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Radiographic cervical spine injury patterns in admitted blunt trauma patients with and without prehospital spinal motion restriction

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ABSTRACT

Objectives Selective prehospital cervical spine motion restriction (C-SMR) following blunt trauma has increasingly been used by emergency medical service (EMS) providers. We determined rates of prehospital C-SMR and concomitant radiographic injury patterns.

Methods A retrospective trauma registry and chart review was conducted for all adult blunt trauma patients who were transported by EMS and hospitalized with radiographic cervical spine injuries from 2011 to 2019 at a level 1 trauma center.

Results Of 658 admitted blunt trauma patients with confirmed cervical spine injury by imaging, 117 (17.8%) did not receive prehospital C-SMR. Patients without prehospital C-SMR were significantly older (76 vs 54 years), more often had low fall as mechanism of injury (59.8% vs 15.9%) and had lower Injury Severity Score (10 vs 17). Patients without C-SMR (Non-SMR) experienced the full array of cervical spine injury types and locations. While the non-SMR patients most often had dens fractures,C-SMR patients most often had C7 fractures; frequencies of fractures at the remaining vertebral levels were comparable. On MRI, cervical spinal cord (8.5% vs 19.6%) and ligamentous injuries (5.1% vs 12.6%) occurred less often in non-SMR patients. Approximately 8.5% of non-SMR patients and 20% of C-SMR patients required cervical spine surgery.

Conclusion Patients without prehospital C-SMR demonstrate a broad array of cervical spine injuries. While the rates of certain cervical injuries are lower in prehospital non-SMR patients, they are not insignificant.

Level of evidence Level III.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Prehospital cervical spine motion restriction (C-SMR) can have deleterious effects and its benefits have been debated.
⇒ As a result, selective prehospital C-SMR following blunt trauma has been increasingly used by emergency medical service (EMS) providers.
⇒ A secondary analysis of a level 1 trauma center registry was performed to describe baseline characteristics and outcomes in adult patients sustaining blunt trauma and transported by EMS with or without prehospital C-SMR.

WHAT THIS STUDY ADDS

⇒ While the rates of certain injuries are lower in prehospital non-SMR patients, they are not insignificant, as a C-collar was maintained in the hospital in the vast majority of these patients and 8.5% of these patients required surgery.

HOW THIS STUDY MAY AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Patients without prehospital C-SMR demonstrated a broad array of cervical spine injuries.
⇒ The absence of a cervical collar should not pre-empt further cervical spine evaluation.

INTRODUCTION

Over 2% of blunt trauma patients sustain injury to the cervical spine.[1] Universal application of prehospital cervical spine motion restriction (C-SMR) (ie, immobilization) by emergency medical service (EMS) personnel in trauma patients had been the mainstay of trauma care to prevent cervical SCI in patients whose injuries were yet to be determined, even in the absence of the signs or symptoms.[2–4] This practice was based on the rationale that excessive C-spine motion or manipulation during transport and resuscitation could exacerbate spinal injuries.[5 6]

However, recent protocols suggest that a more selective prehospital motion restriction algorithm based on specific patient criteria may reduce adverse outcomes associated with C-SMR such as: (1) reduced cerebral venous drainage and resultant elevated intracranial pressure in patients with intracranial injuries; (2) compromised airway access; (3) derangement in oxygenation and ventilation parameters; (4) dysphagia and attendant increased risk of aspiration; (5) pressure ulcers on the occiput, chin, shoulders, and back; (6) potential for unnecessary radiation exposure to 'clear the cervical spine'; (7) potential for harm in patients with spinal conditions such as ankylosing spondylitis.[7–13] Furthermore, there is debate regarding their efficacy in terms of restriction of motion; one study demonstrated that four commonly used rigid collars decreased neck mobility by only about one-half to two-thirds of baseline.[14] Additionally, a cadaver study indicated that several collars were ineffective in neck immobilization in an unstable C-spine.[15]

As such, there has been a national trend toward selective prehospital C-SMR. National guidelines have indicated that EMS personnel can be trained to apply criteria for selective C-SMR in adults.[16] Indeed, recent consensus guidelines from American College of Emergency Physicians/American College of Surgeons Committee on Trauma/National Association of Emergency Medical Services Providers state that indications for C-SMR in blunt trauma are: acute altered level of consciousness, midline neck or back pain and/or tenderness, focal neurological signs and/or symptoms, anatomic spinal deformity and/or distracting circumstances or injury that impedes the patient's ability to contribute to a reliable examination.[17] The Eastern Association for the Surgery of Trauma guidelines for C-SMR in penetrating trauma go further by conditionally recommending against prehospital spinal motion restriction as it did not mitigate against neurological deficits and was associated with increased mortality.[18] While several studies have suggested the validity of field protocols that selectively immobilize general trauma patients, these studies have also emphasized that special caution is needed when applying these protocols to the geriatric population.[19] To this end, a substantial incidence of vertebral fractures among the elderly admitted following falls from low height was demonstrated in one county.[20] This increased fracture frequency in the geriatric population is largely attributed to age-related changes, which make the spinal column more susceptible to injury.[21] We determined the rates and types of C-spine injuries sustained by patients who did or did not receive prehospital C-SMR, hypothesizing that admitted blunt trauma patients without prehospital C-SMR would have different injury patterns.

METHODS

A retrospective review of a single institution's trauma registry (maintained on Trauma One, V.4.1, Lancet Technologies, Boston, Massachusetts, USA) was performed. All patients 18 years of age and older discharged from the hospital between January 2011 and August 2019 after sustaining blunt trauma and transported by EMS from the field to the regional/level 1 trauma center for a suburban county of approximately 1.5 million in New York State were included. Exclusion criteria included burns, drowning/diving injuries, hangings, penetrating trauma, death in the emergency department (ED), interfacility transfers, and non-EMS mode of arrival. Interfacility transfers were excluded as they may or may not reflect EMS decision making, for example, if the cervical collar was applied by the referring facility, then it is improbable that EMS would remove it for transfer. Of note, as this query is based on discharge criteria, three patients who were admitted with cervical spine injury in 2010 but discharged in 2011 were included.

