Cervical Spine Injury in Burned Trauma Patients: Incidence, Predictors, and Outcomes

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Cervical spine injuries (CIs) carry significant morbidity and mortality; hence, cervical spine immobilization is used liberally in trauma patients, including burns. The incidence, predictors, and outcomes of CI in burn patients are unknown. A retrospective cohort from the National Trauma Data Bank between 2007 and 2012 included all burned patients with and without CI. Predictors of CI were identified by logistic regression. Outcomes with and without CI were compared with Wilcoxon rank sum test. A total of 94,964 patients were identified with burn injuries. The incidence of CI was 0.79% (n = 745). Mechanism of injury, age, and injury severity score (ISS) were significant predictors of CI. Odds of CI were 109.4 (95% CI: 61.2–195.3, $P < .0001$) for motor vehicle injury, 87.8 (95% CI: 47.0–164.0, $P < .0001$) for falls, 1.2 (95% CI: 0.6–2.3, $P = .66$) for fire/flame, and 2.4 (95% CI: 1.0–5.5, $P < .0001$) for explosion compared with reference of hot object/substance. For every year increase in age, there were 1.02 higher odds of CI (95% CI: 1.01–1.02, $P < .0001$). For each point increase in ISS, there were 1.05 higher odds of CI (95% CI: 1.04–1.05, $P < .0001$). Patients with CI had higher mortality (10.3% vs 2.9%, $P < .0001$), longer total length of stay (12.0 vs 2.0 days, $P < .0001$), intensive care unit length of stay (4.0 vs 0.0 days, $P < .001$), and ventilator days (1.0 vs 0.0 days, $P < .0001$). The incidence of CI in burn patients is low, especially when due to fire, flame, or scalds; however, CI is associated with higher mortality and worse outcomes.

Cervical spine injuries (CIs) result in significant morbidity and mortality including quadriplegia and death.[1–4] The incidence of CI in the trauma population is 3.7 to 6.2%.[3,5] Therefore, cervical spine immobilization is used liberally in trauma patients to prevent further neurological damage until CI can be ruled out.[6–9] However, cervical collars have associated morbidities including pressure ulcers, pain, and increased intracranial pressure.[10–17] Additionally, cervical spine immobilization limits early mobility and increases patient care demands.

Cervical spine collar clearance algorithms for blunt trauma include physical examination for the awake and alert patient as defined by the NEXUS study. Computed tomography (CT) imaging is recommended for patients who are not alert, have midline cervical tenderness or neurological deficits, or who were injured with a dangerous mechanism.[18–20] For the obtunded patient with a normal CT of the spine, evidence varies on the necessity of magnetic resonance imaging (MRI).[21–23]

Burn patients represent a subset of the trauma population that require 40,000 hospitalizations per year in the United States.[24] Although CIs have been extensively studied in the trauma population as a whole, minimal literature exists on CIs specifically in burn patients, including the appropriate criteria for placement and removal of collars. We hypothesized that the incidence of CI in burn patients is lower than published rates in trauma patients and that the mechanism of injury is a significant predictor for the presence of CI.

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METHODS

Study Design and Population

A retrospective cohort was created using the National Trauma Data Bank (NTDB) research datasets from 2007 to 2012, which was the most recent data available at the time of IRB approval. The NTDB is the world's largest trauma data repository compiled by voluntary data submission.[25] This data set allowed for an appropriate sample size to study the uncommon event of CI in burn patients, a specific subset of the trauma population. The cohort was comprised of all patients with burns based on ICD-9 diagnosis codes 940–949, which included all patients who were admitted, transferred to a trauma center, or who died due to traumatic injury. CI was designated based on diagnosis codes 805, 806, 839, and 952. Demographic and predictor variables included age, gender, injury severity score (ISS), and mechanism of injury,

which were categorized into subsets by ecodes. "Motor vehicle injury" included injuries sustained by transport as a vehicle occupant, pedestrian, cyclist, or other unspecified relationship to a vehicle. "Explosion" included injuries due to an explosion or explosives. "Hot object/substance," "Fire/flame," and "Fall" were each already defined by ecodes in the data set. The mechanism of "Other" was comprised of the ecode for "other, specified" and all remaining mechanisms comprising less than 1% of the patients. Outcome variables included mortality during hospitalization, ventilator days, intensive care unit (ICU) days, and length of stay (days) as reported in the data set. Patients with ventilator days and ICU days listed as "not applicable" were assigned a value of zero. Following identification of 119,692 patients with a burn injury, those with missing ISS (n = 3,042; 2.5%), ventilator days (n = 10,810; 9.0%), ICU days (n = 10,195; 8.5%), or length of stay (n = 243, 0.2%) were excluded from the analysis (Figure 1). This cohort study was reported according to the STROBE guidelines.[26] IRB approval was granted for this project by the University of California, Davis (IRB #678228-2).

