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Clinical Study

Predicting survival in older patients treated for cervical spine fractures: development of a clinical survival score

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Abstract

BACKGROUND CONTEXT: Emerging literature has identified the importance of pretreatment health and functional status as influential in the prognostication of survival. A comprehensive, accessible, predictive model for survival following cervical spine fracture has yet to be developed.

PURPOSE: To develop an accessible and intuitive predictive model for survival in individuals aged 50 and older treated for cervical spine fractures.

STUDY DESIGN: Retrospective review of records from two tertiary care centers (2009–2016).

PATIENT SAMPLE: Patients age 50 and older who received operative or nonoperative management for cervical fractures.

OUTCOME MEASURES: One-year mortality was the primary outcome with 3-month and 2-year mortality considered secondarily.

METHODS: Multivariable logistic regression was used to identify factors independently associated with mortality. The magnitude and precision of the relationship with 1-year mortality for statistically significant variables determined weighting in the scoring system subsequently developed. Score performance was tested through multivariable regression and bootstrap simulation. In a sensitivity test, the performance of the score developed for 1-year mortality was assessed using figures for the 3-month and 2-year time-points.

RESULTS: We included 1,758 patients. Mortality rates were 12% at 3 months, 17% at 1 year, and 21% at 2 years. Following multivariable testing age, injury severity score and Glasgow coma scale demonstrated the strongest predictive values for a base score, followed by serum albumin and ambulatory status. The resultant composite score ranged from 0 (base score≤4, albumin≤3.5 g/dL, and dependent/nonambulator at presentation) to a maximum of 4 (base score≥5, albumin>3.5 g/dL, and independent ambulator at presentation). Following multivariable analysis, when compared to patients with a score of 4, significantly increased odds of 1-year mortality were appreciated for those with scores of 3 (odds ratio [OR] 7.35; 95% confidence interval [CI] 3.77, 14.32), 2 (OR 8.43; 95% CI 4.66, 15.25), 1 (OR 17.47; 95% CI 9.81, 31.11), and 0 (OR 26.58; 95% CI 13.87, 50.92). Score performance was unchanged in bootstrap testing and sensitivity analyses.

CONCLUSIONS: We have developed a useful prognostic utility capable of informing survival in individuals age 50 and older, following cervical spine fractures. The score can be applied to adjust

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patient expectations, anticipate outcomes, and as an adjunct to decision-making in the postinjury period.

Keywords: Albumin; Cervical spine fracture; Functional status; Prognostic models; Survival; geriatrics

Introduction

The demographic over age 65 represents the fastest growing segment of the US population and accounts for a sizable proportion of hospital trauma admissions [1,2]. Cervical fractures comprise over 40% of all spinal injuries within this cohort, with relatively high rates of morbidity and even accelerated mortality following such trauma [3–7]. Rates of surgical management for cervical fractures have risen in parallel, resulting in increased financial burdens on the healthcare system [8]. In recent work, care for C2 fractures alone has been estimated to account for nearly $1.5 billion in hospital expenditures per year [3,9].

Treatment decisions in elderly patients must balance the risk of adverse outcomes such as chronic pain, pseudarthrosis, and threat to neurovascular structures against anticipated longevity and the ability to tolerate an intervention. Post-treatment mortality following cervical spine fractures in elderly patients has been reported to exceed that of the general population [6,8–12]. Additionally, adverse events such as aspiration, cerebrovascular insult, decubitus ulcers, and wound infections are also high [6,8–12]. A variety of factors influencing survival following cervical fracture have been postulated including patient age, sex, the presence of hyperostotic disease, comorbidity burden, and injury severity [3,4,9,13–15]. Many of these determinations, however, are limited by sample size, study design, and/or the clinical characteristics considered in the investigation [3,4,9,13–15]. While surgical intervention has previously been shown to be protective among specific age groups [9], these findings have not been replicated uniformly across different samples, and are prone to selection bias [12,16]. Furthermore, many of the works currently available do not provide information that can be applied to all individuals who present with a cervical spine fracture, but rather limit the scope to a select injury type (eg, odontoid fracture) or patients who receive surgical intervention.

