial Fracture Patients

Of the 91 patients older than 50 years with subaxial fractures, 3-month, 1-year, and 2-year survival rates were 87.9%, 85.7%, and 85.7%, respectively. **Figure 4** shows the 1- and 2-year follow-up data by age group.

Gender-specific analysis was performed. For men (n = 58), the 3-month, 1-year, and 2-year survival rates were 87.9%, 84.5%, and 84.5%, respectively. Among women (n = 33), 4 deaths were recorded at all time points (87.9% survival).

Figure 5 shows Kaplan-Meier survival curves for the older population with subaxial fractures. A comparison of the curves between genders again showed no significant differences between male and female survival (P = .683, **Figure 5A**). Compared with age- and gender-matched counterparts, men showed decreased relative survival (P < .0001, **Figure 5B**), whereas subaxial fractures did not decrease female survival (P = .554, **Figure 5C**).

The 2-year SMR of 2.90 for men showed higher mortality rates relative to sex- and age-matched controls. Men who were both 50 years old and sustained a subaxial fracture were 2.9 times as likely to die within 2 years of follow-up compared with their counterparts. Similar to odontoid fractures, this increase occurred by the 3-month time point and subsequently normalized. The female rate, which was 1.34 times that of the uninjured population, was not statistically significant.

Comparison of Odontoid and Subaxial Fracture Patients

The survival of subaxial injuries was not significantly different from that of odontoid fractures (P = .113, **Figure 6A**). When analyzed by gender and controlled for age, the rates in both male (P = .347, **Figure 6B**) and female (P = .643, **Figure 6C**) patients did not differ between fracture types.

Discussion

The US population is aging rapidly, with the demographic older than 65 years predicted to more than double in size between 2010 and 2050.[47] As our elderly population grows, the incidence of age-related injuries will rise accordingly. An understanding of mortality risks associated with different fractures will not only assist practitioners in advising patients regarding prognosis but may also lead to improvements in clinical care.[19,48-50] While we know cervical spine trauma is associated with significant morbidity,[29-31] little is known about associated moderate-term mortality rates that can be compared with other known injury patterns, such as hip fractures or osteoporotic compression fractures.

An interesting finding of the present study is the bimodal age distribution of the 59 odontoid fractures (**Figure 2**). The 14 patients younger than 50 years included 3 individuals who died, all within days of their presentation from severe mul-

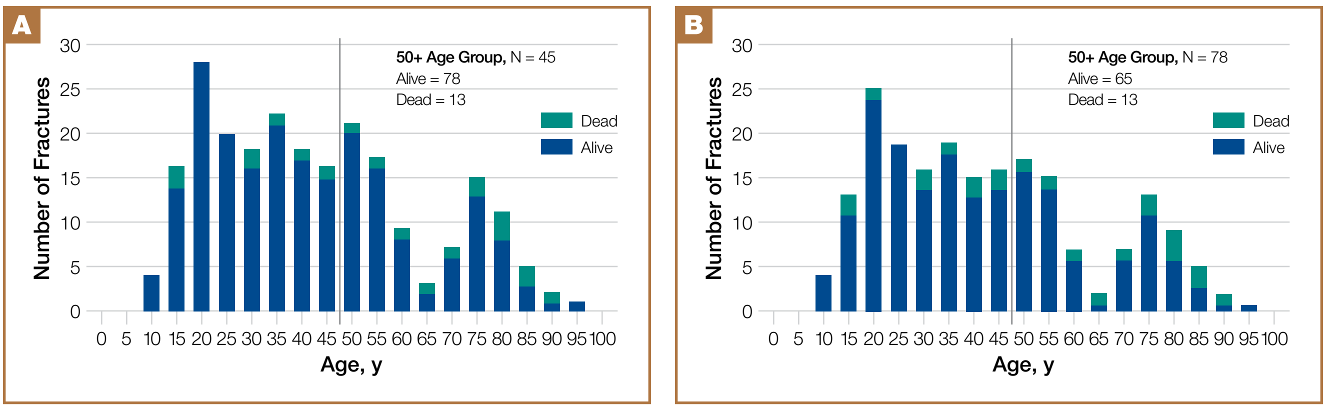

Figure 4. Incidence and survival data of patients with subaxial cervical spine fractures at (A) 1 and (B) 2 years after the time of injury. Similar to odontoid fractures, these injuries are also divided into 2 separate subgroups using a threshold of 50 years. Subjects with less than 2-year follow-up are not included in Figure 4B.