In concordance with national trends, selective prehospital cervical SMR by EMS providers in New York State was mandated by the Department of Health in 2008 and guidelines were further updated in 2015.[22 23] Briefly, the protocol indicated that for patients who do not meet major blunt trauma criteria, criteria for spinal motion restriction include altered mental status for any reason; complaint of neck and/or spine pain or tenderness; weakness, tingling, or numbness of the trunk or extremities at any time since the injury; deformity of the spine not present prior to this incident; distracting injury or circumstance; or high-risk mechanism of injury (MOI) such as axial load, high-speed motorized vehicle crashes or rollover, or falls greater than standing height. It further indicated that if any doubt, suspect spine injury. In 2015, the protocol updated high-risk mechanisms to include falls >3 feet/5 steps or greater than patient's height and also included pedestrian or bicyclist collisions.[23] Additional high-energy MOI include high-speed motor vehicle collision (MVC)/motorcycle collision, a height >3 times the patient's body height, and axial loading forces. In contrast, low-energy MOI include falls from standing height or low surface and low speed MVC. The protocol indicated that a 'positive MOI is not considered means to necessitate full motion restriction but should be used as a guide to heighten a provider's suspicion for an SCI'.[23 24] The corresponding presentation indicated that older age is a high risk factor for spinal injury.[24]

Patients with C-spine injuries meeting study criteria were identified from the state-mandated trauma registry. Demographics, injury characteristics, National Trauma Data Standard defined comorbidities and complications, as well as outcomes were extracted from the trauma registry.[25] The determination of prehospital SMR was initially captured by a data field in the trauma registry indicating prehospital spinal immobilization, which refers to prehospital C-SMR. The registrars concurrently examine the prehospital patient care record (PCR) for documentation indicating the utilization of prehospital spinal motion restriction in the narrative and/or in a PCR field indicating 'spine immobilization neck and back'. Additional sources for these data are ED records, including trauma team activation flowsheets, if any. Secondary chart review was conducted in those without prehospital spinal motion restriction but with C-spine injury. For patients to have been classified as having prehospital C-SMR, they could have had a rigid collar, straps/head blocks, etc. In cases of inconsistency in the medical record on secondary review, patients were classified as having prehospital C-SMR. In one patient with radiographic cervical spine injury, the presence/absence of prehospital C-SMR could not be confirmed and in another the C-spine injury was thought to have likely occurred at a prior event. Hence, these two patients were excluded from all analyses.

The medical records of all patients with cervical spine injury (bone, ligament, and/or SCI) in the trauma registry were examined to characterize imaging findings (CT scan and/or MRI) and management. Patients with C-spine injuries noted only on autopsy were not included, nor were the few patients with spinal cord injury without radiographic abnormality, for example, those with 'stingers' or clinical sprains. Patients with isolated disk herniation were also excluded, unless it was clear that this was an acute injury that resulted in neurological deficit from cord involvement. Bone injury (fracture or subluxation) was characterized based on CT reports. Of note, lateral mass and pars interarticularis fractures were coded as one. Body, endplate, and tubercle fractures were coded as vertebral body fractures. The term posterior elements fractures was also listed in the radiology reports, without further delineation, for example, pedicle, transverse processes, articular processes, lamina, spinous processes in seven patients.

MRI was only used for clarifying the acuity of a bony injury when this was not clear on CT. In contrast, ligamentous and cord injuries were based on MRI only. For ligamentous injuries, we included those where edema was noted in the ligaments as well as statements indicating possible/probable/suggestive/cannot exclude ligamentous injury in the setting of other factors. Hence, there is the potential for under coding of ligamentous injury, as those noted in the operating room would not be included, for example, if a patient went to the operating room for a jumped facet without MRI, likely they would have had a ligamentous injury, but given the absence of an MRI, it would not have been ascribed in this study. For cord injuries, we included cord

compression, cord contusion, cord edema, cord hemorrhage, and cord injury only on MRI. In other words, if no MRI was performed, then no ligamentous or cord injury was counted in this study, regardless of CT or clinical findings. In the rare cases of discrepancy between radiology reports and clinical service, to maintain consistency, we used radiology reports.

The decision to perform spinal imaging in patients with or without prehospital cervical spinal motion restriction is at the discretion of the providers. Similarly, the decision to place or remove a collar on patients presenting to the ED is at the discretion of the treating provider in accordance with guidelines.[26 27] CT scanning of the head/neck in the elderly is liberalized, regardless of symptomatology, in concordance with national trends and caveats of CT spine clearance rules.[26 27] To this end, CT panscans in the elderly after ground level falls have noted significant new findings on imaging.[28] Panscans in patients without obvious injury and significant mechanism has been previously shown to be worthwhile.[29]

Univariate statistical analyses of demographic and outcome variables were performed using SPSS V.26 (IBM, Armonk, New York, USA), Tableau V.2020.4.13 (Seattle, Washington, USA), and R statistical software (Vienna, Austria). No data were imputed; missing variable details are described in the text and/or tables. Median values or percentages were reported as appropriate. Non-parametric tests for independent samples were used to examine the statistical significance of differences in continuous and categorical variables, respectively. Multivariate logistic regression models were also generated using R to determine predictors for prehospital C-SMR. In these analyses, we considered the following demographic factors: age, sex, year of discharge, MOI, Glasgow Coma Score in the ED (ED GCS), and severity of injuries (AIS) in the face, chest, abdomen, and extremity. ED GCS, as opposed to head/neck AIS, was used as it indicates mental status in the ED, regardless of underlying head or C-spine injury. A p value <0.05 was considered statistically significant.

RESULTS

From 2011 to 2019, 7977 admitted adult blunt trauma patients were transported to our facility via EMS. Of these, 41.9% received prehospital C-SMR. Of admitted patients, 658 (8.2%) patients sustained cervical spine injury on imaging and met study inclusion criteria. Of these 658 patients, 117 (17.8%) did not receive prehospital spinal mobilization restriction and 541 (82.2%) received C-SMR (table 1). Of these 117 no prehospital C-SMR patients, 6 refused or removed C-SMR and in 3 patients C-SMR could not be completed for anatomic/physiological/other reasons. While the percentage of patients with C-spine injuries per year remained relatively constant at 7.0%–9.5%, the rate of without prehospital C-SMR (non-SMR) ranged from 5.0% to 34.5%. It generally increased in the later years, with a caveat that 2016 had a 27.8% rate (figure 1). This trend had an r^2 value of 0.74 for linear regression. Concomitantly, the non-SMR rate among patients who did not have a C-spine injury increased from 49.5% to 73.2% with an r^2 value of 0.93, reflecting improving specificity (figure 2).