Emerging literature in other areas of spine surgery has identified the importance of an individual's pretreatment health and functional status as influential factors in the prognostication of survival and other outcomes [18,19]. In these studies, ambulatory status at the time of presentation has been used as a proxy for physical function, while serum albumin has been considered a measure of pretreatment health and nutritional status [18,19]. In this context, we sought to apply this rubric to prognostication of survival in individuals aged 50 and older treated for cervical spine fractures, irrespective of whether operative or nonsurgical management was received. We utilized a large series of patients treated at two level I trauma centers in New England between 2009 and 2016. Based on prior work [18,19], we felt that a scoring scheme consisting of clinical and demographic characteristics, serum albumin, and ambulatory status at the time of presentation would successfully predict survival in patients treated operatively and nonoperatively for cervical fractures. We hypothesized that patients with worse prognostic scores would have higher rates of mortality.

Methods

Data source and abstraction

This study was conducted using data obtained from the Partners Healthcare Research Patient Data Repository (RPDR), a clinical registry that has previously been utilized for research in healthcare policy, orthopedics, and spine surgery [4,11,19–22]. We queried the RPDR using International Classification of Disease ninth Revision (ICD-9) codes to identify patients (age 50 and older) treated for cervical spine fractures at Brigham and Women's Hospital or Massachusetts General Hospital between 2009 and 2016.

Patients who met inclusion criteria had their medical records reviewed by one of the four authors (PKC, AWB, CCM, and EKS) to extract sociodemographic characteristics including patient age at the time of presentation, biologic sex, race, smoking status, and body mass index. Clinical characteristics obtained consisted of the location of cervical injury, presence of hyperostotic disease (eg, ankylosing spondylitis or diffuse idiopathic skeletal hyperostosis) [20] number of medical comorbidities as characterized using the Deyo-modified Charlson comorbidity index (CCI) [23], mechanism of injury, injury severity score (ISS), presence of polytrauma, and Glasgow coma scale (GCS). Serum albumin within 30 days of injury, symptoms, and ambulatory status at the time of presentation were also determined. We further identified individuals who received surgical intervention for their fracture and, in such situations, recorded the surgical approach as well. Mortality, including the date of death, as reported in the RPDR (which is linked to the National Death Index) [4,11,19–21] or medical record were also abstracted.

Variable definition

One-year mortality was used as the primary outcome with 3-month and 2-year mortality considered secondarily. All variables abstracted were considered eligible predictors. Age was evaluated using deciles from 50 to >90, with those 50 to 60 serving as the referent. This was performed to allow for a referent category with variation in comorbidities, injury mechanism, and patterns, as well as indications for treatment that would approximate those encountered in

the more advanced age groups considered here. Race was dichotomized as White or non-White (eg, African-American, Hispanic, Asian, Native American, Other Race, Mixed Race, No Race reported) based on patient self-report. Level of injury was classified as upper cervical (including occipitocervical junction) without odontoid fracture, upper cervical with odontoid fracture, and subaxial [4–7]. Mechanism of injury was defined as high (eg, motor vehicle or motorcycle accident) or low (eg, fall from standing, fall out of bed) velocity. Symptoms at presentation were stratified as asymptomatic or axial pain only vs neurologic symptoms (eg, radicular symptoms, hemiparesis, complete or incomplete spinal cord injury). CCI, ISS, and GCS were handled as continuous variables. In line with prior research [18,19], serum albumin was dichotomized using 3.5 mg/dL as the threshold and ambulatory status at presentation was defined as independent or dependent (eg, requiring cane, walker, or other assistive device)/nonambulatory based on documentation in the medical record at the time of injury.