tisystem trauma. This is consistent with the determination that high-energy forces are required to fracture the odontoid process in younger individuals.[38,45,46,51,52] Given the severity of their nonspinal injuries, the cause of death was likely not primarily related to their odontoid fractures. Also in line with previous studies, the majority (76%) of odontoid fractures were documented in subjects older than 50 years.[32,53,54] Within our cohort older than 50 years, the deaths appear to be spread evenly across age groups and do not seem to be skewed by the oldest portion of the population (**Figure 2**).

Our gender-specific analyses revealed that older men with odontoid injuries exhibited higher mortality compared with an age-matched male cohort, with 6 of the 8 deaths occurring within 3 months. However, after this exaggerated decline in survival, the rate normalized towards general population mortality rates (**Figure 3B**). As in the younger cohort, these earlier deaths were largely attributable to multisystem trauma, whereas medical comorbidities were implicated in those who died later. In contrast, the Kaplan-Meier curve of older women with odontoid fractures closely approximates that of age-matched women at every time point (**Figure 3C**), indicating that these injuries do not decrease survival as they do in their male counterparts.

When comparing the survival of older patients with subaxial cervical spine fractures with that of gender- and age-matched controls, the mortality rates of women were, once again, essentially equivalent. However, the survival of older men was significantly compromised by these injuries. In men, 7 of the 9 deaths were within 3 months, with the remaining 2 deaths occurring within 7 months. Nevertheless, beyond this initial period of elevated mortality, the survival curve again stabilized and paralleled that of the general population. As with odontoid fractures, there was no sustained increase in the mortality of male patients who lived at least 3 months after injury.

The mortality rates of odontoid and subaxial fractures were also compared in the older population. When controlled for

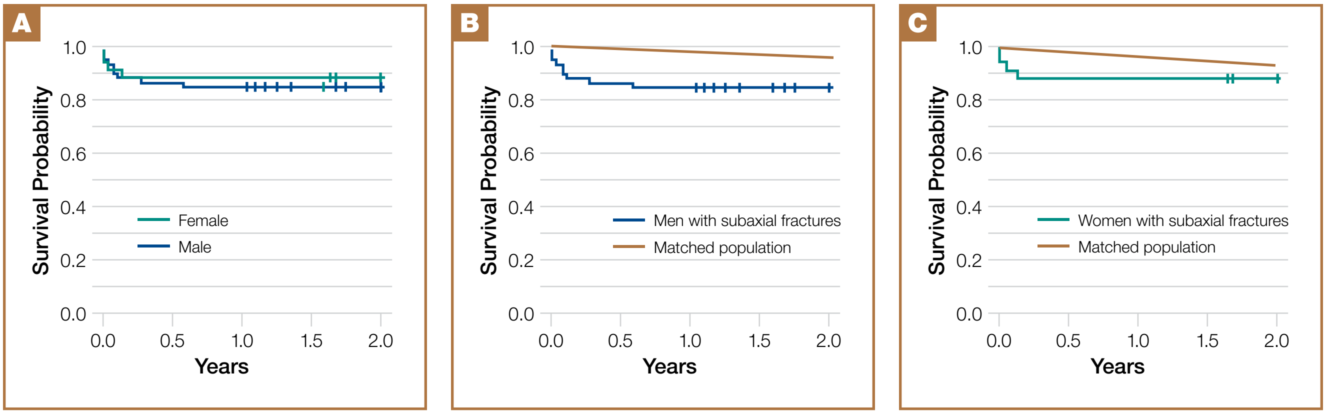

Figure 5. Comparison of the Kaplan-Meier survival curves of patients 50 years or older with fractures of the subaxial cervical spine with those derived for the general population. (A) Survival curves of male and female subjects with subaxial fractures. (B) Survival curves of men with subaxial fractures and corresponding male controls. (C) Survival curves of women with subaxial fractures and corresponding female controls.

