Cervical Spine Injury is Highly Dependent on the Mechanism of Injury Following Blunt and Penetrating Assault

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Background: **The mechanism of injury has not been highly regarded as an important variable when evaluating cervical spine injuries. The aim of this study was to determine the incidence of cervical spine fracture (CSF) and cervical spinal cord injury (CSCI) based on mechanism following blunt and penetrating assault to better aid prioritization of management.**

Methods: **Retrospective analysis from two large urban Level I trauma centers over 87 and 144 months caused by gunshot wounds (GSW), stab wounds (SW) or blunt assault (BA).**

Results: **During the study period, there were 57,532 trauma patients evaluated at the two trauma centers, of which 42.3% were following blunt or penetrating assault. The rates of CSF and CSCI for the various mechanisms were similar between the two centers. The rates for having CSF were significantly different ($p < 0.05$) for the various mechanisms. GSW (1.35%) was the highest followed by BA (0.41%) and then SW (0.12%). The rates of CSCI for GSW (0.94%) were significantly ($p < 0.05$) higher than BA (0.14%) and SW (0.11%). For GSW patients, all patients with CSF or CSCI had a point of entry between the ears and the nipple. For SW patients, the wound was directly in the neck below the mandible and above the trapezius muscle. Although many of the SW patients also suffered blunt assault, none of the CSF or CSCI injuries were from blunt forces. In addition, all patients, both blunt and penetrating who had CSCI had neurologic deficit at the time of presentation. Surgical stabilization or tongs were applied in 15.5% (26 of 168) of the GSWs, 27.8% (3 of 11) of the SWs and 31.6% (6 of 19) of the BA patients. There was a BA patient (1 of 4,390) patient with CSF that was neurologically intact that required surgical stabilization and this patient had neck pain on admission. No penetrating injury patients with CSCI regained significant neurologic recovery during the hospitalization.**

Summary: **The rate of CSF or CSCI is low following assault and dependent on mechanism of injury. Thus the concern and extent of evaluation should also be dependent on the mechanism of injury. Neurologic deficits from penetrating assault were established and final at the time of presentation. Concern for protecting the neck should not hinder the evaluation process or life saving procedures.**

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Cervical spine fracture (CSF) and cervical spinal cord injury (CSCI) can be devastating and thus, the detection of these injuries is of major concern when evaluating a trauma patient.[1] The incidence of these injuries following trauma ranges in the literature from 2.0% to 5.0%,[2–5] with a recent national survey demonstrating that the overall rate of cervical injury is 4.3%.[6]

The Advanced Trauma Life Support (ATLS) course teaches that one should 'assume a cervical spine injury in any patient with multisystem trauma, especially with an altered level of unconsciousness or a blunt injury above the clavicle.'[7] The various mechanisms of injury are not stressed as an important variable in determining ones level of concern. The guidelines established by the Eastern Association for the Surgery of Trauma, also state that the mechanism of injury has not been shown to be a predictor of clinically significant cervical spine injuries.[8]

While it is known that certain mechanisms are more prone to cervical injuries such as motor vehicle collisions and falls from heights, trauma patients are customarily only categorized broadly into blunt and penetrating trauma. However, taking into account the mechanism of injury should be important, as the forces that are transferred can be significantly different. With the emergence of motorized vehicles and firearms, the evolutionary mechanisms made to protect the spinal cord can be defeated. The forces from stabbings or blunt assaults are less, as compared with motor vehicle collisions or gunshot wounds. The different kinematics results in different injury patterns. In spite of this, the evaluation process in trauma care often is protocol driven without regard to the mechanism of injury. In a national survey of trauma centers (Levels I-III), it was found that 88% of assault victims with abrasions and contusions about the head and face would warrant cervical spine clearance even if they had denial of pain.[5] This illustrates the point that the mechanism of injury is not heavily factored into the diagnostic algorithm.

Our premise for this study was that the incidence of CSF/CSCI varies, and is dependent upon the mechanism of

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Table 1 ICD-9 codes used to identify cervical injuries

805.00 – 805.19 - cervical fracture without spinal cord injury
806.00 - 806.19 - cervical fracture with cord injury
839.00 – 839.18 - cervical dislocations (multiple and ill defined)
952.00 – 952.90 - cervical spinal cord without bony injury.

injury following penetrating and blunt assault. In addition, unlike CSF/CSCI after a motor vehicle collision, the injuries following penetrating assault are more evident during the initial evaluation. Thus, the goal of this report was to document the incidence of CSF/CSCI following blunt and penetrating assault.