Statistical analysis

The unadjusted relationship between predictor variables and 1-year mortality was assessed using chi-square testing for categorical variables and Student's *t* test for continuous variables with the Wilcoxon log rank test employed for nonparametric data. Multivariable logistic regression was utilized to adjust for all covariates in the model and identify factors independently associated with mortality within 1 year of presentation. Clinically relevant factors, such as level of injury and surgical intervention, were forced into the multivariable model irrespective of their performance in unadjusted bivariate testing. Model discrimination and calibrations were evaluated using the c-statistic and Hosmer–Lemeshow goodness of fit test, respectively [24]. Statistical significance in multivariable testing was determined, a priori, to be present for factors with odds ratio (OR) and 95% confidence interval (CI) exclusive of 1.0 and with p values <.05.

The magnitude and precision of the relationship with 1-year mortality for statistically significant variables was used to determine weighting in the scoring systems subsequently developed [18,24]. Score performance was then tested through multivariable regression and bootstrap simulation with sample size of 750 and 1,000 replications [24]. The most parsimonious system that demonstrated a stepwise increase in the odds of mortality without losing significance was chosen as the final score [18,24]. In a sensitivity test, the performance of the final score developed for 1-year mortality was assessed using mortality figures for the 3-month and 2-year time-points.

All statistical analyses were performed using STATA v15.0 (STATA Corp., College Station, TX). This investigation received institutional review board approval prior to its initiation and was performed in accordance with the Transparent Reporting of a multivariable prediction model for Individual Prognosis or Diagnosis (TRIPOD) guidelines [25].

Results

In the period under study, 1,758 patients met inclusion criteria. The average age of the cohort as a whole was 75.4 (SD 11.94), with 51% of the population female. Eighty-nine percent of the population were White and the average body mass index was 26.12 (SD 5.7). A low velocity injury was the most common mechanism (68%) with polytrauma encountered in 29%. The average ISS was 8.2 (SD 9.5) and the average GCS was 14.16 (SD 2.46). The most common location of injury was the subaxial cervical spine (43%), followed by upper cervical injuries that included or solely consisted of an odontoid fracture (37%). Surgery was performed in 14% of cases (n=240), with a stand-alone posterior approach most frequently utilized (n=187/240; 78%).

Mortality rates were 12% (n=215) at 3 months, 17% (n=304) at 1 year, and 21% (n=377) at 2 years following fracture. Unadjusted evaluation of clinical and demographic characteristics at baseline demonstrated a number of factors that were significantly different between patients who were alive and those who died by the 1-year time-point (Table 1). These variables included age, female sex, CCI, presence of hyperostotic disease, ISS, GCS, mechanism of injury, as well as surgical intervention. Importantly, 41% of patients with low serum albumin had died by 1 year, as compared to 18% of those with albumin >3.5 g/dL (p<.001). Similarly, 1-year mortality was significantly higher (p<.001) among those with impaired ambulatory function at presentation, in contrast to independent ambulators.

Multivariable model

Following multivariable logistic regression analysis that adjusted for the above factors, age, biologic sex, ISS, GCS, low serum albumin, and dependent/nonambulatory function were identified as significantly associated with 1-year mortality (Table 2). There was a significant interaction between age and CCI (p<.001). The c-statistic for this final model was 0.85 and there was no statistically significant evidence of poor model fit (p=.35).

Scoring rubric

We considered weighting of variables based on their performance in the multivariable model, with age, ISS, and GCS having the strongest predictive value to formulate a base score. The most parsimonious model utilized these variables as a base, encapsulating demographic and injury characteristics, with a subsequent layer that accounted for serum albumin and ambulatory function at presentation (Table 3). This model employs a stratified weighting by patient age with 3 points assigned if age≤70, 2 points allocated for ages 71 to 80, 1 point for ages 81 to 90, and 0 points for ages 91 and older. ISS<9 is associated with 1

Table 1
Demographic and clinical characteristics of patients treated for cervical spine fractures (2006–2016) in the context of 1-year mortality*