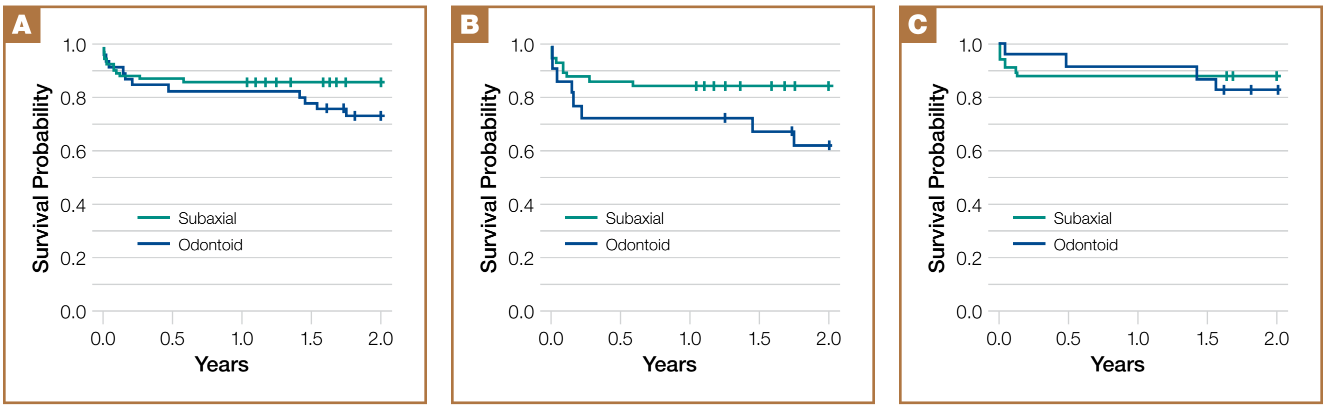

Figure 6. Comparison of the Kaplan-Meier survival curves of patients 50 years or older with either odontoid or subaxial cervical spine fractures. (A) Survival curves for subaxial and odontoid fracture cohorts. (B) Survival curves of men with subaxial or odontoid fractures. (C) Survival curves of women with subaxial or odontoid fractures.

age, there was no difference in mortality rates between these 2 groups. When individually analyzed in both men and women, the mortality rates of both fracture types matched those of the general population at all time points.

It is useful to contextualize our findings alongside the mortality of older individuals with other fracture types. Based on our results, we believe that the survival curves of geriatric men with odontoid or subaxial cervical spine fractures most closely resemble the characteristic pattern seen in hip fractures. Hip fractures have shown an early spike in mortality by as much as 8% to 49% in the first 6 to 12 months that returns to baseline after 1 year.[1-10] This presumably reflects the natural history of these injuries in response to appropriate therapeutic interventions. Interestingly, the male mortality rates for both odontoid and subaxial cervical spine fractures in this study are largely analogous to those reported by various hip fracture surveys.[1,5,55-58] In contrast, similar to prior studies of rib or wrist fractures, older women with these cervical spine fractures did not show a survival decrease after their injuries.[12,16-18]

While the reasons underlying the differential effects of cervical fractures on the mortality of men and women have not been established, one explanation is that the female geriatric population is relatively more osteoporotic; thus, cervical injuries may occur after lower-energy forces, leading to less severe associated trauma that could otherwise decrease survival. Another explanation is that men are more likely to be involved in high-energy accidents,[59,60] thus decreasing their overall survival after injury.

This investigation is not without limitations. Our primary concern is the determination of survival. The NDI maintained by the NCHS is an extremely reliable tool regularly employed by epidemiologists to collect mortality data. However, it is possible that deaths may have been missed. We believe this number would be small, because the NDI database provided multiple probable matches that were carefully compared with supplemental personal information. It is also possible that deaths that were not appropriately registered with the NDI are not represented in this series. Another limitation lies in the determination of controls. As with any case–control study, the patients sustaining these odontoid fractures may differ in some significant way from the average population. A final limitation is that a small portion of patients in the study have only 1-year follow-up, because patient data was collected through 2006, although access to NDI data ended in 2007.

