ORIGINAL RESEARCH

# Cervical Spine Injury is Rare in Self-Inflicted Craniofacial Gunshot Wounds: An Institutional Review and Comparison to the US National Trauma Data Bank (NTDB)

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**Abbreviations:**
AIS: abbreviated injury scale
CPR: cardiopulmonary resuscitation
CT: computerized tomography
EMS: Emergency Medical Services
GSW: gunshot wound
ICU: intensive care unit
LOS: length-of-stay
MRI: magnetic resonance imaging
NTDB: National Trauma Data Bank
SI: self-inflicted
SMR: spinal motion restriction

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## Abstract
**Background:** Cadaveric and older radiographic studies suggest that concurrent cervical spine fractures are rare in gunshot wounds (GSWs) to the head. Despite this knowledge, patients with craniofacial GSWs often arrive with spinal motion restriction (SMR) in place. This study quantifies the incidence of cervical spine injuries in GSWs to the head, identified using computerized tomography (CT). Fracture frequency is hypothesized to be lower in self-inflicted (SI) injuries.
**Methods:** Isolated craniofacial GSWs were queried from this Level I trauma center registry from 2013-2017 and the US National Trauma Data Bank (NTDB) from 2012–2016 (head or face abbreviated injury scale [AIS] >2). Datasets included age, gender, SI versus not, cervical spine injury, spinal surgery, and mortality. For this hospital's data, prehospital factors, SMR, and CTs performed were assessed. Statistical evaluation was done with Stata software, with $P < .05$ significant.
**Results:** Two-hundred forty-one patients from this hospital (mean age 39; 85% male; 66% SI) and 5,849 from the NTDB (mean age 38; 84% male; 53% SI) were included. For both cohorts, SI patients were older ($P < .01$) and had increased mortality ($P < .01$). Overall, cervical spine fractures occurred in 3.7%, with 5.4% requiring spinal surgery (0.2% of all patients). The frequency of fracture was five-fold greater in non-SI ($P < .05$). Locally, SMR was present in 121 (50.2%) prior to arrival with six collars (2.5%) placed in the trauma bay. Frequency of SMR was similar regardless of SI status (49.0% versus 51.0%; P = not significant) but less frequent in hypotensive patients and those receiving cardiopulmonary resuscitation (CPR). The presence of SMR was associated with an increased use of CT of the cervical spine (80.0% versus 33.0%; $P < .01$).
**Conclusion:** Cervical spine fractures were identified in less than four percent of isolated GSWs to the head and face, more frequently in non-SI cases. Prehospital SMR should be avoided in cases consistent with SI injury, and for all others, SMR should be discontinued once CT imaging is completed with negative results.

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## Background
Gunshot wounds (GSWs) to the head are highly morbid and are frequently lethal injuries. Despite recent reports of improved outcomes with aggressive resuscitation,[1] most studies have low rates of survival with many patients dying pre-hospital or in the emergency room.[2] Self-inflicted (SI) GSWs to the head, in particular, may have survival rates of only 10%-15%.[3]

In the local population, there is a high frequency of SI GSWs to the head, and many of these patients are brought in by Emergency Medical Services (EMS) with an extrication collar in place. Studies on spinal motion restriction (SMR) in penetrating trauma have indicated a lack of cost-effectiveness as well as an increased risk of mortality.[4–6] The use of SMR may impede airway management and hemorrhage control.[4,7] Moreover, cadaveric and imaging studies suggest that concurrent cervical spine fractures are rare in GSWs to the head and indirect cervical spine injuries do not occur.[4,8,9] These radiographic studies predominantly evaluated for bony injuries through plain radiographs of the cervical spine; the frequency of

| Prehospital Characteristics and Interventions | SMR (n = 121) | No SMR (n = 120) | P |
|---|---|---|---|
| Tachycardia (>120bpm) | 17 (14) | 17 (14) | NS |
| Hypotensive (<90mmHg) | 20 (17) | 32 (27) | .04 |
| Low GCS (≤8) | 79 (65) | 81 (68) | NS |
| Endotracheal Intubation | 56 (46) | 55 (46) | NS |
| CPR | 15 (12) | 30 (25) | .01 |



**Table 1.** Prehospital Characteristics of Patients with Spinal Motion Restriction
Note: Data presented as n (%).
Abbreviations: CPR, cardiopulmonary resuscitation; GCS, Glasgow Coma Scale; NS, not significant; SMR, spinal motion restriction.

cervical spine injury identified through thin-slice computerized tomography (CT) is not known.