METHODS

The local institutional review boards at Los Angeles County Medical Center + University of Southern California (LAC+USC) and Washington Hospital Center, Washington D.C. (WHC) both approved the study. Both institutions are urban Level I trauma centers and their individual trauma registries were utilized to identify all patients seen in the trauma center following an assault. The data from LAC+USC was over a 144 month time period from January 1992 to December 2003, whereas the data from WHC was over an 87 month period from January 1993 to March 2000. E codes for intentional injuries were used (960.0 - 968.9) to identify those patients who were assaulted. From this group, all patients with cervical injuries were identified by using the ICD-9 codes listed in Table 1. The data were separated by mechanism of injury: gunshot wounds (GSW), stab wounds (SW), and blunt assaults (BA). If the patient had blunt assault and penetrating injury, the penetrating injury was used as the primary mechanism of injury. At WHC, all the records of patients with injuries were reviewed and 75% at LAC+USC were available for review.

The data were analyzed using a commercially available software package (SPSS Windows version 7.5, SPSS Inc, Chicago, Illinois). Means were compared using independent *t* test, and proportions were compared using χ^2. Significance was defined as $p < 0.05$.

RESULTS

A total of 57,532 trauma patients were evaluated (LAC+USC: 44,665 and WHC: 12,867) during the combined 231 months. The intentional injury rates from blunt or penetrating assaults were 44.2% at LAC+USC compared with 34.8% at WHC. Thus the total combined patients who were evaluated following assault was 24,246 and these patients were the focus of this study. The demographics of this patient population are shown in Table 2; they were similar between the two centers.

The rate of CSF and CSCI diagnosed are shown in Table 3. The injury pattern was similar between the two centers. The rate of CSF or CSCI was significantly higher ($p < 0.05$) for GSW (1.35%) than BA (0.43%) which was also significantly higher ($p < 0.05$) than SW (0.15%). For GSW patients with CSF, 69.1% (114/165) had CSCI and there were three patients who did not have a fracture, but had CSCI. Similarly, SW patients with CSF had CSCI 66.7% (6 of 9) of the time, and there were two patients who did not have a fracture but had CSCI. In contrast, BA patients with CSF had CSCI only 27.8% (5 of 18) of the time and this was significantly lower ($p < 0.05$) than penetrating assault patients.

For BA patients, one patient did not have a fracture, but had CSCI. This BA patient had episodic paralysis without a fracture due to pre-existing congenital spinal stenosis. This patient was flaccid at the scene and could not move his extremities after being assaulted but regained function during transport to the trauma center. This patient was discharged to home neurologically intact and required no therapy. For patients with CSF following BA, 33.3% (6 of 18) required operative fixation or Halo for stabilization. All six patients were symptomatic with neurologic deficits or had neck pain on admission. Five of the six patients who required stabilization (2 surgical and 3 Halo) had neurologic deficit on admission. There was one patient with CSF that presented with neck pain that did not have a CSCI but required surgical stabilization. The patients CSF or CSCI that were not treated with stabilization were usually treated with either soft or hard collar for 6 weeks.

All patients with CSF and/or CSCI following GSW were shot between the ear and the nipples. The vast majority (98.2%) were shot directly in the neck. There were three patients that had their GSW site elsewhere (one to the mastoid and two the axilla). Stabilization of the spine was required in 15.5% (26 of 168; 9 surgical, 17 Halo) patients. Despite stabilization, there was no significant neurologic recovery in any of the patients with CSCI that had their spine stabilized. The majority were stabilized for rehabilitation placement. CSF without CSCI occurred in 51 patients and 4 of these patients required intervention (2 surgical, 2 Halo). The frequency of having cervical neck stabilization following a GSW in patients who were neurologically intact was 0.03% (4 of 12,559).

For SW patients, three patients required spine stabilization. All patients with CSCI had obvious neurologic deficit at the time of presentation and all had a stabbing wound to the neck between the angle of the mandible and the clavicle. One of the patients that required surgery was stabbed in the neck, but the patient had a history of a previous cerebrovascular accident in the past and was hemiplegic on the same side upon presentation. A laminar fracture on the same side of the stab wound necessitated exploration, but the dura was intact. There were no patients who required cervical neck stabilization who presented neurologically intact following a stab wound.

DISCUSSION

The data from this analysis demonstrate that the incidence of CSF and CSCI are significantly different depending

Table 2 Demographics Based on Mechanism of Injury

	BA		GSW		SW	
	LAC+USC	WHC	LAC+USC	WHC	LAC+USC	WHC
N (% of total)	3,523 (17.6)	867 (19.3)	10,527 (52.7)	2,046 (45.6)	5,912 (29.6)	1,571 (35.0)
Mean Age	36 ± 13	35 ± 11	26 ± 11	27 ± 10	32 ± 11	31 ± 11
Percent male	89.7%	83.8%	92.4%	91.9%	91.4%	87.2%
Mean ISS	8.0	7.0	12.9	14.1	6.8	10.5

Age, mean + standard deviation; ISS, injury severity score.

