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Risk factors for cervical spine injury among patients with traumatic brain injury

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An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
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Abstract

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By Tomoko Fujii

Study Objective: Diagnosis of cervical spine injury is difficult for patients with altered level of consciousness due to traumatic brain injury (TBI). Some studies reported increased risk of cervical spine injury among patients with TBI and older adults are at higher risk for TBI caused by fall injuries. This study examined factors associated with cervical spine injury among TBI patients and investigated whether older adults are disproportionally at higher risk for cervical spine injury when they sustain TBI from a fall-related injury.

Methods: All trauma cases with TBI in the National Trauma Data Bank (NTDB) National Sample Project (NSP) 2007 data were analyzed. Logistic regression was used to identify risk factors for cervical spine injury and test for interaction between age and injury mechanism.

Results: In motor vehicle traffic injuries, older age groups had significantly higher odds of cervical spine injury (OR: 1.44, 95% CI: 1.27, 1.64), but, in fall injuries, age did not have a significant effect. Skull/face fractures, other spine fracture/dislocation, upper limb injury, thorax injury and hypotension in emergency department were significantly associated with cervical spine injury. Pelvic injuries had a protective effect (OR: 0.63, 95% CI: 0.56, 0.70). Black or African Americans were associated with significantly higher odds of cervical spine injury compared to Whites in motor vehicle traffic injuries. Other races for motor vehicle traffic injuries and Asians for fall injuries had significantly lower odds.

Conclusion: These identified risk factors can inform physicians in evaluating cervical spine injuries among patients with TBI.

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INTRODUCTION AND BACKGROUND

The diagnosis of cervical spine injury is difficult for patients with multiple injuries and/or altered level of consciousness. These difficulties can lead to a delayed or missed diagnosis (1, 2). One study reported that the rate of overlooked cervical spine injury among TBI cases with a Glasgow Coma Scale (GCS) score of 8 or lower was 10.5% in 1991 and 2.3% during 1994 to 2003 (3). Due to their condition, these patients are often unable to report their neck pain, and a thorough neurological examination is difficult because cervical spine injury is often associated with other acute polytrauma with life threatening conditions.

Increased risk of cervical spine injury among patients with traumatic brain injuries (TBI) has been reported. However, the reported incidence of cervical spine injury among patients with TBI is relatively uncommon and reported ranges are from 1.7% to 8% depending on the inclusion criteria for TBI (3-6).

The appropriate clinical clearance of the cervical spine, that is, the evaluation for the cervical spine injury, is under debate. The guidelines have undergone rapid changes. In 2000, the Eastern Association for the Surgery of Trauma recommended that, for patients with altered mental status, 3−view cervical spine x-rays and axial computed tomography (CT) images at 3 mm interval with sagittal reconstruction from the base of the occiput through C2 and any suspicious areas on x-rays should be obtained for cervical spine clearance. If lower cervical spine is not adequately visualized additional CT images or the technique to obtain x-ray to visualize cervico-thoracic junction (called Swimmer's view) were recommended. If x-rays and CT images are normal, flexion/extension lateral cervical spine fluoroscopy was recommended. (7). In the 2009 guidelines, axial CT is recommended as the primary screening modality for patients with altered mental status. And the guidelines indicate that plain radiographs do not contribute any additional information (8). In light of the rapidly changing guidelines, the identification of additional risk factors for cervical spine injury will lead to fewer missed diagnosis and better patient outcomes.

Plain radiography sometimes fails to detect cervical spine fractures, and ligamantous injury and cord injury can be missed even with CT (9). Delay in detecting cervical spine injury can lead to more damage to the spinal cord due to failure to properly immobilize the patient. The identification of high risk patients with various conscious levels may indicate the need for full cervical spine CT or magnetic resonance imaging (MRI) for diagnosis and the implementation of procedures to prevent further damage to the cervical spine. Also, knowing the risk factors for injury with respect to specific age groups can help shape future interventions designed toward injury prevention.

Several factors associated with cervical spine injury among TBI or other trauma patients were reported in the literature. In a study that analyzed 41,142 TBI cases from the Pennsylvania Trauma Outcome Study database it was reported that age, GCS, injury mechanism, thoracolumbosacral spine fracture, limb fracture, facial fracture, and hypotension were significant factors for cervical spine injury (3). Another study analyzed 8,401 motor vehicle pedestrian injuries from the Los Angeles County and University of Southern California Medical Center and identified 178 cervical spine injury cases. They reported that age, severe head trauma (Abbreviated Injury Scale (AIS) >3), severe chest trauma (AIS >3), pelvic fracture and femur fracture were associated with cervical spine injury (10). A different study examined 1,026 TBI cases where GCS was 12 or lower.

Seventy one (6.92%) of these cases had cervical spine injury. Their study revealed that GCS, motorcycle accident and skull base fracture were associated with cervical spine injury (5). To date, there has not been a study which investigates injury cases using national level trauma registry data.