This study characterizes cervical spine injuries identified on CT at this institution and compares them to the frequency observed in a review of the US National Trauma Data Bank (NTDB; American College of Surgeons Committee on Trauma; Chicago, Illinois USA). Fracture incidence is hypothesized to be lower in the SI GSW population. Secondarily, factors associated with prehospital SMR use are evaluated.

## Methods

The institutional review board at University Medical Center (Las Vegas, Nevada USA) approved this protocol (UMC-2017-112). Gunshot wounds to the head and face were queried from the hospital's prospectively maintained Level 1 trauma registry from 2013-2017. Patients with GSWs to the neck, multiple GSWs, polytrauma, less than 17 years of age, and incomplete records were excluded. Datasets included age, gender, SI versus not, cervical spine fracture, spinal surgery, length-of-stay (LOS), and mortality. The EMS run sheets and trauma documentation were reviewed for the presence of SMR (namely a cervical collar), hypotension, cardiopulmonary resuscitation (CPR), and intubation prior to arrival. Type of imaging (x-ray, CT, or magnetic resonance imaging [MRI]) and duration of SMR were assessed.

Institutional data were compared to the US NTDB Research Data Sets from 2012 through 2016.[10] The NTDB, which is maintained by the American College of Surgeons Committee on Trauma, is a publicly available repository containing data from over 900 registered trauma centers and 6,000,000 records. For each data year, ICD-9/10 E-Codes (mechanism of injury) were used to identify records for GSWs and separated by intent – suicide (ICD-9 955; ICD-10 X72-74) and non-suicide (ICD-9 922, 965, 985; ICD-10 W32-34, X93-95, Y22-24). Craniofacial GSWs were identified as having an abbreviated injury scale (AIS) greater than two for the head or face region. Records were excluded with AIS greater than two for other body regions (suggesting polytrauma or multiple GSWs) or age less than 17. Datasets were evaluated for presence of cervical spine fracture by D-codes (diagnosis; ICD-9 805, 806, 839; ICD-10, S12-13), spinal surgery (CPT codes), demographics, LOS, and mortality.

Statistical analysis was performed with Stata Version 14 (Stata Corp.; College Station, Texas USA). Descriptive variables are reported as number of patients and percentage of cohort with 95% confidence intervals (CI). Continuous variables are reported as mean and standard deviation (SD), with ranges when appropriate. Non-normally distributed data are presented as median with inter-quartile ranges (IQR). Normally distributed variables were compared using Student's t-test, with Chi-square or Fisher exact test for categorical comparisons. Significance was set at a P value of less than .05.

## Results

### *Demographics*

Isolated craniofacial GSWs occurred in 241 patients with a mean age 39 (SD = 18) years (range 17 to 92). The cohort had 205 (85%) males. Injuries were SI in 158 (66%), with no difference by gender (P = not significant). Overall, 137 (57%) individuals died: 107 (68%) of SI and 30 (36%) of non-SI GSWs (P < .01). Seventy patients (29%) died in the emergency department, with the remaining 67 (28%) dying after intensive care unit (ICU) admission. For the 104 surviving patients, median hospital LOS was 14 days (IQR 4-29), ICU LOS six days (IQR 2-12), and mechanical ventilation 3.5 days (IQR 0-7.5). Craniotomy was performed in 25 (24%) and tracheostomy in 35 (34%).

### *EMS Intervention*

Emergency Medical Services placed SMR for 121 (50%) patients prior to hospital arrival, with six (2%) additional cervical collars placed in the trauma bay at the discretion of the attending physician. Emergency Medical Services intubated 111 (46%) and performed CPR on 45 (19%) individuals. Patients arriving without SMR had increased frequency of hypotension or receiving CPR (Table 1); SMR was placed for 80 (51%) SI and 41 (49%) non-SI patients (P = not significant).

### *Imaging*

One or more CT scans were obtained in 183 (76%) patients; the remaining 58 (50 SI and eight non-SI) died prior to imaging. Patients with SMR had increased use of cervical spine CT (80% versus 33%; P <.01). Frequency of brain and maxillofacial CTs were not different (Figure 1). No patients received x-rays of their cervical spine; however, one (<1%) had a subsequent MRI to exclude ligamentous injury. There was no evidence of any missed injuries.