Table 3 Incidence of CSF/CSCI per Patients Evaluated

	Blunt (N=4,390)			GSW (N=12,573)			SW (N=7,483)		
	CSF+	CSF−	Total	CSF+	CSF−	Total	CSF+	CSF−	Total
CSCI+	5	1	6	114	3	117	6	2	8
CSCI-	13	0	13	51	0	51	3	0	3
Total	18	1	19	165	3	168	9	2	11
			rate			rate			rate
CSF or CSCI		19	0.43%*		168	1.35%		11	0.15%*#
CSF		18	0.41%*		165	1.31%		9	0.12%*#
CSCI		6	0.14%*		117	0.94%		8	0.11%*
CSF and CSCI		5	0.11%*		114	0.92%		6	0.08%*

CSF, cervical spine injury; CSCI, cervical spinal cord injury.
* $p < 0.05$ compared to GSW.
# $p < 0.05$ compared to BA.

on the mechanism of injury following assault. While injuries do occur, the rate of CSF or CSCI is relatively low, with GSW having the highest occurrence followed by blunt assault and stabbings. Compared with GSWs, the frequency of injury to the cervical spine is one third for blunt assault and one tenth for stabbings. While combinations of different mechanisms frequently occur, none of the GSW and SW patients in this study had their CSF or CSCI due to blunt forces. Customarily, blunt assault victims are categorized as blunt traumas and subsequently treated the same. For penetrating injury, both GSW and SW are also categorized together. While the distinction exists between blunt and penetrating, the subtleties and differences within this category are not always emphasized. In Los Angeles, all patients irregardless of the mechanism of injury are brought to the trauma centers on a backboard, with the cervical color and supportive blocks in place. Because the rate of injury depends on the mechanism of injury, so should the index of suspicion, the extent of the evaluation process and management priorities.

It is classically taught that there are three stabilizing columns in the spine and that they are generally aligned in an anterior to posterior direction. It is thought that it takes two adjacent columns to be injured to make the spine unstable. Following gunshot wounds, if two of these stabilizing columns in the spine have been disrupted, it is highly likely that the spinal cord has been injured as well. In this study, all patients with CSCI had their injury at the time of their GSW and no patients regained meaningful recovery. In a study by Harrop et al., they found that of the 1,904 consecutive patients with acute spinal trauma, no patients had deterioration following penetrating trauma.[9] Connell et al. reported that out of 34,903 patients, there were 12 patients reported as having spinal injury. All had obvious evidence of spinal cord injury on assessment or were in traumatic cardiac arrest. They concluded that in fully conscious patients with isolated penetrating trauma and no neurologic deficit, that they do not require spinal immobilization.[10]

Because unstable cervical spine injury from GSW usually results in permanent injury to the cord, the benefits of cervical spine protection with a cervical collar should be weighed against the potential risk.[11] The risk is that when patients are brought to hospitals with the cervical collar in place, there is hesitancy to remove it and this could affect life saving management.[12] This is despite reports in literature that emphasizes the need to address life threatening injuries before the concern for immobilizing the neck as instability from the initial missile injury is rare.[13–16] For example, in patients with isolated GSW to the head, although there are reports that immobilization and diagnostic radiography is of minimal use,[17–19] Kaups et al., demonstrated that airway management was compromised by cervical immobilization as more intubation attempts occurred with cervical spine immobilization than without.[20]

The emphasis of the mechanism of injury and its association with cervical spinal injuries would also be beneficial to the military where penetrating injury is the predominant mechanism. Arishita et al. showed that the number of people that may have benefited from cervical protection is exceedingly small.[21] Out of 4,555 casualties over a 3-year period there were 472 penetrating neck injuries and none had spinal immobilization. Of the 296 survivors reaching care, only 11

had cervical spine column injuries. They concluded that of these 11 casualties, 7 would not have benefited from CS immobilization, and only 4 (1.4%) might have benefited. They concluded that mandatory immobilization of the CS following penetrating neck injury has no benefit because of the added risk taken by medics in application of the immobilization collar. Barkana examined the autopsy reports of 44 military casualties in Israel with a penetrating neck injury during a 4.5-year time period and concluded that it was extremely rare for penetrating injury to result in an unstable cervical spine. They also concluded that life threatening complications due to penetrating neck injury are common and may be overlooked if the neck is covered by a stabilization device.[22]