Of 658 patients with cervical spine injury, the median age in patients with C-SMR was 54 years vs 76 years in those without C-SMR. Patients without C-SMR were less often male (55.5% vs 65.4%), less often had multisystem injury (11.9% vs 30.6%), with a median Injury Severity Score of 10 vs 17 (table 1). They had thoracic spine injuries less often (12.8% vs 25.8%). The median ED GCS in non-SMR patients was 15 (IQR 15–15) vs 15 (IQR 14–15) in C-SMR patients ($p<0.001$). Patients without C-SMR most often had low fall as MOI (59.8% vs 15.9%). Patients without C-SMR were more often white (91.4% vs 82.1%). Patients without C-SMR were more often Medicare enrollees (62.4% vs 22.0%).

With regard to injuries, 22/658 patients had unclear traumatic spine findings on imaging. They were included in the study because they were treated with a cervical collar during hospitalization as follows: age indeterminate cervical spine fracture by CT but acute by MRI (n=1); subacute/healing/evolving fracture (n=3); cervical spine body versus osteophyte fractures (n=4); age indeterminate (n=8); and unclear if non-union/chronic fracture/or other anatomic abnormality such as a vascular groove (n=6).

However, these 22 patients were not included in analyses of acute cervical spine fracture patterns, leaving 489 patients who had an acute cervical spine fracture; the remaining had injuries other than fractures (*vide infra*). Approximately 24.7% of patients with or without C-SMR had two cervical vertebrae fractured; three or more vertebral level fractures occurred in 9.1% of those without C-SMR and 11.2% of those with C-SMR (figure 3). The incidence of C1, C3, C4, C5, and C6 fractures were not significantly different between groups. While C2 fracture incidence did not reach statistical significance (36.4% vs 26.2%, p=0.057), fractures of the dens (26.1% vs 11.2%, p=0.001) occurred significantly more often in non-SMR group. Meanwhile, C7 (22.7% vs 37.6%, p=0.02) fractures occurred significantly less often in non-SMR patients. Indeed, C2 was the most frequently fractured vertebra in the non-SMR group and C7 was the most frequently fractured vertebra in the C-SMR group. Subluxation, including acute vertebral anterolisthesis/posterolisthesis and perched facets, occurred significantly less often in the non-SMR group (11.4% vs 21.9%, p=0.04).

The parts of a vertebra that were acutely fractured were not significantly different between those without and with prehospital C-SMR (figure 4). The most common fracture locations in both groups were transverse process (25.0% without C-SMR vs 29.7% with C-SMR) and vertebral body (29.5% without C-SMR vs 24.9% with C-SMR). Notably, patients may have had involvement of more than one part of a single cervical vertebra via extension of the fracture and/or as a separate fracture, approximately 39.8% without C-SMR and 30.4% with C-SMR had more than one fracture of a single vertebra on CT scan (p=0.13). Furthermore, ligamentous injuries by MRI occurred less often (5.1% vs 12.6%, p=0.001) in those without C-SMR versus with C-SMR. Spinal cord injuries by MRI were also not infrequent in both groups, but occurred less often (8.6% vs 19.6%, p=0.008) in those without C-SMR versus with C-SMR.

With regard to hospitalization outcomes in patients confirmed to have a spinal injury on imaging, a cervical collar was placed in the ED in all patients that had not received prehospital motion restriction. In non-operative non-SMR patients, the collar was cleared during hospitalization in nine patients. Cervical spine surgery, including treatment with a halo, was performed less often in non-SMR patients than C-SMR patients (8.5% vs 20.0%, p=0.004) during the hospitalization (table 1). In the non-SMR group, there were six anterior cervical diskectomy fusions (ACDF), three posterior cervical fusions, and one open reduction internal fixation of the dens; three of these procedures were performed in patients without fractures (two ACDF and one posterior fusion). Those without prehospital C-SMR had a significantly lower intensive care unit (ICU) admission rate (29.1% vs 55.2%) and median length of hospital stay (6 days vs 8 days), but not ICU length of stay (LOS). The rate of cervical

Table 1 Demographic characteristics and hospitalization outcomes of all cervical spine injury patients

Demographics	Spinal motion restriction (n=541)	No spinal motion restriction (n=117)	P value
Median age, years (IQR)	54 (31, 71)	76 (62, 85)	<0.001
Male sex (%)	354 (65.4%)	65 (55.5%)	0.044
Mechanism of injury			
MVC/MCC (%)	276 (51.0%)	29 (24.9%)	<0.001
Pedestrian/Bicyclist struck (%)	67 (12.4%)	4 (3.4%)	0.003
High fall (>3 feet) (%)	99 (18.3%)	12 (10.3%)	0.035
Low fall (≤3 feet) (%)	86 (15.9%)	70 (59.3%)	<0.001
Other (%)	13 (2.4%)	2 (1.7%)	1
Injury Severity Score (median, IQR)	17 (9, 25)	10 (5, 14)	<0.001
Multisystem injury (%)*	166 (30.7%)	14 (12.0%)	<0.001
ED GCS (median, IQR)†	15 (14, 15)	15 (15, 15)	<0.001
Head/Neck AIS (median, IQR)	3 (2, 4)	2 (2, 3)	0.022
Face AIS (median, IQR)	2 (1, 2)	2 (1, 2)	0.657
Chest AIS (median, IQR)	3 (2, 4)	2.5 (2, 3)	0.008
Abdomen AIS (median, IQR)	2 (2, 3)	2 (2, 3)	0.867
Extremity AIS (median, IQR)	2 (2, 3)	2 (2, 3)	0.309
External AIS (median, IQR)	1 (1, 1)	1 (1, 1)	0.006
Thoracic spine injury (%)	140 (25.9%)	15 (12.8%)	0.003
Lumbar spine injury (%)	78 (14.4%)	10 (8.5%)	0.091
Cervical spine surgery (%)	108 (20.0%)	10 (8.5%)	0.004
ICU admission (n, %)	299 (55.2%)	34 (29.1%)	<0.001
Hospital LOS, days (median, IQR)	8 (5, 18)	6 (4, 11)	<0.001
ICU LOS, days (median, IQR)	7 (4, 18)	5 (3, 14)	0.092
Insurance status			
Commercial	84 (15.5%)	9 (7.7%)	0.027
Medicaid/Medicaid pending	24 (4.4%)	7 (6.0%)	0.474
Medicare	119 (22%)	73 (62.39%)	<0.001
No-fault auto	249 (46.0%)	24 (20.5%)	<0.001
Self-pay	39 (7.2%)	2 (1.7%)	0.021
Workmen's compensation	21 (3.9%)	1 (0.8%)	0.152
Other	5 (0.9%)	1 (0.8%)	1
Race‡			
White	444 (82.1%)	107 (91.4%)	0.013
Black	39 (7.2%)	5 (4.3%)	0.310
Hospital discharge disposition§			
Home	256 (47.3%)	53 (45.3%)	0.691
Rehabilitation	233 (43.1%)	55 (47.0%)	0.436
Nursing home	4 (0.7%)	1 (0.8%)	1
Other hospital	6 (1.1%)	2 (1.7%)	0.637
Hospice/Home hospice care	2 (0.4%)	1 (0.8%)	0.445
In-hospital mortality (n, %)	40 (7.4%)	5 (4.3%)	0.312