### *Cervical Spine Fractures*

Cervical spine fractures were identified in six (3%) patients, of which five of five (100%) brought in by EMS had SMR prior to arrival. Patient 3 was transported by private vehicle and without neurologic deficits, and thus was placed into SMR after his C1 transverse process fracture was discovered. All fractures were direct ballistic injuries and are described in Table 2. The frequency of cervical spine fracture was higher in non-SI wounds (7% [5/75] versus <1% [1/108]; P = .03). Patient 4 arrived with a complete spinal cord injury and was the only patient to undergo surgical



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| Patient | Age/Gender | SI (Y/N) | Head CT (Y/N) | C-Spine CT (Y/N) | Injury | Outcome |
|---|---|---|---|---|---|---|
| 1 | 70M | N | Y | Y | C1 anterior arch | LTAC |
| 2 | 50M | N | Y | Y | C1 anterior arch, occipital condyle | Death |
| 3 | 32M | N | Y | Y | C1 transverse process | Home |
| 4 | 27F | Y | Y | Y | C4 corner, C5 burst, C5/6 facet | LTAC |
| 5 | 24M | N | Y | Y | C1 lateral mass, occipital condyle | Home |
| 6 | 17M | N | Y | N | C2/3 transverse process | Death |



**Table 2.** Institutional Cervical Spine Fractures
Note: Patient 3 arrived by private vehicle and was not in spinal motion restriction (SMR) until his C1 transverse process fracture was discovered.
Abbreviations: CT, computerized tomography; LTAC, long-term acute care facility; SI, self-inflicted.

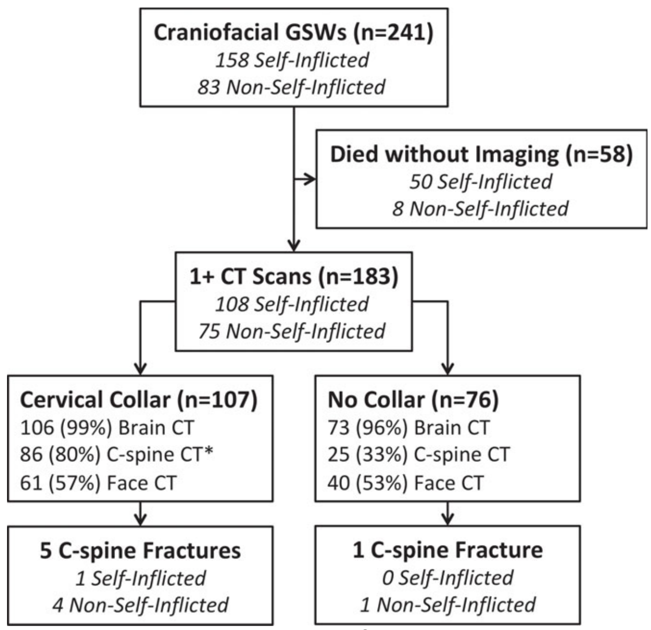




**Figure 1.** Imaging and SMR Management in Craniofacial GSWs.
Note: One cervical collar was placed after CT imaging revealed a C1 fracture in a patient arriving by private vehicle and without neurologic deficits.
Abbreviations: CT, computerized tomography; GSW, gunshot wound; SMR, spinal motion restriction.
*C-spine CT was performed more frequently ($P < .01$) in patients having SMR in place.

decompression. All others were managed non-operatively with a cervical collar.

*Comparison of Fracture Frequency to the NTDB*

The 241 local patients were compared to 5,849 from the NTDB with isolated craniofacial GSWs. Mean age of the NTDB cohort was 38 (SD = 17) years (range 17 to 89) with 3,093 (53%) SI cases. The frequency of SI cases was higher at this institution than the NTDB (66% versus 53%). For both institutional and NTDB cohorts, patients were predominantly male (>80%) with SI subsets being older ($P < .01$) and having higher mortality ($P < .01$; Table 3). Overall, cervical spine fractures occurred in 223 (4%), of which 12 (5%) underwent spinal surgery (<1% of total study population). The frequency of fracture was five-fold greater in non-SI patients ($P < .05$).

## Discussion

This study demonstrated a low frequency of cervical spine fractures in isolated craniofacial GSWs; GSWs to the head are highly morbid and are frequently lethal injuries. Self-inflicted GSWs to the head have an overall survival of only 10%-15%.[3] Gunshot wounds crossing midline (as in many SI cases), involving multiple lobes, or significant intraventricular hemorrhage are identified as highly lethal injury patterns. The majority of patients die on-scene, and of those surviving to the hospital, approximately 50% will die in the emergency department.[2] Within this severely injured population, this study identified a low incidence of concurrent cervical spine fractures.