Older adults require special considerations. They have degenerative changes in the cervical spine which makes them vulnerable to cervical spine injuries caused by low energy mechanism such as falls from standing height (11, 12). One study reported that among cervical spinal cord injury patients who were 65 years or older, 21.4% had spondylosis and 16.7% had cervical canal stenosis (13). Additionally, older adults are at greater risk of falls and, consequently, brain injuries. More than 30 % of older adults fall each year (14). Among people aged 65 years or older, fall-related brain injury death and nonfatal hospitalization rates increased with age, and fall-related TBI accounted for 50% of unintentional fall death in this age group (15).

One study reported increasing proportion of older adults and fall mechanism among spinal cord injuries. It analyzed 30,532 spinal cord injuries who admitted to Model Spinal Cord Injury System facilities in the United States from 1973 to 2003. It reported that the proportion of cases who were 65 years or older increased from 4.8% during 1973−1979 to 12.1% during 2000 to 2003 and the proportion of fall mechanism increased from 16.5 % during 1973−1979 to 23.8% during 2000 to 2003. Fall mechanism was the primary cause for spinal cord injury in cases who were older than 61 years (16). Because of the degenerative change in spine and higher risk for fall injury combined with an aging population, the number of older adult patients with TBI and resulting cervical spine injury will increase.

Given the difficulty in diagnosing cervical spine injury among TBI cases, the primary purpose of this study is to examine significant factors associated with cervical spine injury among trauma patients with TBI in the United States using the National Trauma Data Bank (NTDB) National Sample Project (NSP) 2007 data (17). The secondary purpose of this study is to investigate whether older adults are disproportionally at higher risk for cervical spine injury when they sustain TBI from fall-related injury.

METHODS

This study is a retrospective analysis of prospectively collected data. The American College of Surgeons established NTDB which contains data on trauma cases (all ages) from more than 900 trauma centers all over the United States. Trauma centers voluntarily report trauma related data to NTDB. The NTDB NSP is a stratified sample of 100 hospitals which is intended to produce national representative estimates. The strata are based on NTDB participation, trauma level and region. NTDB NSP 2007 includes data from 82 level 1 or level 2 trauma centers.

The NTDB NSP 2007 contains 148,270 trauma records for all ages. Inclusion criterion in this study was all TBI cases. TBI was defined as cases with corresponding International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis code (DCODE) 800, 801, 803, 804, 850−854.1, 950.1−3, 995.55, and 959.01 according to the definition by Centers for Disease Control and Prevention (CDC) (18). Cases that were excluded from this study were those without an ICD-9-CM diagnosis code, those declared dead on arrival with minimal or no resuscitation attempt, or those younger than 18 years old. The outcome variable was cervical spine injury that included cervical spine fracture and/or dislocation regardless of injury to the spinal cord or spinal cord injury without fracture or dislocation. Corresponding ICD-9-CM codes are: 805.00−805.18, 806.00−806.19, 839.00−839.18, and 952.00−952.09 (3).

Many variables were considered. Age, sex, race, mechanism of injury, total GCS at emergency department (ED), injury severity score (ISS), concomitant skull and face fractures (vault, base or face fractures), other spine fracture and/or dislocation (thoracic, lumber, sacrum or coccyx), upper extremity fracture and/or dislocation (upper extremity injury), lower extremity fracture and/or dislocation (lower extremity injury), pelvic fracture and/or dislocation (pelvic injury), thorax fracture and/or dislocation (thorax injury), hypotension in ED and dyspnea in ED were evaluated as potential risk factors for cervical spine injury. Skull/face fractures, other spine fracture/dislocation, upper and lower extremity injury, pelvic injury and thorax injury were noted if a case had at least one corresponding ICD-9-CM code for each injury. Hypotension in ED was defined as systolic blood pressure in ED lower than 90 mmHg and dyspnea in ED was defined as respiratory rate in ED fewer than 10, or more than 29 per minute according to guidelines for field triage of injured patients (19).

Two age typologies were used in the analysis. The first consisted of two age groups: 18 to 64 years old and 65 years or older. The second included five groups: 18 to 29 years old, 30 to 54 years old, 55 to 64 years old, 65 to 75 years old and older than 75 years old. It is known that risk of injury death increases after age 55 years (19). Race was categorized into 4 groups: White, Black or African American, Asian and other. Five injury mechanisms were analyzed: ‘Motor vehicle traffic (MVT)’, ‘Falls’, ‘Assault’, ‘Struck by and against’ and ‘Other and unspecified’ based on ICD-9-CM E-Codes in the NTDB NSP (18). Four GCS categories were defined: ≤ 8, 9 −12, 13−15 and unknown (2, 20, 21). Unknown categories were defined as sex, GCS category, hypotension and dyspnea in ED, because there was a possibility that the data were not missing at random. The youngest age group, males, White race, ‘Other and unspecified’ mechanism, GCS 13 −15, those without skull/face fractures, those without other spine fracture/dislocation, those without upper limb injury, those without lower limb injury, those without pelvic injury, those without thorax injury, those without hypotension in ED and those without dyspnea in ED were used as the reference category for age, sex, race, mechanism, GCS, skull/face fractures, other spine fracture/dislocation, upper limb injury, lower limb injury, pelvic injury, thorax injury, hypotension in ED and dyspneas in ED variables.