*Multisystem injury is defined as AIS >3 in at least two of the following body parts: head/neck, face, thorax, abdomen, spine, extremity.
†ED GCS was indeterminate in 13 non-SMR and 15 C-SMR patients.
‡Race was not determined in one non-SMR and five C-SMR patients.
§Home includes against medical advice/homeless/prison; rehabilitation includes acute/subacute/and traumatic brain injury; nursing home includes skilled nursing facility and intermediate care facility; other hospital includes inpatient psychiatric care, long-term care hospital, and other hospital as inpatient.
AIS, Abbreviated Injury Score; ED GCS, Glasgow Coma Score in emergency department; ICU, intensive care unit; LOS, length of stay; MCC, motorcycle collision; MVC, motor vehicle collision; SCI, spinal cord injury.

collar-associated decubitus was 1.2% (one without prehospital C-SMR and seven with prehospital C-SMR). These patients had prolonged cervical collar immobilization, with hospital LOS of weeks to months. In-hospital mortality was not significantly different between those without prehospital spinal motion restriction and those with (4.3% vs 7.4%). Hospital discharge disposition was also not significantly different between groups.

Of the factors considered in multivariate analysis (table 2), only age (OR 1.02), discharge year (OR 1.21), and low fall MOI (OR 3.12) were significant predictors for non-SMR prehospital in those with spinal injuries. ED GCS and sex were not. Severity of injury in the defined body regions (ie, face AIS, chest AIS, abdomen AIS, extremity AIS) were also not significant predictors. The model had an area under the curve of 0.81.

DISCUSSION

Principal findings from this study are: (1) rate of prehospital cervical spinal motion restriction decreased; (2) patients without C-SMR had similar bony vertebral components injured as those with prehospital C-SMR, although they less often had spinal cord or ligamentous injuries on MRI; (3) dens fractures occurred

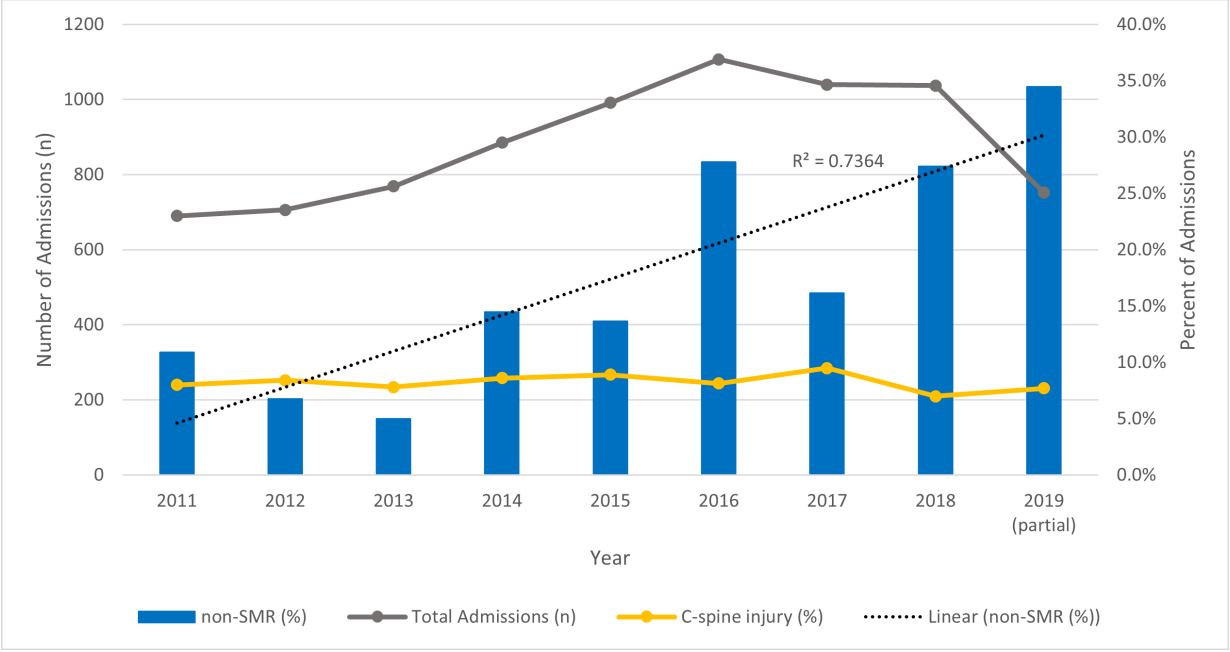

Figure 1 Annual number of blunt trauma admissions meeting study criteria, rate of cervical spine injury, rate of no prehospital C-spine motion restriction (C-SMR), and r^2 value (Linear regression of non-SMR percent) of the latter.

more often in those without C-SMR while C7 fractures occurred more often in those with C-SMR; and (4) those without prehospital C-SMR were older and more often sustained a low fall as the MOI.