Conclusion

Our results indicate that the survival of older men with either odontoid or subaxial cervical spine fractures shares many of the same mortality characteristics as hip fractures, with diminished survival in the first 3 months that normalizes to the survival rate of the age-matched population. Interestingly, and perhaps because of disparate rates of osteoporosis and traumatic forces, the mortality rates in the female cohort were similar to that of the age-matched general population at all time points. These trends were nearly identical for both odontoid and subaxial cervical fractures.

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References

1. Gennarelli TA, Champion HR, Sacco WJ, Copes WS, Alves WM. Mortality of patients with head injury and extracranial injury treated in trauma centers. *J Trauma*. 1989;29(9):1193-1201; discussion 1201-1202.
2. George GH, Patel S. Secondary prevention of hip fracture. *Rheumatology (Oxford)*. 2000;39(4):346-349.
3. Gerrelts BD, Petersen EU, Mabry J, Petersen SR. Delayed diagnosis of cervical spine injuries. *J Trauma*. 1991;31(12):1622-1626.
4. Giannoudis PV, Mehta SS, Tsiridis E. Incidence and outcome of whiplash injury after multiple trauma. *Spine*. 2007;32(7):776-781.
5. Goldberg W, Mueller C, Panacek E, et al. Distribution and patterns of blunt traumatic cervical spine injury. *Ann Emerg Med*. 2001;38(1):17-21.
6. Grauer JN, Shafi B, Hilibrand AS, et al. Proposal of a modified, treatment-oriented classification of odontoid fractures. *Spine J*. 2005;5(2):123-129.
7. Greene KA, Dickman CA, Marciano FF, Drabier JB, Hadley MN, Sonntag VK. Acute axis fractures. Analysis of management and outcome in 340 consecutive cases. *Spine*. 1997;22(16):1843-1852.
8. Gulli B, Templeman D. Compartment syndrome of the lower extremity. *Orthop Clin North Am*. 1994;25(4):677-684.
9. Guthkelch AN, Fleischer AS. Patterns of cervical spine injury and their associated lesions. *West J Med*. 1987;147(4):428-431.
10. Hackl W, Hausberger K, Sailer R, Ulmer H, Gassner R. Prevalence of cervical spine injuries in patients with facial trauma. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2001;92(4):370-376.
11. Doruk H, Mas MR, Yildiz C, Sonmez A, Kyrdemir V. The effect of the timing of hip fracture surgery on the activity of daily living and mortality in elderly. *Arch Gerontol Geriatr*. 2004;39(2):179-185.
12. Garabige V, Giraud P, De Rycke Y, et al. [Impact of nutrition management in patients with head and neck cancers treated with irradiation: is the nutritional intervention useful?]. *Cancer Radiother*. 2007;11(3):111-116.
13. Garbuz DS, Leitch K, Wright JG. The treatment of supracondylar fractures in children with an absent radial pulse. *J Pediatr Orthop*. 1996;16(5):594-596.
14. Henderson RL, Reid DC, Saboe LA. Multiple noncontiguous spine fractures. *Spine*. 1991;16(2):128-131.
15. Henrikson B. Supracondylar fracture of the humerus in children. A late review of end-results with special reference to the cause of deformity, disability and complications. *Acta Chir Scand Suppl*. 1966;369:1-72.
16. De Boeck H, De Smet P, Penders W, De Rydt D. Supracondylar elbow fractures with impaction of the medial condyle in children. *J Pediatr Orthop*. 1995;15(4):444-448.
17. Gelberman RH, Panagis JS, Taleisnik J, Baumgaertner M. The arterial anatomy of the human carpus. Part I: The extraosseous vascularity. *J Hand Surg Am*. 1983;8(4):367-375.
18. Hu J, Liao Q, Long W. Diagnosis and treatment of multiple-level non-contiguous spinal fractures. *Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi*. 2005;19(6):424-426.
19. Eleraky MA, Theodore N, Adams M, Rekate HL, Sonntag VK. Pediatric cervical spine injuries: report of 102 cases and review of the literature. *J Neurosurg*. 2000;92(1 suppl):12-17.
20. Ioannidis G, Papaioannou A, Hopman WM, et al. Relation between fractures and mortality: results from the Canadian Multicentre Osteoporosis Study. *CMAJ*. 2009;181(5):265-271.