The estimates for frequency and proportion of all categories, mean age, mean GCS and mean ISS were first assessed. Univariate analysis was done with potential risk factors, and then multiple logistic regression models were fitted to identify significant risk factors for cervical spine injuries. The models were checked for possible multi-collinearity problems. The interaction between age and injury mechanism was assessed using a likelihood ratio test between a model with interaction terms and a model without interaction terms. Then, logistic regression models were fit to cases with MVT injuries and to cases with fall injuries separately. The odds ratio (OR) for cervical spine injury and corresponding 95% confidence interval were calculated. Statistical analysis was performed using SAS version 9.2 (SAS Institute Ins., Cary, NC). Since NTDB NSP has a complex sampling design, PROC SURVEYFREQ, PROC SURVEYMEANS and PROC SURVEYLOGISTIC were used to obtain estimates that control for the sampling effect. A significance level of 0.05 was used for all statistical tests.

The Institutional Review Board (IRB) at Emory University determined that the current study was not human subject research and, therefore, IRB review was not required.

RESULTS

The 2007 NTDB NSP had 148,270 raw records, which represented weighted 630,645 trauma cases. Of the 630,645 cases, 3 cases (0.0005%) did not have a DCODE, 976 (0.15%) were declared dead on arrival with minimal or no resuscitation attempt, and 79,432(12.60%) cases were younger than 18 years old or their age was missing. Among the remaining 550,313 cases, 187,709 (34.1%) had TBI. There were 37,496 (6.8%) cervical spine injuries overall. The prevalence of cervical spine injury among all TBI cases was 8.6% and significantly higher than cases without TBI (8.6% vs. 5.9%, Wald χ^2=42.76, P <0.0001). Further analysis was done for 187,709 TBI.

The demographic data, injury mechanisms, total GCS at ED, ISS, the prevalence of concomitant injuries, hypotension and dyspnea in ED were calculated (Table 1). Among these TBI cases, mean age was 46.7 years, 68% were males and 70% were White. Forty-four percent had MVT and 32% had fall-related injuries. The mean GCS was 12.7 and mean ISS was 14.3. Among these TBI patients face fracture was frequent and 31% had skull or face fractures. Twelve percent had other spine fracture/dislocation, 17% had upper limb injury, 12% had lower limb injury, 7% had pelvic injury and 17% had thorax injury. Among them 3.5% had hypotension and 8.7% had dyspnea in ED.

Table 2 shows the proportion of injury mechanisms by 5 age groups for all TBI cases, cases with cervical spine injury and cases without cervical spine injury. The table for all TBI cases shows that, as age increased, the proportion of MVT injury decreased whereas the proportion of fall injury increased. Among people who were 65 years old or older, the majority of cases got injuries due to falls. The proportion of injury mechanism was similar among cases without cervical spine injury. However, among cases with cervical spine injury, older cases were more likely to suffer from MVT injury rather than fall-related injury compared to cases without cervical spine injuries.

The results of the univariate analysis are shown in Table 3. Those who were 30 to 54 years old and those who were 65 to 75 years old had significantly higher odds of cervical spine injury compared to those who were 18 to 29 years old. Females had significantly lower odds than males. Other races had significantly lower odds of cervical spine injury than Whites. Patients with MVT injuries had significantly higher odds of cervical spine injury compared with other and unspecified mechanism. Fall injury and assault had significantly lower odds of cervical spine injury. GCS sore 8 or lower and GCS sore 9‒12 categories had significantly higher odds compared to GCS 13–15. Higher ISS was associated with significantly higher odds of cervical spine injury. Skull/face fractures, other spine fracture/dislocation, upper limb injury, lower limb injury, pelvic injury and thorax injury were all associated with significantly higher odds of cervical spine injury. Those who had hypotension in ED, who had dypnea in ED or those whose respiratory rate in ED was unknown had significantly higher odds of cervical spine injury.

A multiple logistic regression model was fitted with the following variables: age (2 categories), sex, race, injury mechanism (mechanism), GCS categories (GCS), skull /face fractures (skull), other spine fracture/dislocation (other spine), upper limb injury (upper limb), lower limb injury (lower limb), pelvic injury (pelvis), thorax injury (thorax), hypotension in ED (hypotension) and dyspnea in ED (dyspnea). To examine the interaction between age and injury mechanism, the interaction terms of 2 age categories with 5 injury mechanisms were added to the model:

$$\text{logit}(\text{cervical spine injury}) = \beta_0 + \beta_1(\text{age}) + \beta_2(\text{sex}) + \beta_3(\text{race}) + \beta_4(\text{mechanism}) + \beta_5(\text{GCS}) + \beta_6(\text{skull}) + \beta_7(\text{other spine}) + \beta_8(\text{upper limb}) + \beta_9(\text{lower limb}) + \beta_{10}(\text{pelvis}) + \beta_{11}(\text{thorax}) + \beta_{12}(\text{hypotension}) + \beta_{13}(\text{dyspnea}) + \beta_{14}(\text{age}) \times (\text{mechansim})$$

The highest condition index of this model was 20.68, so there were no multi-collinearity problems. Then the model without interaction terms of age with mechanism was fit. Likelihood ratio test between the two models showed that there was significant interaction between age and injury mechanism (χ^2=93.73, P<0.0001).