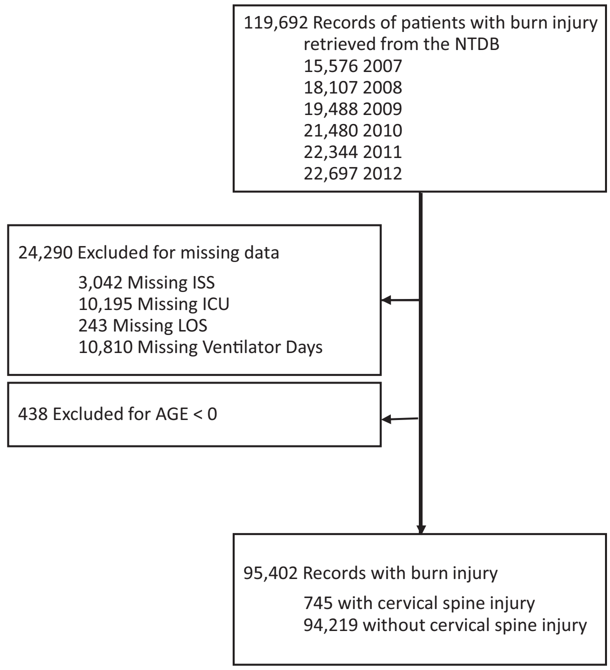

Figure 1. Study flow diagram. The retrospective cohort of all patients with burn injury from 2007 to 2012 National Trauma Data Bank (NTDB). Records were excluded for missing data and inaccurate age.

Statistical Analysis

Analysis was performed using SAS version 9.4 (SAS Institute Inc., Cary, NC). Continuous variables were reported as medians with interquartile ranges, and categorical variables were reported as percentages. For predictor and outcome variables, the Wilcoxon rank sum test was used to compare continuous variables, and the chi-squared test was used for categorical variables. A P value less than .05 was considered statistically significant.

A logistic regression was performed for the outcome of CI using variables defined by entry into the model as a P value less than .1 and to stay in the model as a P value less than .05. Odds ratios for mechanism of injury used "Hot object/substance" as the reference category. ISS was included in the model as it met the above criteria, though up to 36 points of the ISS may be attributed to a neck injury. However, the results were minimally changed with removal of ISS from the model, so the variable was left in place. A receiver–operator curve was created for the final predictive model of CI, which included three predictor variables: mechanism of injury, age, and ISS.

Unadjusted mortality rates were compared using the chi-squared test. Logistic regression was performed to determine the adjusted odds of mortality with CI using age, ISS, and mechanism of injury as the variables for risk stratification.

RESULTS

Incidence

A total of 94,964 patients with burns were identified, 745 of whom had a CI. The incidence of CI was 0.79%.

Demographics

The median age of patients with CI was higher than those without injury (39 with CI vs 31 years, $P < .0001$). Males comprised the majority of all patients (70.2%) and had significantly higher rates of CI compared with females (0.86% males with CI vs 0.62% females with CI, $P < .002$). Median ISS was higher in patients with CI (22.0 with CI vs 1.0, $P < .0001$; Table 1). Of the 745 patients with CI, the majority were caused by motor vehicle accidents (72.1%) and falls (9.8%; Figure 2). The incidence of CI in each subset was 8.47% with "motor vehicle injury," 6.34% with "fall," 0.08% with "fire/flame," 0.03% with "hot object/substance," 0.15% with "explosion," and 0.88% with "other."

Logistic Regression

Mechanism of injury, age, and ISS were all significant predictors of CI. Gender was not a significant predictor of CI. Compared with injury due to "hot object/substance," the subsets of "explosion," "falls," "motor vehicle injury," and "other" had significantly higher odds of CI (Table 2). Notably, injury due to motor vehicle injury had 109 times higher odds of CI compared with "hot object/substance" (95% CI: 61.2–195.3). The odds of CI were not significantly different from those with "fire/flame" injury compared with those with "hot object/substance" injury (OR 1.2, 95% CI: 0.6–2.3). For every year increase in age, there were 1.02 higher odds of CI (95% CI: 1.01–1.02). For each point increase in ISS, there were 1.05 higher odds of CI (95% CI: 1.05–1.06).