We observed a general increase in no prehospital C-SMR rates in the latter part of the study, with a notable exception in 2016, where the rate was a large uptick in patients with C-spine injuries. We hypothesize that this uptick was related to the adoption of the guideline update at the end of 2015. Concomitantly, the rate of C-SMR in patients without C-spine injury also decreased from 2011 to 2019 (50.6% to 26.8%). Our state's guidelines emphasized selective spinal motion restriction based on recommendations in the guidelines and the clinical judgment of EMS providers as opposed to universal application of C-SMR in trauma patients. To this end, as all EMS agencies were mandated by the state Department of Health to complete protocol training within the same calendar years, namely 2008 and 2015, the general decline in cervical SMR over the study period would be congruent with protocol adherence.[22 23] This is consistent with recent trends, whereby an increasing number of emergency

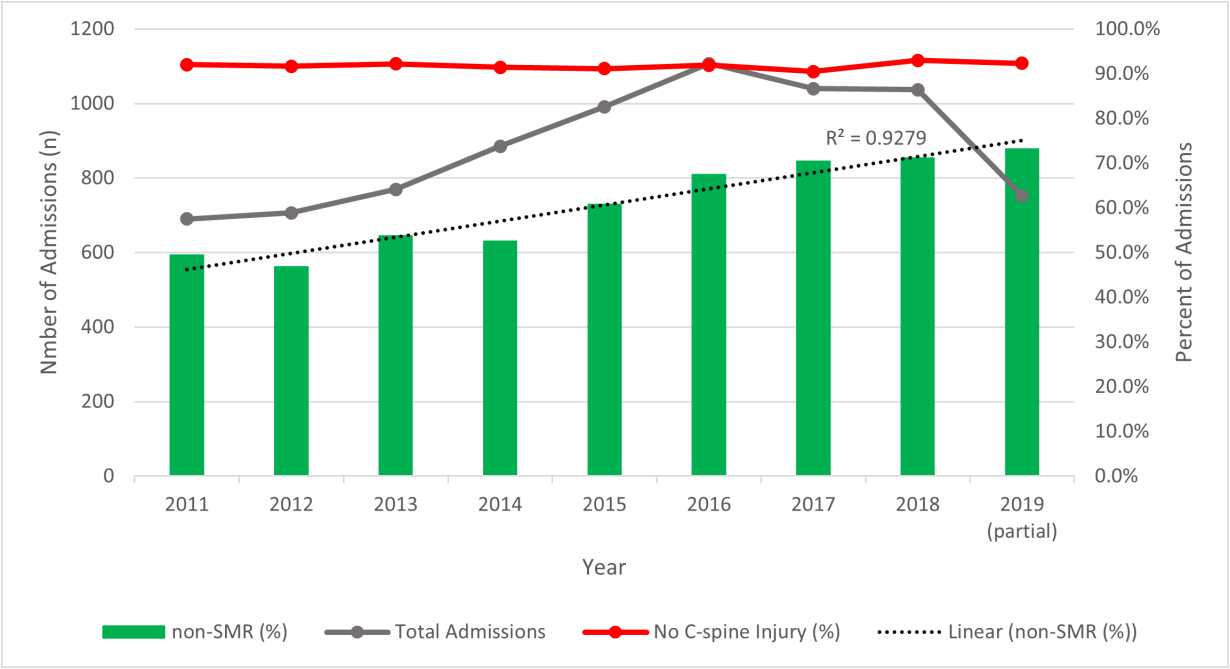

Figure 2 Annual number of blunt trauma admissions meeting study criteria, rate of no cervical spine injury, rate of no pre-hospital C-SMR, and r^2 value (Linear regression of non-SMR percent) of the latter.

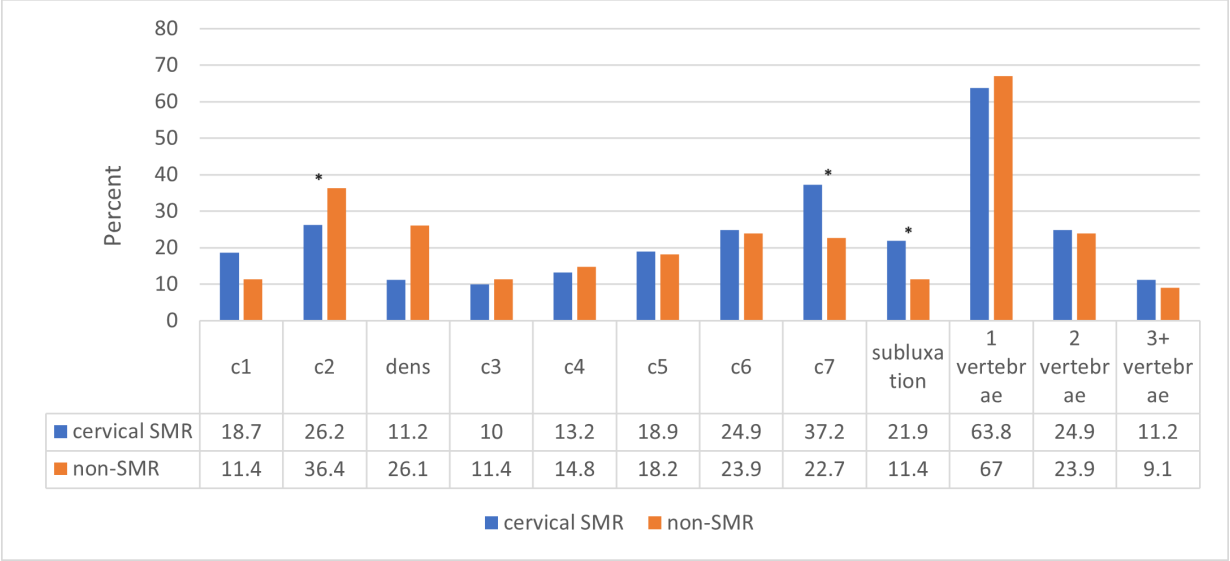

Figure 3 Vertebral injury level and number of vertebrae injured on CT (n=489). Only dens fractures, c7 fractures, and cervical spine subluxation were significantly different (p<0.05) between patients with and without pre-hospital cervical spine motion restriction. Note that subluxation term also encompasses antero- and posterolisthesis as well as perched facets. Numbers may exceed 100% as patients may have had more than one injury type.

medical service agencies have implemented selective C-SMR.[30–32] Reasons for the decreasing use of prehospital C-SMR across the country include questions on the efficacy of cervical collars in injury prevention, potential for spinal manipulation during C-collar application, optimal use of finite resources, time spent (and therefore cost) by prehospital providers in C-SMR application and maintenance throughout the patient transport process, among others previously mentioned.[33 34]

A further notable finding of this study is that patients who did not receive prehospital C-SMR had many injury patterns that were similar to those with prehospital C-SMR. Both groups had the various components of a vertebrae (ie, lamina, facet, body, etc) injured in similar frequencies, with transverse process and vertebral body fractures being the most common. The number of cervical vertebrae fractures was also not significantly different between groups; nearly 25% of patients in both groups had more than two fractured cervical vertebrae. By vertebral level, the groups also sustained similar frequencies of injuries to C1, C3, C4, C5, and C6.