The results from the model with interaction terms of age with mechanism are shown in Table 4. Among cases with MVT, old age group had significantly higher odds of cervical spine injury (OR: 1.44, 95% CI: 1.27, 1.64). There are no significant difference in odds of cervical injury between young and old age groups in falls and assault. Old age group had significantly higher odds of cervical spine injury in ‘struck by and against’ (OR: 2.98, 95%CI: 1.53, 5.80) and other and unspecified mechanism (OR: 2.12, 95%CI: 1.69, 2.66). In terms of injury mechanism, MVT had significantly higher odds compared to other and unspecified mechanisms only in young age group (OR: 1.60, 95%CI: 1.43, 1.79). Falls were associated with significantly lower odds compared to other and unspecified mechanisms only in old age group (OR: 0.55, 95%CI: 0.43, 0.69). Assault had significantly lower odds both in young and old age groups. Females had significantly lower odds (OR: 0.87, 95% CI: 0.81, 0.93). Black or African Americans had significantly higher odds of cervical spine injury compared to Whites (OR: 1.23, 95% CI: 1.05, 1.44). Other races had significantly lower odds compared to Whites (OR: 0.88, 95% CI: 0.77, 0.99). A GCS score 8 or lower (OR: 1.37, 95% CI: 1.24, 1.51) and GCS sore 9−12 (OR: 1.29, 95% CI: 1.07, 1.54) were associated with significantly higher odds and those whose GCS was unknown were associated with significantly lower odds of cervical spine injury (OR: 0.65, 95% CI: 0.46, 0.93) compared to GCS 13−15. Skull/face fractures (OR: 1.41, 95% CI: 1.29, 1.54), other spine fracture/dislocation (OR: 3.36, 95% CI: 3.01, 3.74), upper limb injury (OR: 1.28, 95% CI: 1.19, 1.38), thorax injury (OR: 1.57, 95% CI: 1.44, 1.70) were all associated with cervical spine injury. Pelvic injury had a protective effect for cervical spine injury (OR: 0.63, 95% CI: 0.56, 0.70). Lower limb injury did not have a significant effect. Hypotension in ED was associated with significantly higher odds (OR: 1.41, 95% CI: 1.21, 1.65). The existence of dyspnea in ED was not significant but those whose respiratory rate in ED was unknown had significantly higher odds (OR: 1.40, 95% CI: 1.13, 1.72).

Since MVT and falls are the two major injury mechanisms, a model controlling for all above variables (except injury mechanism) was fit separately to cases with MVT injury and cases with fall injury. To examine the age effect further, 5 age categories were used in this model:

$$\text{logit}(\text{cervical spine injury}) = \beta_0 + \beta_1(\text{age}) + \beta_2(\text{sex}) + \beta_3(\text{race}) + \beta_4(\text{GCS}) + \beta_5(\text{skull}) + \beta_6(\text{other spine}) + \beta_7(\text{upper limb}) + \beta_8(\text{lower limb}) + \beta_9(\text{pelvis}) + \beta_{10}(\text{thorax}) + \beta_{11}(\text{hypotension}) + \beta_{12}(\text{dyspnea})$$

The results from these models are shown in Table 5. In MVT injury, the odds of cervical spine injury increased significantly as age increased. Odds among those older than 75 years were 1.85 times as those who were 18 to 29 years old (OR: 1.85, 95% CI:

1.48, 2.31). Females had significantly lower odds (OR: 0.82, 95% CI: 0.75, 0.90) of cervical spine injury. Black or African Americans had significantly higher odds (OR: 1.25, 95% CI: 1.05, 1.49) and other races had significantly lower odds (OR: 0.82, 95% CI: 0.71, 0.95) compared to Whites. GCS sore 8 or lower (OR: 1.58, 95% CI: 1.39, 1.79), GCS sore 9−12 (OR: 1.73, 95% CI: 1.39, 2.16), skull/face fractures (OR: 1.37, 95% CI: 1.25, 1.50), other spine fracture/dislocation (OR: 3.08, 95% CI: 2.71, 3.50), upper limb injury (OR: 1.21, 95% CI: 1.10, 1.34), thorax injury (OR: 1.50, 95% CI: 1.36, 1.66) were all associated with cervical spine injury. Pelvic injury had a protective effect (OR: 0.66, 95% CI: 0.57, 0.75). Hypotension in ED was associated with significantly higher odds (OR: 1.35, 95% CI: 1.13, 1.61). The existence of dyspnea in ED was not significant but those whose respiratory rate in ED was unknown had significantly higher odds (OR: 1.45, 95% CI: 1.12, 1.89).