The current results of a four percent prevalence of cervical spine fractures in GSW to the head as identified by CT parallels previous literature reporting on radiographic and cadaveric studies. This body of research predominantly used plain radiographs as the imaging modality for cervical spine evaluation with less frequent flexion-extension x-rays, fluoroscopy, or CT. Kennedy, et al noted a 10% incidence of cervical spine fractures with GSW trajectory involving the face or neck.[11] Kaups and Davis reported a 93% cervical clearance rate with radiographs, with three direct bullet injuries suggested by trajectory and no evidence of indirect spinal column injuries.[4] Cervical spine fractures have not been identified when the trajectory is limited to the cranium.[8,9,11,12] Thus, it is logical that the rate of cervical spine fractures in the SI cohort is lower than the assault population, as most SI tracts (bitemporal, transoral, or submental) would be limited to the cranium. Similarly, penetrating spinal injuries rarely results in instability, thus, the very low overall rate of spinal surgery in this population. A review of over 300 GSWs with bony spinal column injury identified only two cases (<1%) requiring decompression of spinal canal and no cases of instability requiring operative intervention.[7]

The frequency of cervical spine fractures in patients with craniofacial GSW was four percent in a review of five years of NTDB data. The higher frequency of cervical spine fracture in non-SI GSW patients was similar to frequencies in the NTDB cohort. The single case of SI-GSW with a cervical spine fracture was caused by an unusual trajectory through the mandible, hyoid bone, and into the spinal column at the C5 level, and was identified on CT scan. No cervical spine fractures were observed in SI patients with the more common submental, transoral, or bitemporal trajectories.

Spinal immobilization is suggested to have limited benefit and high potential for harm. A retrospective analysis of the NTDB demonstrated twice the risk of death from penetrating trauma in spine-immobilized patients.[6] Similarly, the Eastern Association for the Surgery of Trauma (EAST; Chicago, Illinois USA) practices management guideline for spinal immobilization found a risk



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| | | Institution | | | NTDB | | |
|---|---|---|---|---|---|---|---|
| | | All (n = 241) | SI (n = 158) | Non-SI (n = 83) | All (n = 5849) | SI (n = 3093) | Non-SI (n = 2756) |
| Age, mean (SD) | | 39 (18) | 41 (20)[a] | 34 (13) | 38 (17) | 44 (19)[a] | 31 (13) |
| Male | N (%) | 205 (85) | 135 (85) | 70 (84) | 4902 (84) | 2630 (85) | 2272 (82) |
| | CI | [79–89] | [79–91] | [75–91] | [83–85] | [84–86] | [81–84] |
| Mortality | N (%) | 137 (57) | 107 (68)[a] | 30 (36) | 3470 (59) | 2248 (73)[a] | 1222 (44) |
| | CI | [50–63] | [60–75] | [26–47] | [58–61] | [71–74] | [42–46] |
| C-Spine Fracture | N (%) | 6 (3.3) | 1 (0.9)[b] | 5 (6.7) | 217 (3.7) | 37 (1.2)[a] | 180 (6.5) |
| | CI | [1.2–7.0] | [0.02–5.0] | [2.2–15.0] | [3.2–4.2] | [0.8–1.6] | [5.6–7.5] |
| Spine surgery | N (%) | 1 (0.5) | 1 (0.9) | 0 (0.0) | 11 (0.2) | 0 (0.0) | 11 (0.4) |
| | CI | [0.01–3.0] | [0.02–5.0] | [0.0–4.7] | [0.09–0.3] | [0.0–0.1] | [0.2–0.7] |



**Table 3.** Frequency of Cervical Spine Injury in Isolated Craniofacial GSWs
Abbreviations: GSW, gunshot wound; NTDB; National Trauma Data Bank; SI, self-inflicted.
[a] $P < .01$.
[b] $P < .05$.

ratio of 2.4 for mortality and no benefit on mitigating neurologic defects.[13] Prehospital spine immobilization is not cost-effective for penetrating torso or extremity injuries and is unlikely to be advantageous for penetrating head injuries.[5] Cervical spine immobilization has the potential to mask potentially life-threatening conditions and impede airway or hemorrhage management. Specifically, cervical spine immobilization has been associated with an increased number of intubation attempts.[4] Given these findings, it is recommended to delay or omit cervical spine immobilization in favor of airway and hemorrhage management.[7,13,14]

Despite these concerns, one-half of the GSWs to the head presenting at this institution arrived in SMR, with no difference in frequency between SI and assault cases. Contraindications for SMR in the local EMS protocols include penetrating trauma to the head or neck with no evidence of spinal injury; cases where airway management, ventilation, or hemorrhage control is compromised; and cardiac arrest.[15] Patients that were hypotensive or receiving CPR had lower rates of SMR, in line with these guidelines. Apart from hemodynamic instability, there were no other factors consistently associated with SMR use. Not surprisingly, the presence of SMR increased the frequency of dedicated cervical spine imaging.