21. Husby J, Sorensen KH. Fracture of the odontoid process of the axis. *Acta Orthop Scand*. 1974;45(2):182-192.
22. Schoenfeld AJ, Bono CM, Reichmann WM, et al. Type II odontoid fractures of the cervical spine: do treatment type and medical comorbidities affect mortality in elderly patients? *Spine*. 2011;36(11):879-885.
23. Ensrud KE, Thompson DE, Cauley JA, et al. Prevalent vertebral deformities predict mortality and hospitalization in older women with low bone mass. Fracture Intervention Trial Research Group. *J Am Geriatr Soc*. 2000;48(3):241-249.
24. Fassett DR, Dailey AT, Vaccaro AR. Vertebral artery injuries associated with cervical spine injuries: a review of the literature. *J Spinal Disord Tech*. 2008;21(4):252-258.
25. Ippolito E, Caterini R, Scola E. Supracondylar fractures of the humerus in children. Analysis at maturity of fifty-three patients treated conservatively. *J Bone Joint Surg Am*. 1986;68(3):333-344.
26. Spence KF Jr, Decker S, Sell KW. Bursting atlantal fracture associated with rupture of the transverse ligament. *J Bone Joint Surg Am*. 1970;52(3): 543-549.
27. Irwin ZN, Arthur M, Mullins RJ, Hart RA. Variations in injury patterns, treatment, and outcome for spinal fracture and paralysis in adult versus geriatric patients. *Spine.* 2004;29(7):796-802.
28. Ismail AA, O'Neill TW, Cooper C, et al. Mortality associated with vertebral deformity in men and women: results from the European Prospective Osteoporosis Study (EPOS). *Osteoporos Int*. 1998;8(3):291-297.
29. Iyengar SR, Hoffinger SA, Townsend DR. Early versus delayed reduction and pinning of type III displaced supracondylar fractures of the humerus in children: a comparative study. *J Orthop Trauma*. 1999;13(1):51-55.
30. Jackson AP, Haak MH, Khan N, Meyer PR. Cervical spine injuries in the elderly: acute postoperative mortality. *Spine*. 2005;30(13):1524-1527.
31. Jacobsen SJ, Goldberg J, Miles TP, Brody JA, Stiers W, Rimm AA. Race and sex differences in mortality following fracture of the hip. *Am J Public Health*. 1992;82(8):1147-1150.
32. Fisher ES, Baron JA, Malenka DJ, et al. Hip fracture incidence and mortality in New England. *Epidemiology.* 1991;2(2):116-122.
33. Chapman J, Smith JS, Kopjar B, et al. The AOSpine North America Geriatric Odontoid Fracture Mortality Study: a retrospective review of mortality outcomes for operative versus nonoperative treatment of 322 patients with long-term follow-up. *Spine*. 2013;38:1098-1104.
34. Denault A, Bains I, Moghadam K, Hu RW, Swamy G. Evaluation of mortality following an odontoid fracture in the octogenarian population. *J Bone Joint Surg Br.* 2011;93(Supp IV):585.
35. Molinari WJ III, Molinari RW, Khera OA, Gruhn WL. Functional outcomes, morbidity, mortality, and fracture healing in 58 consecutive patients with geriatric odontoid fracture treated with cervical collar or posterior fusion. *Global Spine J*. 2013;3(1):21-32.
36. Hanigan WC, Powell FC, Elwood PW, Henderson JP. Odontoid fractures in elderly patients. *J Neurosurg*. 1993;78(1):32-35.
37. Korres DS, Boscainos PJ, Papagelopoulos PJ, Psycharis I, Goudelis G, Nikolopoulos K. Multiple level noncontiguous fractures of the spine. *Clin Orthop*. 2003;411:95-102.
38. Leet AI, Frisancho J, Ebramzadeh E. Delayed treatment of type 3 supracondylar humerus fractures in children. *J Pediatr Orthop*. 2002;22(2):203-207.
39. Leone A, Cerase A, Colosimo C, Lauro L, Puca A, Marano P. Occipital condylar fractures: a review. *Radiology*. 2000;216(3):635-644.