In fall injuries, those who were 30 to 54 year old and those who were 65 to 75 years old had marginally significantly higher odds of cervical spine injury than those who were 18 to 29 years old and OR were 1.26 (95% CI: 0.99, 1.59, P=0.056) and 1.42 (95% CI: 0.99, 2.02, P=0.055) respectively. Sex did not have a significant effect. Asians had significantly lower odds than Whites (OR: 0.47, 95% CI: 0.23, 0.95). Lower GCS was not associated with cervical spine injury, but those whose GCS was unknown had significantly lower odds (OR: 0.51, 95% CI: 0.38, 0.68). Skull/face fractures (OR: 1.72, 95% CI: 1.46, 2.02), other spine fracture/dislocation (OR: 4.31, 95% CI: 3.73, 4.98) and thorax injury (OR: 1.52, 95% CI: 1.22, 1.90) were associated with cervical spine injury. Pelvic injury had a protective effect (OR: 0.61, 95% CI: 0.46, 0.81). Hypotension in ED were associated with significantly higher odds (OR: 1.92, 95% CI: 1.32, 2.79). Dyspnea in ED was not a significant factor.

DISCUSSION

Age, GCS in MVT injury, skull/face fractures, other spine fracture/dislocation, upper limb injury in MVT, thorax injury and hypotension in ED were significantly associated with cervical spine injury among cases with TBI, which is consistent with former studies (3, 5). These results may help physicians in ED to identify TBI patients at higher risk for cervical spine injury.

Cases with pelvic injuries had significantly lower odds of cervical spine injury than cases without pelvic injuries both in MVT and fall injuries when controlling for other variables. This result is inconsistent with the literature (10). Lower spine fracture/dislocation was associated with higher odds of cervical spine injury, so it is interesting that fracture and/or dislocation of pelvis which is connected to lumbar spine was associated with decreased odds of cervical spine injury. Pelvic injury might suggest that more energy affected the lower part of the body even though these cases have TBI.

Among TBI patients in this study Black or African Americans had significantly higher odds of cervical spine injury compared to Whites in MVT. The other race category with MVT injury and Asians with fall injuries had significantly lower odds of cervical injury. There are few reports about race/ethnicity as risk factor for cervical spine injury. National Emergency X-Radiography Utilization Study (NEXUS) collected demographic information of all patients with blunt trauma who underwent cervical spine radiography in the participating EDs. They reported that the risk for cervical spine injury was highest among Whites and lowest among African American patients (22). The reasons for the difference of the results between their report and the present study might be due to differences in the study design or samples. The denominator of the NEXUS study consisted of cases that underwent radiography at the discretion of the treating physician, whereas the denominator in the present study consisted of all TBI cases. Also, samples in NTDB NSP data are trauma cases that were taken to level 1 or level 2 trauma centers, so these cases might be more severe than cases in the NEXUS database.

Lower GCS was associated with higher odds of cervical spine injury among cases with MVT injury. For fall injuries, cases with an unknown GCS had significantly lower odds which suggest the possibility that missing data were associated with the outcome. The practice of using GCS as an indicating factor can be troublesome because of patient sedation and/or intubation. ISS can be used to control overall severity of patients instead of GCS and other injuries although ISS may include outcome of cervical spine injury. In the future study, the model controlling for ISS needs to be examined whether it can fit better than the model which controls for GCS when assessing cervical spine injuries among TBI patients.

There was overall interaction between age and injury mechanism. Models which were fit separately to cases with MVT and cases with falls showed that there is difference in the effect of age between MVT injury and fall-related injury. Older cases had significantly higher odds for cervical injury in MVT injury and cases that were older than 75 were 1.85 times more likely to have cervical spine injury than cases that were 18 to 29 years old. In fall injuries, effect of age was not significant at the 0.05 significant level. However, there is still the possibility that patients with TBI and cervical spine injury, who suffered from low energy mechanisms such as falls from standing height, did not go to hospital with EMS because mild cervical spine injury in older adults with TBI can be missed at first. In such a scenario, these individuals would be underrepresented in this sample.

The strength of this study is the large sample size which made it possible to control many variables simultaneously and still detect significant results. The NTDB NSP was used to generate national estimates of patients seen at trauma centers. Consequently, the results from this study allows for more generalizability compared to using data from a single or even several trauma centers.

This study has several limitations. Because data were reported by each hospital voluntarily, data missing might not occur at random and missing data might be associated with risk factors or the outcome.

The data for this study are from trauma registries and not from patients' medical records, so detailed descriptions of cervical injuries or retrospective validation of diagnosis was not available. Also, coding schemes might differ across hospitals. For example, a patient with C3, 4 closed fractures and complete spinal cord injury could be coded with 806.01 'Closed fracture of C1−C4 level with complete lesion of cord' or 805.08 'Closed fracture of multiple cervical vertebrae' and 952.01 'C1−C4 level with complete lesion of spinal cord'. Because of these reasons, accurate categorization of the injury level was not possible.

Protective devises such as seat belts also affect the risk for cervical spine injury (23). However, use of protective devises was not examined in the present study because only 7,669 records out of 148,270 had the information about protective devises.