However, there were also important differences in injury patterns. The most commonly injured vertebra in non-SMR patients was C2; 26.1% of patients having dens fractures. Indeed, C2 type 2 dens fractures have been previously dubbed as geriatric odontoid fractures because of their increased frequency in the elderly low-level fall patients and are thought to be secondary to degenerative changes.[35] In contrast, C7 was often injured in C-SMR patients; these patients also had a higher incidence of traumatic vertebral listhesis/subluxation. While

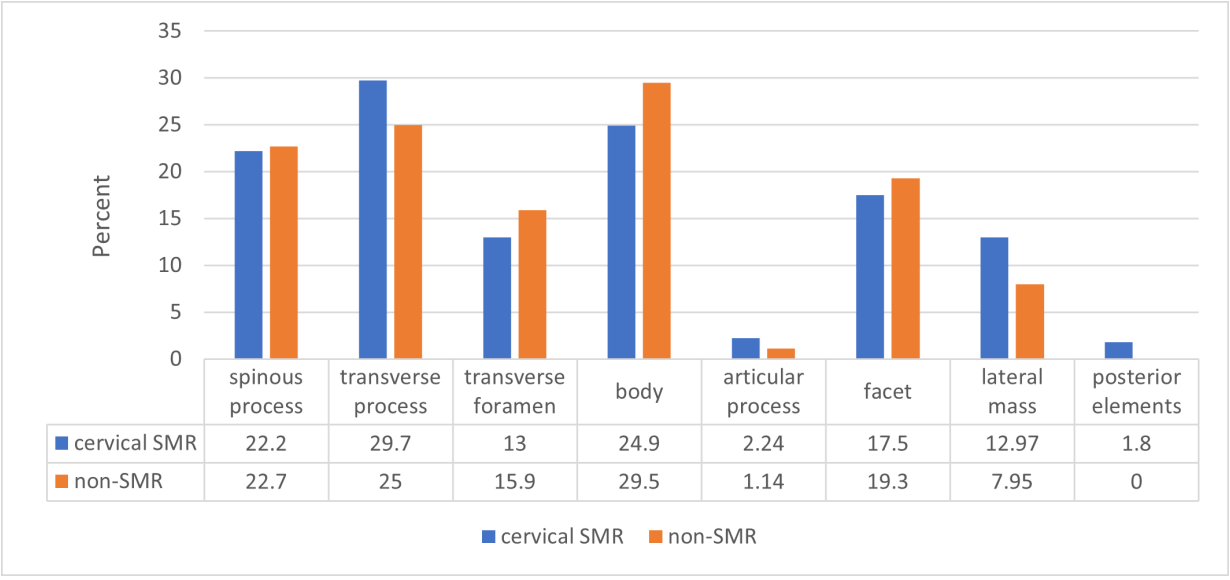

Figure 4 Vertebral component fractured on CT (n=489). The percentage of the named components above was not significantly different for any component between patients with and without pre-hospital cervical spine motion restriction. The term "posterior elements" was used as is in the radiology report; recognizing that it is composed of other elements provided in the graph; in 1 of 7 cases it was further specified as facet. Numbers may exceed 100% as patients may have had more than one injury type.*

Table 2 Multivariate logistic regression for predictors of no prehospital cervical spinal motion restriction in patients with cervical spine injuries

Characteristic	OR (IQR)	P value
Age	1.02 (1.01–1.04)	0.003
Male sex	0.90 (0.55–1.49)	0.7
MVC/MCC	Reference	n/a
Low fall	3.12 (1.60–6.20)	<0.001
High fall	0.65 (0.29–1.40)	0.3
Pedestrian/Bicyclist struck	0.80 (0.28–1.94)	0.6
Other mechanism of injury	0.46 (0.02–2.51)	0.5
ED GCS	1.13 (1.01–1.31)	0.06
Face AIS	0.80 (0.52–1.16)	0.3
Chest AIS	0.92 (0.74–1.12)	0.4
Abdomen AIS	0.92 (0.66–1.25)	0.6
Extremity AIS	0.94 (0.74–1.16)	0.6
Year of discharge	1.21 (1.09–1.35)	<0.001

AIS, Abbreviated Injury Score; ED GCS, Glasgow Coma Score in emergency department; MCC, motorcycle collision; MVC, motor vehicle collision; n/a, not available.

C-SMR patients had higher frequencies of cervical cord injuries on MRI, ligamentous injuries on MRI as well as need for cervical spine surgery, rates in the non-SMR group were still substantial. Except for possibly patients who underwent surgery for central cord syndrome, the need for surgery implies a potentially unstable or at least serious spine injury in those not receiving prehospital C-SMR. In turn, delayed diagnosis and management of traumatic C-spine instability can lead to poor outcomes, and timely motion restriction substantially reduces the risk.[33] The vast majority of cervical spine injury patients were treated non-operatively with a C-collar in the hospital and at discharge, that is, the cervical spine was only cleared early during hospitalization in nine patients who did not have prehospital C-SMR and did not undergo surgery. Hence, non-SMR patients did not only have 'trivial' injuries, but rather the whole gamut of injuries; a substantial number required cervical spine surgery.

The cervical spine injury pattern is also consistent with other findings on univariate analysis in that the non-SMR group had older patients, predominantly Medicare enrollees, with low-level fall as the most common MOI. This suggests potential underutilization of C-SMR in the elderly population and is consistent with previous reports.[36] Of note, cervical spine pain or tenderness is not felt to be a reliable indicator of cervical spine fractures as a study of patients aged 55 years or older with cervical spine fractures found that 21% did not have either of these findings.[37] Concomitantly, GCS <15 or altered level of consciousness have also not demonstrated a clear association with cervical spine injury.[38] We also did not find an association between ED GCS and prehospital C-SMR.