	Alive at 1 year	Died by 1 year	p Value
Number of cases (%)	1,454 (83)	304 (17)	–
Age (mean, SD)	74.2 (12.0)	81.3 (9.6)	<.001
Female Sex (%)	773 (53)	130 (43)	.001
White (%)	1,288 (89)	274 (90)	.44
Body mass index (mean, SD)	26.2 (5.7)	25.8 (5.6)	.81
CCI (mean, SD)	1.1 (1.2)	1.8 (1.4)	<.001
Albumin ≤3.5g/dL (%)	255 (18)	125 (41)	<.001
Smoker (%)	383 (26)	68 (22)	.15
Hyperostotic disease (%)	49 (3)	18 (6)	.04
Injury severity score (mean, SD)	6.8 (6.5)	14.9 (16.2)	<.001
Glasgow coma scale (mean, SD)	14.5 (1.8)	12.6 (4.0)	<.001
Level of injury (%)			.05
Upper cervical with odontoid fracture	513 (36)	129 (43)	
Upper cervical without odontoid fracture	299 (21)	62 (20)	
Subaxial	633 (44)	112 (37)	
Polytrauma (%)	406 (29)	97 (33)	.11
High velocity mechanism (%)	476 (33)	72 (25)	.004
Surgical intervention (%)	211 (15)	29 (10)	.02
Ambulatory function (%)			<.001
Independent	1,139 (78)	154 (51)	
Dependent/nonambulatory	300 (21)	149 (49)	
Symptoms at presentation (%)			.05
Axial pain/asymptomatic	1,271 (87)	253 (83)	
Neurologic symptoms	183 (13)	51 (17)	

* Percentages are rounded.

Table 2
Results of the multivariable logistic regression analysis regarding clinical and demographic factors associated with 1-year mortality following cervical spine fracture

	OR	95% CI	p Value
Age group	-	-	-
Age≤60	Ref	Ref	Ref
Age 61–70	11.85	3.05, 45.94	<.001
Age 71–80	28.51	7.43, 109.36	<.001
Age 81–90	39.46	10.33, 150.78	<.001
Age≥91	50.66	12.40, 207.04	<.001
Male sex	2.18	1.55, 3.06	<.001
CCI	1.40	1.23, 1.59	<.001
Albumin≤35 g/dL	1.57	1.10, 2.25	.01
Smoker	0.92	0.62, 1.37	.68
Hyperostotic disease	1.39	0.64, 3.00	.40
Injury severity score*	1.09	1.06, 1.11	<.001
Glasgow coma scale*	0.88	0.83, 0.94	<.001
Level of injury	-	-	-
Subaxial	Ref	Ref	Ref
Upper cervical with odontoid fracture	1.22	0.84, 1.79	.30
Upper cervical without odontoid fracture	1.12	0.72, 1.76	.61
Mechanism of injury	1.31	0.86, 2.00	.21
Surgical intervention	0.78	0.44, 1.36	.38
Ambulatory function	-	-	-
Independent	Ref	Ref	Ref
Dependent/nonambulatory	1.96	1.36, 2.83	<.001
Symptoms at presentation	-	-	-
Axial pain/asymptomatic	Ref	Ref	Ref
Neurologic symptoms	1.50	0.86, 2.59	.15

OR, odds ratio; CI, confidence interval; Ref, referent; CCI, Charlson comorbidity index.
* Per point increase.

point and GCS≥9 merits 2 points. Patients with a base score≥5, in any combination, receive 2 points while those with scores≤4 receive 0 points toward the global score (Table 3). Additional points appended to the total are derived from serum albumin (1 point if albumin>3.5 g/dL) and ambulatory function (1 point if independent). Thus, the global scoring system, which we refer to as the New England Survival Score-Cervical (NESS-C), ranges from 0 (base score≤4, albumin≤3.5 g/dL and dependent/nonambulator at presentation) to a maximum of 4 (base score≥5, albumin>3.5 g/dL, and independent ambulator at presentation).