One may argue that systolic blood pressure and respiratory rate in ED had been already modified by medical procedures such as intra venous infusion by EMS. Hypotension or dyspnea caused by cervical spine injury might be fixed by EMS before the patient arrived at ED. In addition, as an indicator for cervical spine injury, hypotension or dyspnea in EMS will be more helpful for EMS and physicians in ED to prepare for the patient treatment. However, systolic blood pressure and respiratory rate in ED was used rather than those in EMS in this study because systolic blood pressure in EMS was missing in 49.19 % of records and respiratory rate in EMS was missing in 50.26% of record. Systolic blood pressure in ED was missing in 3.64 % of records and respiratory rate in ED was missing in 6.06% of records. In the future study, the utilization of vital signs in EMS would be compared to that of vital signs in ED to assess cervical spine injuries among trauma patients.

There was a significant difference in odds of cervical spine injury across race categories and the effect of race was different between MVT injury and falls. This difference might be further explored by controlling for ISS, protective devices or other variables in the future studies.

Pelvic injuries appeared to have a protective effect on cervical spine injury when controlling for other variables in this study. This result is inconsistent with the literature (10). The relationship between pelvic injuries and cervical spine injuries could be further explored by conducting biomechanical studies.

CONCLUSIONS

Among TBI patients, older age groups had significantly higher odds for cervical spine injury in MVT injuries but in fall injuries, age did not have a significant effect. Pelvic injuries appeared to have a protective effect on cervical spine injury. Skull/face fractures, other spine fracture/dislocation, upper limb injury, thorax injury and hypotension in ED were all associated with cervical spine injury. There was significant difference in odds of cervical spine injury across race categories. These identified risk factors can inform physicians in evaluating cervical spine injuries among TBI patients with various level of consciousness.

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TABLE 1.Characteristics of traumatic brain injury cases (n=187,709), National Trauma Data Bank National Sample Project, 2007

	All TBI* (n=187,709)		Cervical spine Injury (n=16,078)		Non cervical spine injury (n=171,631)	
Mean age (SD)**	46.7	(0.44)	46.88	(0.52)	46.68	(0.45)
Age category (%)						
18-29	54,206	(28.88)	4,274	(26.58)	49,932	(29.09)
30-54	70,568	(37.59)	6,576	(40.90)	63,992	(37.28)
55-64	19,868	(10.58)	1,669	(10.38)	18,199	(10.60)
65-75	14,542	(7.75)	1,379	(8.58)	13,162	(7.67)
76+	28,525	(15.20)	2,180	(13.56)	26,345	(15.35)
Sex (%)						
Male	127,351	(67.84)	11,216	(69.76)	116,135	(67.67)
Female	58,455	(31.14)	4,665	(29.01)	53,790	(31.34)
Unknown	1,903	(1.01)	197	(1.23)	1,706	(0.99)
Race (%)						
White	131,426	(70.02)	11,574	(71.98)	119,852	(69.83)
Asian	2,865	(1.53)	228	(1.42)	2,636	(1.54)
Black or African American	20,050	(10.68)	1,816	(11.30)	18,234	(10.62)
Other	33,368	(17.78)	2,460	(15.30)	30,908	(18.01)
Injury mechanism (%)						
MVT†	82,046	(43.71)	10,021	(62.33)	72,025	(41.97)
Falls	60,143	(32.04)	3,717	(23.12)	56,426	(32.88)
Assault	22,169	(11.81)	484	(3.01)	21,686	(12.64)
Struck by and against	3,307	(1.76)	235	(1.46)	3,073	(1.79)
Other and unspecified	20,043	(10.68)	1,621	(10.08)	18,422	(10.73)

TABLE 1. continued

	All TBI (n=187,709)		Cervical spine Injury (n=16,078)		Non cervical spine injury (n=171,631)	
Mean ED‡ GCS (SD)	12.71	(0.09)	11.48	(0.11)	12.83	(0.09)
ED GCS category (%)						
≤ 8	28,879	(15.39)	4,174	(25.96)	24,705	(14.39)
9 - 12	7,496	(3.99)	786	(4.89)	6,710	(3.91)
13 - 15	130,675	(69.62)	10,117	(62.93)	120,558	(70.24)
Unknown	20,658	(11.01)	1,001	(6.22)	19,658	(11.45)
Mean ISS (SD)	14.34	(0.37)	19.77	(0.38)	13.84	(0.36)
Skull/face fracture (%)	58,995	(31.43)	6,178	38.43	52,817	(30.77)
Other spine fracture/dislocation(%)	23,212	(12.37)	5,540	(34.46)	17,672	(10.30)
Upper limb injury (%)	32,286	(17.20)	4,678	(29.09)	27,608	(16.09)
Lower limb injury (%)	21,826	(11.63)	2,700	(16.80)	19,126	(11.14)
Pelvic injury (%)	12,203	(6.50)	1,689	(10.51)	10,514	(6.13)
Thorax injury (%)	31,049	(16.54)	5,658	(35.19)	25,391	(14.79)
ED Hypotension (%)						
Negative	175,918	(93.72)	14,487	(90.10)	161,431	(94.06)
Positive	6,572	(3.50)	1,201	(7.47)	5,372	(3.13)
Unknown	5,218	(2.78)	390	(2.43)	4,828	(2.81)
ED Dyspnea (%)						
Negative	161,504	(86.04)	12,617	(78.47)	148,887	(86.75)
Positive	16,393	(8.73)	2,327	(14.47)	14,066	(8.20)
Unknown	9,813	(5.23)	1,135	(7.06)	8,678	(5.06)