As the geriatric population in the USA continues to grow, an increasing incidence of low falls and resultant injury would be expected.[39] According to the 2016 American College of Surgeons National Trauma Databank findings, 39% of trauma victims were over the age of 65 years.[40] The geriatric population is more likely to experience spinal injury even after low-energy MOI due to age-related physiological changes.[41] Accurate prehospital and in-hospital trauma assessment of the geriatric population is challenged by physiological changes, medications, and comorbid conditions.[42] These factors likely contribute to the exclusion of patients over the age of 65 years from C-spine clearance via the Nexus criteria or Canadian C-spine rule.[35 36] Considering these factors together suggests the presence of a distinct patient population warranting further consideration of prehospital C-collar application, namely, elderly patients who sustain a low-level fall.

One commonly described complication/concern, namely C-collar-associated decubiti was rarely observed, with a prevalence of 1.1%; these patients had cervical collars for a prolonged period of time in the hospital. Prevalence of C-collar decubiti varies widely among reports, likely due to differences in decubitus prevention protocols or duration of the C-collar than prehospital C-SMR utilization.[9 34 43] The increased vigilance for pressure ulcer injuries in recent years has further decreased the incidence. As all patients received a C-collar in the ED, no neurological complications are attributable to the absence of prehospital C-SMR. An additional reason for the lack of attributable neurological complications from no prehospital C-SMR is that various cervical spine injuries are generally inherently stable.[13]

Limitations

This study has several limitations. Data were collected via a retrospective trauma registry query, with inherent limitations thereof, and subsequent chart review.[44] Therefore, it is possible that a cervical collar was applied in the field but was not charted in the prehospital and ED records. Due to the lack of consistently available complete records from earlier than 2011, our study did not include data from the time period in which the selective prehospital C-SMR protocol was initiated in 2008. However, we observed overall C-SMR trends. As is known, all clinical practice guidelines or protocols are subject to practitioner compliance. We cannot account for the variability in practice patterns of the over 100 largely volunteer-based prehospital EMS agencies with over 4500 licensed personnel that serve our patient population; all of whom were mandated by the state to complete the related training. Secondary EMR review of patients without prehospital C-SMR suggested the protocol when interpreted literally was followed in the majority (over 85%) of cases, but arguably this may reduce to roughly 70% with liberalization in protocol interpretation. Precise protocol compliance was difficult to determine given available documentation and discrepancies in signs/symptoms between providers. Lastly, since the data analyzed were from a single center, the generalizability of the findings need further study.

CONCLUSIONS

The components of a vertebra that are fractured in patients with or without prehospital C-SMR are similar. A substantial proportion of patients with or without prehospital C-SMR will have fractures at more than one cervical vertebral level. Patients without prehospital C-SMR demonstrated a distinct injury pattern in the preponderance of dens fractures—fractures that are common in the elderly sustaining low-level falls. The vast majority of C-spine injuries in non-SMR patients were treated with a cervical collar during hospitalization; approximately 8.5% underwent C-spine surgery. These findings challenge the assumption that patients without prehospital C-SMR would have minor/not clinically significant fractures where further evaluation is not needed.