Score performance

The NESS-C exhibited the desired step-wise association with 1-year mortality, with individuals with a score of 4 demonstrating 3% mortality at this time-point, while those with a score of 3 had 18% mortality and individuals with a score of 2 experienced a mortality rate of 21%. Those with a score of 1 had a 35% mortality rate and patients with a score of 0 demonstrated 45% mortality (Fig. 1). This pattern was preserved in unadjusted survival estimates (Fig. 2) and following adjusted multivariable logistic regression testing (Table 4; Appendix 1). Following multivariable-adjusted analysis, when compared to patients with a NESS-C of 4 as the referent, significantly increased odds of 1-year mortality were appreciated for those with scores of 3 (OR 7.35; 95% CI 3.77, 14.32), 2 (OR 8.43; 95% CI 4.66, 15.25), 1 (OR 17.47; 95% CI 9.81, 31.11), and 0 (OR 26.58; 95% CI 13.87, 50.92). No demonstrable changes in score performance were appreciated in the internal validation process performed through bootstrapping (Table 4). The pattern of the area under the curve and c-statistic for the prognostic model that used the NESS-C rubric (0.79) were not substantially different from that of the full logistic regression model (0.85; Fig. 3). The score performed equally well in secondary testing that used 3-month mortality (Appendix 2) and 2-year mortality (Appendix 3) as the primary outcome.

Discussion

Cervical spine fractures are among the most frequently encountered injuries in elderly individuals who sustain falls or more substantial trauma [3–9]. The care of elderly individuals

Table 3
Characteristics of the New England Survival Score-Cervical (NESS-C). The table is formatted to allow replication as a laminated card that can be used to calculate the score at the point of care

NESS-C components	Predictive score point allocation
Base score: age and injury characteristics	
Age≤70 (3 points)	N/A
Age 71–80 (2 points)	
Age 81–90 (1 point)	N/A
Injury severity score<9 (1 point)	N/A
Glasgow coma scale≥9 (1 point)	N/A
Base score≤4	0
Base score≥5	2
Ambulatory status	
Independent ambulator	1
Dependent/nonambulatory	0
Serum albumin	
≤3.5 g/dL	0
>3.5g/dL	1

is fraught with the potential for morbidity, functional deterioration, and even accelerated demise [4,9,11,16]. Indeed, some authors have proposed that cervical fractures in elderly individuals are often sentinel events, heralding an impending decline that culminates in mortality within a few years of injury [4,11,16].

The surgical treatment of cervical spine fractures has been reported to result in superior outcomes in a number of instances, although it is unclear that an operative approach can arrest functional decline once selection bias is taken into account [4,11–15]. In the current healthcare environment, where heightened attention is being paid to the allocation of resources, it is potentially useful to prognosticate survival for patients with cervical fractures, regardless of treatment strategy. This could be helpful, not only in the elucidation of the natural history and anticipated outcomes for patients with cervical fractures and their families but might also aid in identifying those individuals best situated to benefit from surgery in the event of clinical equipoise.

The ideal prognostic score is easy to utilize, intuitive for healthcare providers, patients and families, and applicable to all patients with the condition of interest (eg, not solely limited to individuals with a certain type of injury/fracture pattern or those receiving surgery). We believe that these metrics have been achieved with our approach to developing the NESS-C for predicting survival in patients older than age 50 with cervical spine fractures. The advantages of this effort include its reliance on data from a large series of patients collected from two tertiary level I trauma centers over the last decade. Robust estimates of survival were potentiated by the dataset's linkage with the national death index. Our access to medical records allowed abstraction of clinically useful details such as fracture location, mechanism of injury, smoking status, ISS, GCS, serum albumin, neurologic symptoms, and ambulatory status at the time of injury. The scoring system demonstrated a step-wise, dose-response, effect for 1-year mortality that remained unchanged in sensitivity tests relying on 3-month and 2-year mortality metrics, and internal validation performed with bootstrap simulation. The discriminative capacity of the model was also only marginally affected by using the composite score in place of each individual variable that it incorporates, and the patterns of respective area under the curve graphs remained relatively static between both models (Fig. 3). The average age of patients in this work, as well as the number of medical comorbidities, rates of surgical intervention, and survival are approximate to other