*TBI traumatic brain injury

**SD standard deviation

†MVT motor vehicle traffic

‡ED emergency department

TABLE 2. Proportion of injury mechanism by age group among all traumatic brain injury cases (n=187,709), cases with cervical spine injury (n=16,078) and cases without cervical spine injury (n=171,631), National Trauma Data Bank National Sample Project, 2007

	All cases (n=187,709)				
	Age group				
	18-29	30-54	55-64	65-75	76 +
MVT† (%)	57.58	47.58	41.44	30.62	16.02
Falls (%)	11.03	21.31	40.13	58.65	79.32
Assault (%)	17.00	15.97	5.99	2.27	0.57
Struck by and against (%)	2.09	1.96	1.57	1.34	1.00
Other and unspecified (%)	12.29	13.18	10.87	7.11	3.10
	Cervical spine injury (n=16,078)				
	Age group				
	18-29	30-54	55-64	65-75	76 +
MVT (%)	75.99	65.35	62.07	47.39	36.09
Falls (%)	8.36	17.48	26.78	38.99	56.23
Assault (%)	3.37	4.44	1.36	1.26	0.35
Struck by and against (%)	0.82	1.68	1.34	0.94	2.46
Other and unspecified (%)	11.46	11.05	8.45	11.43	4.87
	Non cervical spine injury (n=171,631)				
	Age group				
	18-29	30-54	55-64	65-75	76 +
MVT (%)	56.01	45.76	39.55	28.86	14.36
Falls (%)	11.26	21.70	41.36	60.71	81.23
Assault (%)	18.17	17.16	6.41	2.37	0.58
Struck by and against (%)	2.20	1.98	1.59	1.38	0.88
Other and unspecified (%)	12.36	13.40	11.09	6.66	2.95

†MVT motor vehicle traffic

TABLE 3. Univariate analysis of the association between potential risk factors and cervical spine injury among traumatic brain injury cases (n=187,709), National Trauma Data Bank National Sample Project, 2007

	OR*	95% CI*	p value
AGE			
18-29	1.00		
30-54	1.20	1.09, 1.32	0.0001
55-64	1.07	0.96, 1.19	0.21
65-75	1.22	1.08, 1.39	0.002
76+	0.97	0.88, 1.07	0.51
Sex			
Male	1.00		
Female	0.90	0.84, 0.96	0.001
Unknown	1.20	0.75, 1.91	0.45
Race			
White	1.00		
Asian	0.90	0.73, 1.11	0.31
Black or African American	1.03	0.86, 1.24	0.74
Other	0.82	0.71, 0.96	0.01
Injury mechanism			
MVT†	1.58	1.41, 1.78	<.0001
Falls	0.75	0.66, 0.86	<.0001
Assault	0.25	0.18, 0.36	<.0001
Struck by and against	0.87	0.66, 1.15	0.32
Other and unspecified	1.00		
GCS			
≤ 8	2.01	1.80, 2.26	<.0001
9 - 12	1.40	1.19, 1.64	<.0001
13- 15	1.00		
Unknown	0.61	0.36, 1.02	0.06
ISS	1.05	1.05, 1.05	<.0001
Skull/face fracture	1.40	1.27, 1.56	<.0001
Other spine fracture/dislocation	4.58	3.93, 5.34	<.0001
Upper limb injury	2.14	1.97, 2.33	<.0001
Lower limb injury	1.61	1.41, 1.84	<.0001
Pelvic injury	1.80	1.52, 2.13	<.0001
Thorax injury	3.13	2.79, 3.50	<.0001

TABLE 3. continued

	OR*	95% CI*	p value
ED‡ Hypotension			
Negative	1.00		
Positive	2.49	2.14, 2.90	<.0001
Unknown	0.90	0.71, 1.14	0.38
ED Dyspnea			
Negative	1.00		
Positive	1.95	1.68, 2.26	<.0001
Unknown	1.54	1.26, 1.89	<.0001

*OR, odds ratio; CI, confidence interval

†MVT motor vehicle traffic

‡ED emergency department

TABLE 4. Multiple logistic regression analysis of the association between potential risk factors and cervical spine injury among traumatic brain injury cases (n=187,709), National Trauma Data Bank National Sample Project, 2007