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REFERENCES

1 Goldberg W, Mueller C, Panacek E, Tigges S, Hoffman JR, Mower WR, NEXUS Group. Distribution and patterns of blunt traumatic cervical spine injury. *Ann Emerg Med* 2001;38:17–21.
2 Bulger EM, Maier RV. Prehospital care of the injured: what's new. *Surg Clin North Am* 2007;87:37–53,
3 Hadley MN, Walters BC, Grabb PA. Cervical spine immobilization before admission to the hospital. *Neurosurgery* 2002;50:S7–17.
4 Hauswald M, Braude D. Spinal immobilization in trauma patients: is it really necessary *Curr Opin Crit Care* 2002;8:566–70.
5 Eismont FJ, Currier BL, McGuire RA. Cervical spine and spinal cord injuries: recognition and treatment. *Instr Course Lect* 2004;53:341–58.
6 Miglietta MA, Levins T, Robb TV. Evaluation of spine injury in blunt trauma. *J Am Osteopath Assoc* 2002;102:87–91.
7 Abram S, Bulstrode C. Routine spinal immobilization in trauma patients: what are the advantages and disadvantages *Surgeon* 2010;8:218–22.
8 Ay D, Aktaş C, Yeşilyurt S, Sarıkaya S, Cetin A, Ozdoğan ES. Effects of spinal immobilization devices on pulmonary function in healthy volunteer individuals. *Ulus Travma Acil Cerrahi Derg* 2011;17:103–7.
9 Ham HWW, Schoonhoven LL, Galer AA, Shortridge-Baggett LLM. Cervical collar-related pressure ulcers in trauma patients in intensive care unit. *J Trauma Nurs* 2014;21:94–102.
10 Heath KJ. The effect of laryngoscopy of different cervical spine Immobilisation techniques. *Anaesthesia* 1994;49:843–5.
11 Houghton DJ, Curley JW. Dysphagia caused by a hard cervical collar. *Br J Neurosurg* 1996;10:501–2.
12 Núñez-Patiño RA, Rubiano AM, Godoy DA. Impact of cervical collars on intracranial pressure values in traumatic brain injury: a systematic review and meta-analysis of prospective studies. *Neurocrit Care* 2020;32:469–77.
13 Sundstrøm T, Asbjørnsen H, Habiba S, Sunde GA, Wester K. Prehospital use of cervical collars in trauma patients: a critical review. *J Neurotrauma* 2014;31:531–40.
14 Karason S, Reynisson K, Sigvaldason K, Sigurdsson GH. Evaluation of clinical efficacy and safety of cervical trauma collars: differences in immobilization, effect on jugular venous pressure and patient comfort. *Scand J Trauma Resusc Emerg Med* 2014;22:37.
15 Horodyski M, DiPaola CP, Conrad BP, Rechtine GR. Cervical collars are insufficient for immobilizing an unstable cervical spine injury. *J Emerg Med* 2011;41:513–9.
16 Ahn H, Singh J, Nathens A, MacDonald RD, Travers A, Tallon J, Fehlings MG, Yee A. Pre-hospital care management of a potential spinal cord injured patient: a systematic review of the literature and evidence-based guidelines. *J Neurotrauma* 2011;28:1341–61.
17 Available: https://naemsp.org/home/news/spinal-motion-restriction-in-the-trauma-patient-%E2%80%93/ [Accessed 04 Jan 2023].
18 Velopulos CG, Shihab HM, Lottenberg L, Feinman M, Raja A, Salomone J, Haut ER. Prehospital spine immobilization/spinal motion restriction in penetrating trauma: a practice management guideline from the Eastern Association for the surgery of trauma (EAST). *J Trauma Acute Care Surg* 2018;84:736–44.
19 Tatum JM, Melo N, Ko A, Dhillon NK, Smith EJT, Yim DA, Barmparas G, Ley EJ. Validation of a field spinal motion restriction protocol in a level I trauma center. *J Surg Res* 2017;211:223–7.
20 Jawa RS, Singer AJ, Rutigliano DN, McCormack JE, Huang EC, Shapiro MJ, Fields SD, Morelli BN, Vosswinkel JA. Spinal fractures in older adult patients admitted after low-level falls: 10-year incidence and outcomes. *J Am Geriatr Soc* 2017;65:909–15.
21 Ikpeze TC, Mesfin A. Spinal cord injury in the geriatric population: risk factors, treatment options, and long-term management. *Geriatr Orthop Surg Rehabil* 2017;8:115–8.
22 New York State Department of health. Available: https://www.health.ny.gov/professionals/ems/spinal/docs/spinal_protocol.pdf [Accessed 10 Jun 2022].
23 New York State Department of Health. Suspected spinal injuries. Available: https://www.health.ny.gov/professionals/ems/pdf/t-8_suspected_spinal_injury_2015.pdf [Accessed 31 Oct 2022].
24 Bureau of Emergency Medical Services. Suspected spinal injury. Health NYSDoh; 2015.
25 American College of Surgeons, National Trauma Databank. National trauma data standard (NTDS). Available: https://www.facs.org/quality-programs/trauma/tqp/center-programs/ntdb/ntds [Accessed 28 Sep 2021].
26 Hoffman JR, Mower WR, Wolfson AB, Todd KH, Zucker MI. Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. National emergency X-radiography utilization study group. *N Engl J Med* 2000;343:94–9.
27 Stiell IG, Wells GA, Vandemheen KL, Clement CM, Lesiuk H, De Maio VJ, Laupacis A, Schull M, McKnight RD, Verbeek R, *et al*. The Canadian C-spine rule for radiography in alert and stable trauma patients. *JAMA* 2001;286:1841–8.
28 Kim C, Sartin R, Dissanaike S. Is a "Pan-scan" indicated in the older patient with a ground level fall? *Am Surg* 2018;84:1480–3.
29 Salim A, Sangthong B, Martin M, Brown C, Plurad D, Demetriades D. Whole body imaging in blunt multisystem trauma patients without obvious signs of injury: results of a prospective study. *Arch Surg* 2006;141:468–73.
30 Morrissey JF, Kusel ER, Sporer KA. Spinal motion restriction: an educational and implementation program to redefine prehospital spinal assessment and care. *Prehosp Emerg Care* 2014;18:429–32.
31 Moss R, Porter K, Greaves I, consensus group. Minimal patient handling: a faculty of prehospital care consensus statement. *Emerg Med J* 2013;30:1065–6.
32 White CC, Domeier RM, Millin MG, Standards and Clinical Practice Committee, National Association of EMS Physicians. EMS spinal precautions and the use of the long backboard - resource document to the position statement of the National Association of EMS physicians and the American college of Surgeons Committee on trauma. *Prehosp Emerg Care* 2014;18:306–14.
33 Theodore N, Hadley MN, Aarabi B, Dhall SS, Gelb DE, Hurlbert RJ, Rozzelle CJ, Ryken TC, Walters BC. Prehospital cervical spinal immobilization after trauma. *Neurosurgery* 2013;72:22–34.
34 Lacey L, Palokas M, Walker J. Preventative interventions, protocols or guidelines for trauma patients at risk of cervical collar-related pressure ulcers: a scoping review. *JBI Database System Rev Implement Rep* 2019;17:2452–75.
35 Raudenbush B, Molinari R. Longer-term outcomes of geriatric Odontoid fracture nonunion. *Geriatr Orthop Surg Rehabil* 2015;6:251–7.
36 McDonald NE, Curran-Sills G, Thomas RE. Outcomes and characteristics of non-Immobilised, spine-injured trauma patients: a systematic review of prehospital selective immobilisation protocols. *Emerg Med J* 2016;33:732–40.
37 Healey CD, Spilman SK, King BD, Sherrill JE, Pelaez CA. Asymptomatic cervical spine fractures: current guidelines can fail older patients. *J Trauma Acute Care Surg* 2017;83:119–25.
38 McCallum J, Eagles D, Ouyang Y, Ende JV, Vaillancourt C, Fehlmann C, Shorr R, Taljaard M, Stiell I. Cervical spine injuries in adults ≥ 65 years after low-level falls - A systematic review and meta-analysis. *Am J Emerg Med* 2023;67:144–55.
39 Khurrum M, Chehab M, Ditillo M, Richards J, Douglas M, Bible L, Spece L, Joseph B. Trends in geriatric ground-level falls: report from the National trauma data bank. *J Surg Res* 2021;266:261–8.
40 American Colleg of Surgeons. National Trauma Data Bank. Annual Report; 2016.
41 Boonen S, Dejaeger E, Vanderschueren D, Venken K, Bogaerts A, Verschueren S, Milisen K. Osteoporosis and osteoporotic fracture occurrence and prevention in the elderly: a geriatric perspective. *Best Pract Res Clin Endocrinol Metab* 2008;22:765–85.
42 Jeanmonod R, Varacallo M. Geriatric Cervical spine injury. In: *StatPearls*. StatPearls Publishing, Treasure Island (FL). 2021.
43 Maschmann C, Jeppesen E, Rubin MA, Barfod C. New clinical guidelines on the spinal stabilisation of adult trauma patients - consensus and evidence based. *Scand J Trauma Resusc Emerg Med* 2019;27:77.
44 Zehtabchi S, Nishijima DK, McKay MP, Mann NC. Trauma registries: history, logistics, limitations, and contributions to emergency medicine research. *Acad Emerg Med* 2011;18:637–43.