The overall regression model including mechanism of injury, age, and ISS was highly predictive of CI. The AUC for this model was 0.96 (Figure 3).

Outcomes

The unadjusted mortality rate with CI was significantly higher than without CI (10.3% vs 2.9%, $P < .001$). Patients with CI had a higher number of ventilator days (1 vs 0) and ICU days (4 vs 0) and a longer length of stay (12 vs 2 days) compared with those without injury (Table 3). When adjusted for age, ISS, and mechanism of injury, CI was no longer an

Table 1. Patient characteristics by cervical spinal injury

	Without Cervical Spine Injury	Cervical Spine Injury
Patients (n)	94,219	745
Gender (% male)	70.2	76.6
Age*	32 (13–49)	39 (25–53)
Injury Severity Score*	1 (1–5)	22 (14–33)

Seven hundred forty-five patients with cervical spine injury were significantly older and had higher injury severity scores ($P < .002$).
*Median (interquartile range), $P < .002$.

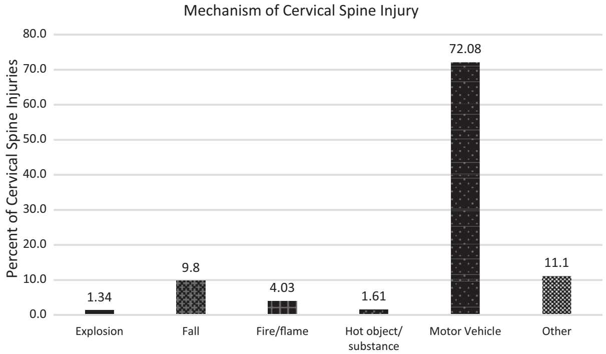

Figure 2. Mechanism of injury. Motor vehicle injury was the most common mechanism associated with cervical spine injury, followed by other, fall, fire/flame, hot object/substance, and explosion.

Table 2. Odds ratios for cervical spinal injury

Predictor	Odds Ratio	95% Confidence Interval
Mechanism of Injury		
Hot object/substance	ref	
Fire/Flame	1.2	0.6–2.3
Explosion	2.4*	1.0–5.5
Fall	87.8*	47.0–164.0
Motor Vehicle	109.4*	61.2–195.3
Other Mechanism	17.9*	9.4–33.9
Age	1.02*	1.01–1.02
Injury Severity Score	1.05*	1.05–1.06

Age, injury severity score, and mechanism of injury were significant predictors of cervical spine injury. Explosion, falls, motor vehicle injury, and other had significantly higher odds of CI compared with injury due to hot object/substance ($P < .05$).
ref = reference variable, *$P \leq .05$.

independent predictor of mortality with odds ratio of 1.07 (95% CI: 0.80–1.43, $P = .67$). Age, ISS, and mechanism of injury were each independently associated with higher risk of mortality (Table 4). Fire/flame burns and explosions had the highest odds of mortality: 2.67 (95% CI: 2.26–3.14) and 2.23 (95% CI: 1.79–2.77), respectively.

DISCUSSION

The incidence of CI in burn patients is 0.79%, which is lower than in the general trauma population. This lower incidence is largely a result of the different mechanism of injury in the burn patient. Blunt trauma comprises the majority of injuries in the general trauma population compared with only 15% in this study's burn population. Injury by motor vehicle has the highest odds of CI, consistent with the general

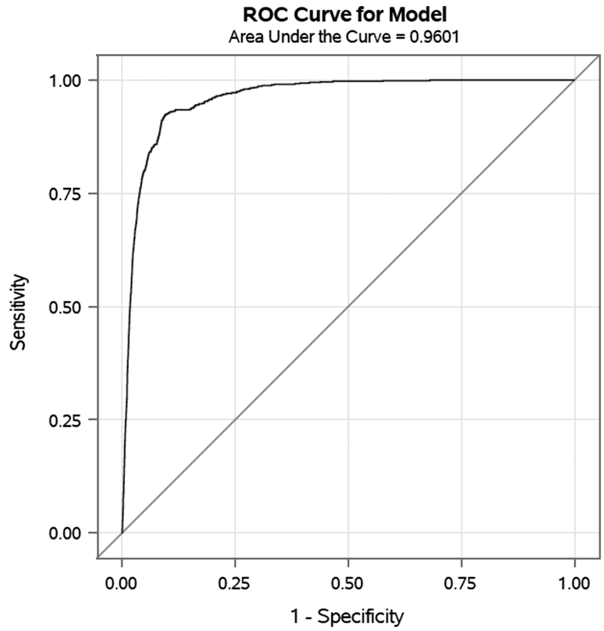

Figure 3. Predictive model of cervical spine injury. Receiver–operator curve has area under the curve = 0.96.