		aOR*	95% CI*	p value
MVT†	**old vs. young******	1.44	1.27, 1.64	<.0001
Falls	**old vs. young**	1.12	0.92, 1.37	0.26
Assault	**old vs. young**	2.15	0.87, 5.31	0.10
Struck by and against	**old vs. young**	2.98	1.53, 5.80	0.001
Other and unspecified	**old vs. young**	2.12	1.69, 2.66	<.0001
Young**	**MVT vs. other**	1.60	1.43, 1.79	<.0001
Old**	**MVT vs. other**	1.09	0.83, 1.43	0.54
Young	**falls vs. other**	1.03	0.86, 1.25	0.72
Old	**falls vs. other**	0.55	0.43, 0.69	<.0001
Young	**assault vs. other**	0.34	0.25, 0.45	<.0001
Old	**assault vs. other**	0.34	0.13, 0.86	0.02
Young	**struck by and against vs. other**	0.88	0.64, 1.21	0.44
Old	**struck by and against vs. other**	1.24	0.69, 2.21	0.48
Sex				
Male		1.00		
Female		0.87	0.81, 0.93	0.0001
Unknown		1.26	0.99, 1.59	0.06
Race				
White		1.00		
Asian		0.95	0.76, 1.18	0.64
Black or African American		1.23	1.05, 1.44	0.01
Other		0.88	0.77, 0.99	0.04

TABLE 4. continued

	aOR*	95% CI*	p value
GCS			
≤ 8	1.37	1.24, 1.51	<.0001
9 - 12	1.29	1.07, 1.54	0.01
13- 15	1.00		
Unknown	0.65	0.46, 0.93	0.02
Skull/face fracture	1.41	1.29, 1.54	<.0001
Other spine fracture/dislocation	3.36	3.01, 3.74	<.0001
Upper limb injury	1.28	1.19, 1.38	<.0001
Lower limb injury	0.95	0.86, 1.04	0.23
Pelvic injury	0.63	0.56, 0.70	<.0001
Thorax injury	1.57	1.44, 1.70	<.0001
ED‡ Hypotension			
Negative	1.00		
Positive	1.41	1.21, 1.65	<.0001
Unknown	1.01	0.77, 1.32	0.94
ED Dyspnea			
Negative	1.00		
Positive	1.02	0.90, 1.16	0.80
Unknown	1.40	1.13, 1.72	0.002

*aOR, adjusted odds ratio; CI, confidence interval

†MVT motor vehicle traffic

** Young, 18-64; Old ≥65

‡ED emergency department

TABLE 5. Multiple logistic regression analysis of the association between potential risk factors and cervical spine injury among motor vehicle traffic injuries (n=82,046) and fall injuries (n=60,143), National Trauma Data Bank National Sample Project, 2007

	MVT† (n=82,046)			Falls (n=60,143)		
	aOR*	95% CI*	p value	aOR	95% CI	p value
AGE						
18-29	1.00			1.00		
30-54	1.17	1.05, 1.30	0.004	1.26	0.99, 1.59	0.056
55-64	1.14	1.00, 1.30	0.04	1.11	0.73, 1.70	0.62
65-75	1.39	1.16, 1.66	0.0003	1.42	0.99, 2.02	0.055
76+	1.85	1.48, 2.31	<.0001	1.39	0.97, 1.98	0.08
Sex						
Male	1.00			1.00		
Female	0.82	0.75, 0.90	<.0001	0.93	0.81, 1.07	0.30
Unknown	1.48	0.97, 2.26	0.07	0.84	0.66, 1.07	0.16
Race						
White	1.00			1.00		
Asian	1.09	0.82, 1.46	0.55	0.47	0.23, 0.95	0.04
Black or African American	1.25	1.05, 1.49	0.01	1.18	0.84, 1.65	0.34
Other	0.82	0.71, 0.95	0.01	1.15	0.94, 1.42	0.18
GCS						
≤ 8	1.58	1.39, 1.79	<.0001	1.10	0.82, 1.47	0.52
9 - 12	1.73	1.39, 2.16	<.0001	0.89	0.66, 1.19	0.43
13- 15	1.00			1.00		
Unknown	0.83	0.63, 1.11	0.21	0.51	0.38, 0.68	<.0001

TABLE 5. continued

	MVT (n=82,046)			Falls (n=60,143)		
	aOR*	95% CI*	p value	aOR	95% CI	p value
Skull/face fracture	1.37	1.25, 1.50	<.0001	1.72	1.46, 2.02	<.0001
Other spine fracture/dislocation	3.08	2.71, 3.50	<.0001	4.31	3.73, 4.98	<.0001
upper limb injury	1.21	1.10, 1.34	0.0001	1.14	0.97, 1.34	0.11
lower limb injury	0.92	0.84, 1.01	0.08	1.07	0.78, 1.48	0.67
pelvic injury	0.66	0.57, 0.75	<.0001	0.61	0.46, 0.81	0.0005
thorax injury	1.50	1.36, 1.66	<.0001	1.52	1.22, 1.90	0.0002
ED‡ Hypotension						
Negative	1.00			1.00		
Positive	1.35	1.13, 1.61	0.0009	1.92	1.32, 2.79	0.0006
Unknown	1.10	0.84, 1.45	0.50	1.06	0.51, 2.19	0.88
ED Dyspnea						
Negative	1.00			1.00		
Positive	1.05	0.89, 1.26	0.56	0.81	0.61, 1.07	0.13
Unknown	1.45	1.12, 1.89	0.01	1.22	0.86, 1.72	0.26

†MVT motor vehicle traffic

*aOR, adjusted odds ratio; CI, confidence interval

‡ED emergency department