Cervical spine injuries from SW are much different from GSWs and should not be globally categorized as penetrating trauma. Unlike GSW injuries, the forces are significantly different. CSCI although rare after SW do occur as there are case reports of this event in the United States.[23,24] Epidemiologic studies from other countries are varied.[25,26] Peacock et al. reported from South Africa reported an extremely high number of occurrences from a variety of stabbing mechanisms but many are machete type injuries.[27]

Blunt assault has a low rate of CSI, however they are often treated similarly as patients who were injured after motor vehicle collisions. It is classically taught that trauma above the level of the clavicle should raise high suspicion for potential cervical spine injury. However, multiple studies have demonstrated that head and facial injuries did not increase the likelihood of CSF.[28–32] In studies specifically addressing blunt assaults, cervical spine injuries were almost non-existent which is consistent with our findings. A study on baseball bat injuries to the head identified no cervical sine injuries.[33] Many blunt assault patients do not have a reliable examination as demonstrated by Patton et al.[34] This study found that of the 102 patients with blunt assaults to the head and neck, 80 were not examinable due to intoxicants or head injury. But in this study population, there were no clinically significant cervical spine injuries identified.

Most trauma guidelines recommend that all trauma patients with a mechanism of injury having the potential to cause cervical spinal injury should be immobilized at the scene and during transport. A review of literature for spinal immobilization for trauma patients shows that there are no randomized controlled trials of spinal immobilization strategies. The effect of spinal immobilization on mortality, neurologic injury, spinal stability and adverse effects in trauma patients remains uncertain. Randomized controlled trails in trauma patients are required to establish the relative effectiveness of alternative strategies for spinal immobilization.[35] While it may be safer to error on the side of immobilizing all patients after trauma in the field, upon arrival to the trauma center, knowledge of the frequency of cervical spine and spinal cord injury may aid in the evaluation process and patient management. For assaulted patients if they are asymptomatic (neurologic deficit, pain, or tenderness) and do not have a wound to the region, the chances of having a cervical spine or spinal cord injury is unlikely and radiographic evaluation is probably not required. Symptomatic patients (neurologic deficit, pain, penetrating injury to the neck) should be immobilized and radiographically evaluated for cervical spine injury. A prospective study would help verify these recommendations.

In summary, this study demonstrates that the mechanism of injury matters in the rate of cervical spinal or spinal cord injury following assault. Blunt assault and stab wounds had a very low rate of cervical spinal or spinal cord injury. In contrast, gunshot wounds have a significantly higher rate, but the injury is evident upon presentation by either paralysis or topographic evidence of injury. Following assault, the probability of spinal instability in the absence of neurologic deficits is miniscule. The presence of a cervical collar to protect against this miniscule probability should be carefully weighed against the need to access the neck for clinical diagnosis and intervention. Knowing the differences in frequency of cervical spine and spinal cord injury may help guide the treating physician in determining their index of suspicion, identifying patients who need radiographic evaluation, and prioritizing the evaluation and treatment process.

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REFERENCES

1. Davis JW, Phreaner DL, Hoyt DB, et al. The etiology of missed cervical spine injuries. *J Trauma.* 1993;34:342–346.
2. Lowery DW, Wald MM, Browne BJ, Tigges S, Hofman JR, Mower WR Nexus Group. Epidemiology of cervical spine injury victims. *Ann Emerg Med* 2001;38:12-16.
3. Pasquale M. Practice management guidelines for trauma: East ad hoc committee on guideline development: Identifying cervical spine instability after trauma. *J Trauma.* 1998;44:945–946.
4. Reiss SJ, Raque GH Jr., Shields CB, et al. Cervical spine fractures with major associated trauma. *Neurosurgery.* 1986;18:327–30.
5. Rodgers WA. Fractures and dislocations of the cervical spine. *J Bone Joint Surg.* 1957;39:341.
6. Grossman MD, Reilly PM, Gillet. The National survey of the incidence of cervical spine injury and the approach to cervical spine clearance. *J Trauma.* 1999;47:684-690.
7. Advanced Trauma Life Support for Doctors. American College of Surgeons, Chicago Il. 1997 ed. P27.
8. Practice Guidelines. Identifying cervical spine injuries following trauma. Available at http://www.east.org. 1997.
9. Harrop JS, Sharan AD, Vaccar AR, Przybylski GJ. The cause of neurologic deterioration after acute cervical spinal cord injury. *Spine.* 2001;26:340–346.
10. Connell RA, Graham CA, Munro PT. Is spinal immobilization necessary for all patients sustaining isolated penetrating trauma? *Injury.* 2003;34:912–914.
11. Carducci B, Lowe RA, Dalsey W. Penetrating Neck Trauma: Consensus and Controversies. *Ann Emerg Med.* 1986;15 (2):208–215.