Table 3. Unadjusted outcomes in patients with and without cervical spine injury

	Without Cervical Spine Injury	Cervical Spine Injury
Ventilator Days	0 (0–0)	1 (1–1)*
Intensive Care Unit Days	0 (0–0)	4 (0–13)*
Length of Stay	2 (1–7)	12 (4–23)*
median (interquartile range), *$P < .001$		
Mortality Rate	2.9	10.3*

Patients with cervical spine injury had significantly worse outcomes than those without injury.
percent, *$P < .001$.

Table 4. Adjusted mortality outcomes

Predictor	Odds Ratio	95% Confidence Interval
Cervical Spine Injury	1.07	0.80–1.43
Mechanism of Injury		
Hot object/substance	ref	
Fire/Flame	2.67*	2.26–3.15
Explosion	2.23*	1.79–2.77
Fall	1.55*	1.10–2.16
Motor Vehicle	1.30*	1.04–1.62
Other Mechanism	1.90*	1.44–2.50
Age	1.05*	1.04–1.05
Injury Severity Score	1.10*	1.10–1.11

Following adjustment for mechanism of injury, injury severity score, and age, cervical spine injury is no longer an independent predictor of mortality.
ref = reference variable, *$P \leq .05$.

trauma literature.[3] Despite a complex mechanism including blast injury, penetrating fragments, and blunt trauma, explosions had a lower incidence of CI at 0.15% than the overall incidence in burn patients. This was lower than previously published civilian explosion CI rate of 0.83%, where CI were largely due to penetrating injuries.[27]

Despite the low incidence, CI in burn patients had a significant impact on outcomes, including higher ventilator days and longer length of stay. The mortality rate in burn patients with CI was 10.3%, which was higher than previously reported rate in general trauma patients at 6.6%.[3] However, when the outcome of mortality was adjusted for additional variables including ISS and mechanism of injury, this increase in mortality for those with CI is no longer apparent. In burn patients, higher rates of mortality in those with CI result from the mechanism and severity of injury.

Increasing age was a significant independent risk factor for CI. Previous studies have shown that patients with CI are significantly older than those without CI; however, this was not an independent risk factor in multivariable analysis.[3] This difference in our study is likely a result of including the pediatric population, which has a lower incidence of CI ranging from 0.98 to 1.2%.[28,29] Given worse outcomes with CI in the elderly population, age remains an important risk factor to consider in a burn patient.[1,30]

Clinical examination following trauma allows for rapid assessment of CI in the alert patient who is able to participate in the examination. Although traditionally performed once the patient is evaluated in the trauma bay, new research suggests that prehospital clinical clearance of the cervical spine by trained emergency medical responders is safe.[31,32] Implementation of prehospital clinical cervical spine clearance may lead to decreased transit time to the ED and may improve patient comfort. Prehospital evaluation has not been studied specifically in the burned trauma population, but given the low incidence, especially when unrelated to motor vehicle injury, prehospital clearance may benefit these patients.

However, the rate of CI is higher in obtunded patients, and these patients are at risk for prolonged spine immobilization if their clinical stability or respiratory status is poor.[5] Severely burned patients are at risk for prolonged spine immobilization if standard trauma cervical spine clearance protocols are used since they require clinical evaluation or MRI.[21] CT scans are accurate and reliable to identify clinically significant CI in intoxicated or obtunded trauma patients.[23,33–38] Combined with the low incidence of CI in patients with burns, the negative predictive value of CT scans in this population would be even higher.

Based on the results of this study and previous literature, we propose a cervical collar clearance algorithm for burn patients (≥20% total body surface area burn) presenting with immobilization (Figure 4). Patients able to be examined should be cleared according to NEXUS criteria. Patients that cannot be examined due to mental status or intubation and patients with neurological symptoms should undergo CT of the cervical spine. Although the rates of CI for mechanisms other than motor vehicle injury are extremely low, we recommend CT of the spine for patients who cannot be examined because these patients have an increased risk of CI.[5] If the CT scan is negative for injury in patients injured by typical burn mechanisms of fire, flame, or scald, the immobilization collar may be removed. No further examination nor MRI is needed with a negative CT in these patients based on its negative predictive value in burn patients.[23,33–38] However, the rate of CI was 8.47% in patients with a motor vehicle injury, including pedestrians, and 6.34% for patients who fell. Because of higher rates of CI in these subgroups, physicians should consider MRI to evaluate for bony or ligamentous injury in patients who are unable to participate in a physical examination. Although we plan to implement this protocol at our institution, we want to emphasize that this algorithm has not yet been validated with a prospective study.