## Limitations

This study is limited by its retrospective, observational design. The EMS run sheets were often incomplete, which limited the ability to evaluate the impact of SMR on interventions. Although endotracheal intubation occurred at a similar frequency regardless of SMR, it was impossible to ascertain the number of attempts or elapsed time from the prehospital documentation. The NTDB allowed a larger scale estimate of cervical fractures in GSWs to the head and paralleled the observation of a higher frequency observed in non-SI cases. As with any database, there are limitations based upon accurate coding/data entry, missing data (excluded in this review), and the ability to extract the desired parameters. Unfortunately, the use of SMR is not a collected prehospital variable in the NTDB dataset.

## Conclusion

Cervical spine fractures were identified in less than four percent of isolated craniofacial GSWs overall, and five-fold more frequently in non-SI cases. Cervical spine CT was an accurate modality for detection of fractures. Prehospital SMR should be avoided in cases consistent with SI injury, and for all others, SMR should be discontinued once CT imaging is completed with negative results.

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**References**

1. Joseph B, Aziz H, Pandit V, et al. Improving survival rates after civilian gunshot wounds to the brain. *J Am Coll Surg.* 2014;218(1):58–65.
2. Cavaliere R, Cavenago L, Siccardi D, et al. Gunshot wounds of the brain in civilians. *Acta Neurochir (Wien).* 1988;94(3-4):133–136.
3. Selden BS, Goodman JM, Cordell W, et al. Outcome of self-inflicted gunshot wounds of the brain. *Ann Emerg Med.* 1988;17(3):247–253.
4. Kaups KL, Davis JW. Patients with gunshot wounds to the head do not require cervical spine immobilization and evaluation. *J Trauma.* 1998;44(5):865–867.
5. Garcia A, Liu TH, Victorino GP. Cost-utility analysis of prehospital spine immobilization recommendations for penetrating trauma. *J Trauma Acute Care Surg.* 2014;76(2):534–541.
6. Haut ER, Kalish BT, Efron DT, et al. Spine immobilization in penetrating trauma: more harm than good? *J Trauma.* 2010;68(1):115–121.
7. DuBose J, Teixeira PGR, Hadjizacharia P, et al. The role of routine spinal imaging and immobilization in asymptomatic patients after gunshot wounds. *Injury.* 2009;40(8): 860–863.
8. Klein Y, Cohn SM, Soffer D, et al. Spine injuries are common among asymptomatic patients after gunshot wounds. *J Trauma.* 2005;58(4):833–836.
9. Lanoix R, Gupta R, Leak L, et al. C-spine injury associated with gunshot wounds to the head: retrospective study and literature review. *J Trauma.* 2000;49(5):860–863.
10. Committee on Trauma, American College of Surgeons. National Trauma Data Bank (NTDB) Version 7.0; Chicago, Illinois USA: 2019. https://www.facs.org/quality-programs/trauma/tqp/center-programs/ntdb/datasets. Accessed January 2020.
11. Kennedy FR, Gonzalez P, Beitler A, et al. Incidence of cervical spine injury in patients with gunshot wounds to the head. *Southern Med Journal.* 1994;87(6):621–623.
12. Chong CL, Ware DN, Harris JH Jr. Is cervical spine imaging indicated in gunshot wounds to the cranium? *J Trauma.* 1998;44(3):501–502.
13. Velopulos CG, Shihab HM, Lottenberg L, et al. Prehospital spine immobilization/spinal motion restriction in penetrating trauma: a practice management guideline from the Eastern Association for the Surgery of Trauma. *J Trauma Acute Care Surg.* 2018; 84(5):736–744.
14. Medzon R, Rothenhaus T, Bono CM, et al. Stability of cervical spine fractures after gunshot wounds to the head and neck. *Spine.* 2005;30(20):2274–2279.
15. Clark County EMS System Emergency Medical Care Protocols. June 1, 2017. www.southernnevadahealthdistrict.org/ems/documents/ems/medical-care-protocols.pdf. Accessed January 2020.