12. Bachulis BL, Long WB, Hynes GD, et al. Clinical indications for cervical spine radiographs in the traumatized patient. *Am J Surg.* 1987;153:473–478.
13. Jallo GI. Neurosurgical management of penetrating spinal injury. *Surg Neurol.* 1997;47:328–330.
14. Kupcha PC, An HS, Cotler JM. Gunshot Wounds to the Cervical Spine. *Spine.* 1990;15:1058–1063.
15. Apfelbaum JD, Cantrill SV, Waldman N. Unstable cervical spine without spinal cord injury in penetrating neck trauma. *Am J Emerg Med.* 2000;18:55–57.
16. Isiklar ZU, Lindsey RW. Low-velocity civilian gunshot wounds of the spine. *Orthopedics.* 1997;20:97–972.
17. Lanoix R, Gupta R, Leak L, Pierre J. C-spine injury associated with gunshot wounds to the head: retrospective study and literature review. *J Trauma.* 2000;49:860–863.
18. Kennedy FR, Gonzalez P, Beitler A, Sterling-Scott R, Fleming AW. Incidence of cervical spine injury in patients with gunshot wounds to the head. *South Med J.* 1994;87:621.–
19. Chong C, Ware D, Harris J Jr . Is Cervical Spine Imaging Indicated in Gunshot Wounds to the Cranium. *J Trauma.* 1998;44 (3):501-502.
20. Kaups KL, Davis JW. Patients with gunshot wounds to the head do not require cervical spine immobilization and evaluation. *J Trauma.* 1998;44:865–867.
21. Arishita GI, Vayer JS, Bellamy RF. Cervical Spine Immobilization of Penetrating Neck Wounds in a Hostile Environment. *J Trauma.* 1989;29 (3):332–337.
22. Barkana Y, Stein M, Scope A, Maor R, Abramovich Y, Friedman Z, Knoller N. Prehospital stabilization of the cervical spine for penetrating injuries of the neck –is it necessary? *Injury.* 2000; 31:305–309.
23. Rubin G, Tallman D, Sagan L, Melgar M. An unusual stab wound of the cervical spinal cord: a case report. *Spine.* 2001;26:444–447.
24. O'NeilS, McKinstry CS, Maguire SM. Unusual stab injury of the spinal cord. *Spinal Cord.* 2004;42:429–430.
25. Karamehmetoglu SS, Nas K, Karacan I, Sarac AJ, Koyuncu H, Ataoglu S, Erdogan F. Traumatic spinal cord injuries in southwest turkey: an epidemiological study. *Spinal Cord.* 1997;35:531–533.
26. Manzone P, Domenech V, Forlino D. Stab injury of the spinal cord surgically treated. *J Spinal Disord.* 2001;14:264–267.
27. Peacock WJ, Shrosbree RD, Key AG. A review of 450 stabwounds of the spinal cord. *S Afr Med J.* 1977;51:961–964.
28. Williams J, Jehle D, Cottingotn E, Shufflebarger C. Head, facial, and clavicular trauma as a predictor of cervical-spine injury. *Ann Emerg Med.* 1992;21:719–22.
29. Hills MW, Deane SA. Head Injury and Facial Injury: Is there an Increased Risk of Cervical Spine Injury? *J Trauma.* 1993;34 (4):549–554.
30. Oller DW. The relationship between face or skull fractures and cervical spine and spinal cord injuries: A review of 13,834 patients. *Accid Anal Prev.* 1992;24:187–192.
31. Neifeld GL, Keene JG, Hevesy G, et al. Cervical injury in head trauma. *J Emerg Med.* 1988;6:203–207.
32. Soicher E, Demetriades D. Cervical Spine Injuries in Patients with Head Injuries. *Br J Surg.* 1991;78:1013–1014.
33. Groleau GA, Tso EL, Olshaker JS, et al. Baseball bat assault injuries. *J Trauma.* 1993;34:366–372.
34. Patton JH, Kralovich KA, Cuscheri J, Gasparri M. Clearing the cervical spine in victims of blunt assault to the head and neck: what is necessary? *Am Surg.* 2000;66:326–330.
35. Kwan I, Bunn F, Roberts I. Spinal immobilization for trauma patients. *Cochrane Database Syst Rev.* 2001;CD002803.