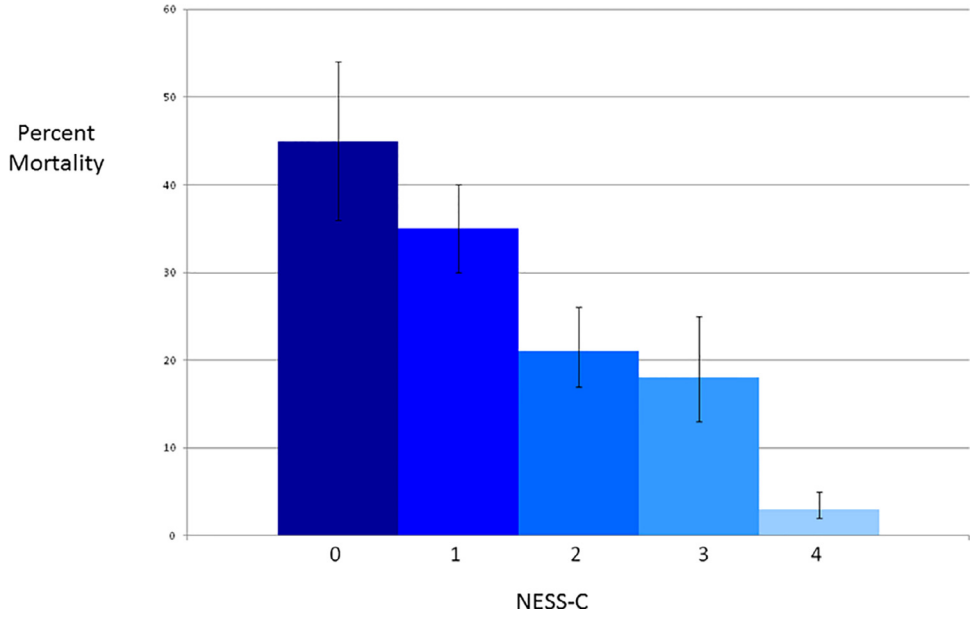

Fig. 1. Percentage of patients, with 95% confidence intervals (*y*-axis), found to have died by the 1-year time-point following cervical fracture by New England Survival Score-Cervical (NESS-C; *x*-axis).

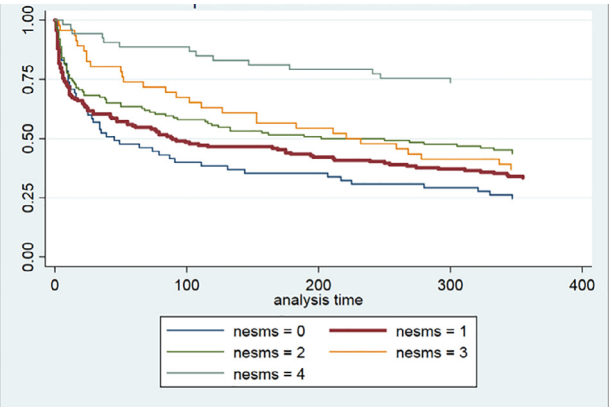

Fig. 2. Estimations of postinjury survival by New England Survival Score-Cervical (NESS-C) in patients treated for cervical fractures (*x*-axis expressed in days).

studies, which reinforces our contention that the findings are ready for immediate clinical application and generalization [4,5,10,11,17].