40. Lyles KW, Colón-Emeric CS, Magaziner JS, et al; HORIZON Recurrent Fracture Trial. Zoledronic acid and clinical fractures and mortality after hip fracture. *N Engl J Med*. 2007;357(18):1799-1809.
41. Müller EJ, Wick M, Russe O, Muhr G. Management of odontoid fractures in the elderly. *Eur Spine J*. 1999;8(5):360-365.
42. Pepin JW, Bourne RB, Hawkins RJ. Odontoid fractures, with special reference to the elderly patient. *Clin Orthop*. 1985;193:178-183.
43. Ryan MD, Henderson JJ. The epidemiology of fractures and fracture-dislocations of the cervical spine. *Injury*. 1992;23(1):38-40.
44. Butler JS, Dolan RT, Burbridge M, et al. The long-term functional outcome of type II odontoid fractures managed non-operatively. *Eur Spine J*. 2010;19(10):1635-1642.
45. Levine AM, Edwards CC. The management of traumatic spondylolisthesis of the axis. *J Bone Joint Surg Am*. 1985;67(2):217-226.
46. Lowery DW, Wald MM, Browne BJ, Tigges S, Hoffman JR, Mover WR; NEXUS Group. Epidemiology of cervical spine injury victims. *Ann Emerg Med*. 2001;38(1):12-16.
47. Jacobsen LA, Kent M, Lee M, Mather M. America's aging population. *Popul Bull*. 2011;66(1):1-16. http://www.prb.org/pdf11/aging-in-america.pdf. Published February 2011. Accessed April 22, 2015.
48. Holly LT, Kelly DF, Counelis GJ, Blinman T, McArthur DL, Cryer HG. Cervical spine trauma associated with moderate and severe head injury: incidence, risk factors, and injury characteristics. *J Neurosurg*. 2002;96(3 suppl):285-291.
49. Holmes JF, Akkinepalli R. Computed tomography versus plain radiography to screen for cervical spine injury: a meta-analysis. *J Trauma*. 2005;58(5):902-905.
50. Hove LM. Epidemiology of scaphoid fractures in Bergen, Norway. *Scand J Plast Reconstr Surg Hand Surg*. 1999;33(4):423-426.
51. Lu-Yao G, Baron Ja, Barrett Ja, Fisher Es. Treatment and survival among elderly Americans with hip fractures: a population-based study. *Am J Public Health*. 1994;84(8):1287-1291.
52. Lu-Yao GL, Keller RB, Littenberg B, Wennberg JE. Outcomes after displaced fractures of the femoral neck. A meta-analysis of one hundred and six published reports. *J Bone Joint Surg Am*. 1994;76(1):15-25.
53. Kado DM, Browner WS, Palermo L, Nevitt MC, Genant HK, Cummings SR. Vertebral fractures and mortality in older women: a prospective study. Study of Osteoporotic Fractures Research Group. *Arch Intern Med*. 1999;159(11):1215-1220.
54. Levine AM, Edwards CC. Fractures of the atlas. *J Bone Joint Surg Am*. 1991;73(5):680-691.
55. Maak TG, Grauer JN. The contemporary treatment of odontoid injuries. *Spine*. 2006;31(11 Suppl):S53-S60; discussion S61.
56. Magaziner J, Fredman L, Hawkes W, et al. Changes in functional status attributable to hip fracture: a comparison of hip fracture patients to community-dwelling aged. *Am J Epidemiol.* 2003;157(11):1023-1031.
57. Magaziner J, Hawkes W, Hebel JR, et al. Recovery from hip fracture in eight areas of function. *J Gerontol A Biol Sci Med Sci*. 2000;55(9):M498-M507.
58. Malham GM, Ackland HM, Jones R, Williamson OD, Varma DK. Occipital condyle fractures: incidence and clinical follow-up at a level 1 trauma centre. *Emerg Radiol*. 2009;16(4):291-297.
59. Probst C, Zelle B, Panzica M, et al. Clinical re-examination 10 or more years after polytrauma: is there a gender related difference? *J Trauma*. 2010;68(3):706-711.
60. Holbrook TL, Hoyt DB, Anderson JP. The importance of gender on outcome after major trauma: functional and psychologic outcomes in women versus men. *J Trauma*. 2001;50(2):270-273.

This paper will be judged for the Resident Writer's Award.