Cervical spine protocols were initiated to protect trauma patients at risk for unidentified cervical spine fractures. Burn injury is indeed a form of trauma, and CI should always be

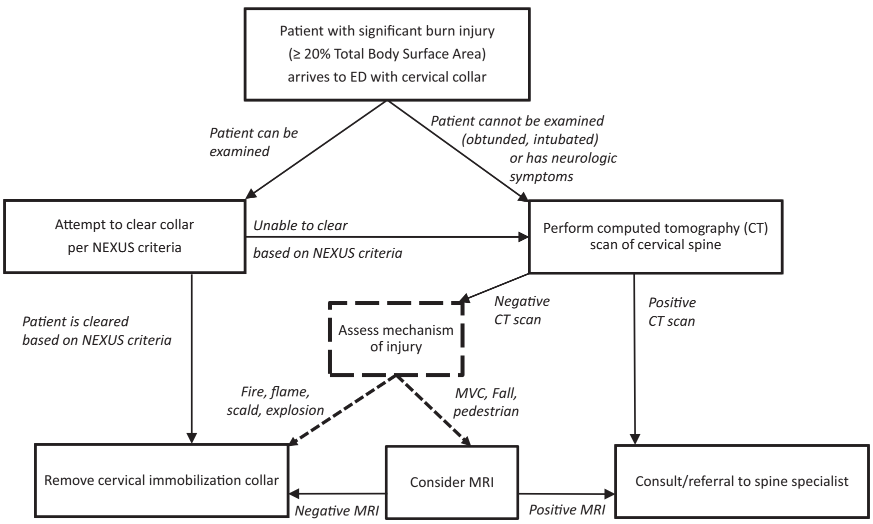

Figure 4. Algorithm for cervical spine clearance in burn patients. Patients able to be examined should be cleared according to NEXUS criteria. Patients that cannot be examined due to mental status or intubation and patients with neurological symptoms should undergo computed tomography of the cervical spine. MRI should be performed based on the mechanism of injury.

considered during initial management. The results of a retrospective study should never be used as the sole mechanism for changing a protocol. However, burn injury is unlike other traumatic injuries in that the mechanism of the burn may not be consistent with a CI. For example, a patient with a grease scald burn on the hand and face has virtually no chance of a cervical spine fracture. Application of the collar would create more risk (ie, pressure ulcer or burn wound compression). However, if the patient with the grease burn falls and strikes the head, cervical spine immobilization is indeed appropriate. We advocate for application of cervical spine precautions in burn patients involved with higher risk injuries, including motor vehicle accidents and falls. For other forms of burn injury, a careful assessment of CI risk should be performed, and if any suggestion of risk remains, the cervical spine should be immobilized and evaluated. However, if no risk is present, cervical spine immobilization may not be in the patient's best interest.

Limitations of this study are related to inherent shortcomings in the databank and its retrospective nature. The NTDB is comprised primarily from patients at Level I and II trauma centers and is therefore not fully representative of all trauma patients. These trauma centers are likely to have higher acuity patients than an emergency department evaluating all levels of severity of injury. Like all data sets, missing data may affect analysis. In this cohort, missing data were less than 10% in all variables used, but totaled 20.2%. The NTDB does not provide details on CT or MRI imaging to determine the rates at which they were obtained in this population. Furthermore, this retrospective cohort did not include patient information on percent total body surface area (TBSA) involved, so we were unable to determine its relation to CI. Additionally, without TBSA our interpretation is limited for patients injured by motor vehicles or falls as the burn injury may be a small percentage of the injury. Finally, the incidence of CI may be higher than we describe in this study since coding for CI is historically underreported.[39] The results of this study have intrinsic limitations because of its retrospective design. We acknowledge that incorporation of the findings into practice may be problematic since this is a single, retrospective study.

CONCLUSION

In this single, retrospective study, the incidence of CI in burn patients is low at 0.79%, especially when due to fire, flame, or scalds. Mechanism of injury, age, and ISS are independent predictors of CI.

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