The NESS-C system is modeled on the progenitor New England Spinal Metastasis Score [18] and relies on a base score that accounts for patient age, injury severity, and neurologic status as quantified by the GCS. Nutritional status (proxied by serum albumin) and functional capacity at the time of injury (indicated by ambulatory status) are employed as layered modifiers to create the final global score (Table 3). Many of these parameters have been highlighted as factors associated with survival following cervical spine injury in the past. For example, in a cohort of elderly patients treated for cervical fractures, Harris et al. reported that age, medical comorbidities, and neurologic status were associated with 3-month and 1-year mortality [4]. Similar findings were documented in the work of Bank et al. [10], Pull ter Gunne et al. [26,27], and Young et al., who relied on data from the National Trauma Databank (NTDB) [17]. In two separate efforts, Pull ter Gunne's group identified the importance of age and neurologic injury, as modulated by the level of cervical, as prognostic of survival [26,27]. The study of Young et al., relying on data abstracted specifically for the NTDB repository, specifically highlighted ISS and mechanism of injury as important prognostic factors associated with survival [17]. In our own regression modeling, the inclusion of age, ISS, and GCS accounted for any of the influence that may have been exerted by trauma mechanism, type of cervical spine fracture, or neurologic status at the time of injury. This latter is also likely encapsulated in our measure of ambulatory status at time of presentation. Similarly, given the interaction between age and CCI identified in our regression tests, the use of age in the base score accounts for much of the variation in survival that may be attributed to comorbidity burden. As a measure of nutritional status and wound healing, serum albumin using the threshold applied here, has been shown in the past to influence survival and outcomes following operative and nonoperative treatment for spinal disorders [18,19,28].

We believe that the NESS-C can be readily applied to patients who present with cervical spine fractures at the time of presentation, with measures easily attained during the initial trauma assessment. Moreover, all variables outside of age and ambulatory function can be discerned without interviewing the patient or family members. Ambulatory ability immediately proximate to the injury event should be used in calculating the score except in the case of spinal cord injury or neurologic impairment. In these scenarios, where the neurologic deficit demonstrably compromises the patient's ambulatory status, this should be accounted for in the score assigned for function.

There are several notable limitations associated with this effort. Foremost, this remains a retrospective investigation, beholden to limitation inherent in such research designs. This includes a restriction to consider only those variables available for the majority of patients through the RPDR or chart abstraction. There is also the potential for residual confounding to influence our models as a result, as well as the possibility that errors in clinical documentation, transcription, or coding, including assessment of ambulatory function and its correlation with neurologic status, biased our findings. While the nature of the RPDR allows for mortality surveillance irrespective of clinical encounters within our system, we cannot determine other treatments or further injuries that may have transpired at other centers. The extent to which such events may have occurred, or how they might have influenced our determinations, cannot reliably be quantified. The fact that the data are derived from two centers that operate under a single healthcare

Table 4
Estimates of the effect of possessing a NESS-C score of zero, one, two, or three on 1-year mortality in unadjusted, multivariable adjusted, and bootstrap analysis. In all testing, a NESS-C score of 4 was used as the referent (ref). Results are presented as odds ratio (OR) with 95% Confidence Interval (CI)

	OR	95% CI	p Value
Unadjusted			
Zero	26.58	13.87, 50.92	<.001
One	17.47	9.81, 31.11	<.001
Two	8.43	4.66, 15.25	<.001
Three	7.35	3.77, 14.32	<.001
Four	Ref	Ref	Ref
Adjusted			
Zero	24.05	11.70, 49.41	<.001
One	17.71	9.35, 33.54	<.001
Two	9.30	4.87, 17.74	<.001
Three	7.30	3.55, 15.02	<.001
Four	Ref	Ref	Ref
Bootstrap procedure			
Zero	26.58	10.67, 66.24	<.001
One	17.47	7.57, 40.34	<.001
Two	8.43	3.63, 19.61	<.001
Three	7.35	2.70, 19.98	<.001
Four	Ref	Ref	Ref

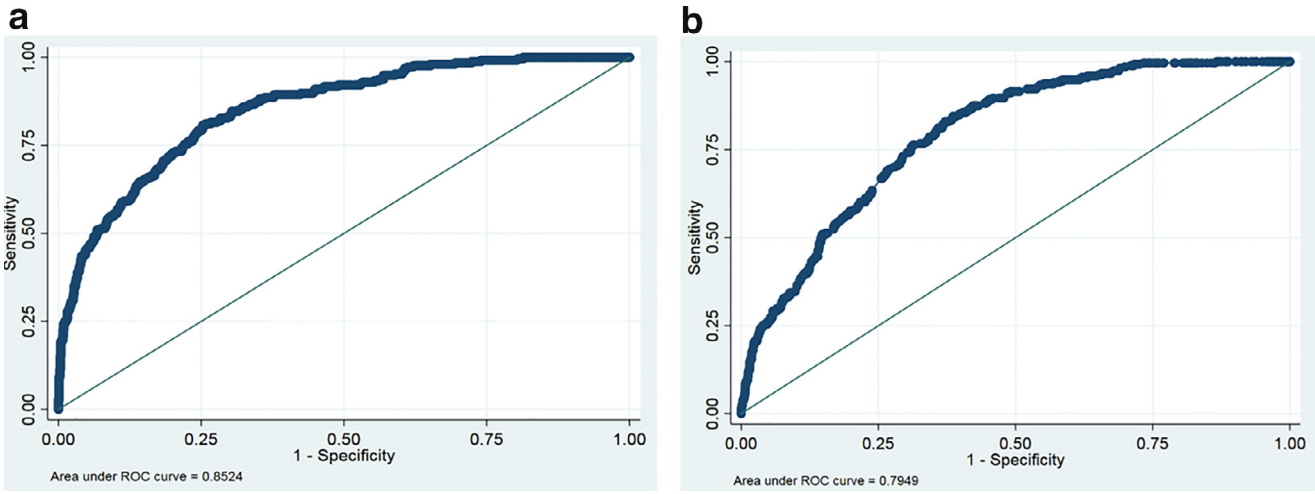

Fig. 3. Comparison of area under the curve graphs and c-statistic for discrimination between the multivariable logistic regression model considering all variables (a) and the adjusted model incorporating the New England Survival Score-Cervical (NESS-C) in place of age, injury severity score, GCS, serum albumin, and ambulatory status at presentation (b).

corporation in one metropolitan area may limit clinical variation with the cohort in some respects. In light of this fact, it is reassuring that the mortality rates and the percentage of patients treated surgically in this analysis mirror figures reported elsewhere [4,5,10,11,17]. We do recognize that the 95% CIs associated with each iteration of the NESS-C are wide, which in some circumstances may be indicative of model fragility [24]. We do not believe that this is the case here, however, since our c-statistics are high and there was no evidence for lack of fit in the source regression model. Rather, the 95% CI metrics encountered in our analysis are reflective of the high rate of mortality in patients with lower NESS-C scores (eg, nearly half of individuals with a score of 0) as compared to the referent group (3% in patients with a NESS-C of 4). Given these limitations, we advocate that our results should be replicated in independent cohorts of patients, as well as through prospective study. As such, we also do not support using the tool as a means of determining which patients should receive operative or nonsurgical care. In certain circumstances, such as patients with mechanical instability or spinal cord injury, surgery may still be the preferred treatment option despite a low NESS-C score. The determinations of NESS-C at this time are only applicable to the immediate postinjury period and how changes in functional ability (eg, neurologic recovery) or other parameters, such as nutritional status, may influence the outcome remains to be assessed in future study. Given our study design, the score likely should not be applied to individuals under age 50. At the present time, when counseling patients, the use of estimations regarding percent-survival by NESS-C score are probably more useful than quoting ORs from the regression models, an approach that is more intuitive for the lay population in any case.

In conclusion, we believe that we have developed a useful prognostic utility capable of informing survival in individuals age 50 and older, following cervical spine fractures. This scoring system, the NESS-C, meets all criteria for an ideal predictive tool, including ease of administration and comprehension for providers and patients, as well as universal relevance to all individuals with cervical fractures, whether or not surgery is performed. The score performs well when estimating 1-year mortality as well as survival at the 3-month and 2-year time-points. Model discrimination is also quite high, with close to 80% of the variation in mortality explained by the factors we included. While further validation is certainly warranted, we believe that the positive attributes of the NESS-C supports its immediate application in clinical practice as a means to help adjust patient expectations, anticipate outcomes and as an adjunct to clinical decision-making in the immediate postinjury period.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.spinee.2019.03.009.

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