Spine Immobilization in Penetrating Trauma: More Harm Than Good?

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Background: Previous studies have suggested that prehospital spine immobilization provides minimal benefit to penetrating trauma patients but takes valuable time, potentially delaying definitive trauma care. We hypothesized that penetrating trauma patients who are spine immobilized before transport have higher mortality than nonimmobilized patients.

Methods: We performed a retrospective analysis of penetrating trauma patients in the National Trauma Data Bank (version 6.2). Multiple logistic regression was used with mortality as the primary outcome measure. We compared patients with versus without prehospital spine immobilization, using patient demographics, mechanism (stab vs. gunshot), physiologic and anatomic injury severity, and other prehospital procedures as covariates. Subset analysis was performed based on Injury Severity Score category, mechanism, and blood pressure. We calculated a number needed to treat and number needed to harm for spine immobilization.

Results: In total, 45,284 penetrating trauma patients were studied; 4.3% of whom underwent spine immobilization. Overall mortality was 8.1%. Unadjusted mortality was twice as high in spine-immobilized patients (14.7% vs. 7.2%, $p < 0.001$). The odds ratio of death for spine-immobilized patients was 2.06 (95% CI: 1.35–3.13) compared with nonimmobilized patients. Subset analysis showed consistent trends in all populations. Only 30 (0.01%) patients had incomplete spinal cord injury and underwent operative spine fixation. The number needed to treat with spine immobilization to potentially benefit one patient was 1,032. The number needed to harm with spine immobilization to potentially contribute to one death was 66.

Conclusions: Prehospital spine immobilization is associated with higher mortality in penetrating trauma and should not be routinely used in every patient with penetrating trauma.

Key Words: Penetrating trauma, Trauma, Gunshot wound, Stab wound, Prehospital care, Spine immobilization.

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Spine immobilization is often part of the current prehospital treatment for patients with penetrating injuries to the head, neck, or torso, although there are no definitive studies that demonstrate its benefit.[1,2] Some locales have instituted selective immobilization protocols based on injury mechanism. However, many prehospital protocols call for spine immobilization whenever there is potential for spinal cord injury.[2,3] This frequent use of spine immobilization is in direct opposition to suggestions from the prehospital trauma life support (PHTLS) course and textbook, which state that spine immobilization is not indicated in patients with penetrating trauma to the head, neck, or torso without neurologic deficit or complaint.[4]

The extent to which field interventions such as spine immobilization are beneficial to penetrating trauma patients remains controversial. Some providers argue for a more robust, procedure driven, and time intensive approach to emergency medical services (EMS) care and emphasize the importance of field stabilization, whereas many others assert that the clinical benefits of interventions will be negated by the increased time to definitive care. PHTLS emphasizes a balanced approach, with a goal scene time of <10 minutes, and a rapid transport to the closest appropriate facility.[5] The debate regarding the importance of prehospital procedures in trauma has largely focused on intravenous (IV) fluid resuscitation and intubation. A randomized controlled trial of delayed versus immediate IV fluid resuscitation found that delaying fluid administration until operative intervention improved outcomes in patients with penetrating torso injuries.[6] In a retrospective analysis of the National Trauma Data Bank (NTDB), Shafi and Gentilello[7] demonstrated that prehospital endotracheal intubation of trauma patients was associated with hypotension and decreased survival. Another recent study showed that mortality was no better after the implementation of a more robust advanced life support (ALS) system for the prehospital care of trauma patients.[8] Such studies support the paradigm shift toward minimizing field interventions and prehospital care by EMS providers to expedite transport to and definitive care at a trauma center.

Spine immobilization, like IV fluid administration and endotracheal intubation, has the potential to delay the transport of trauma patients. Data suggest that prehospital spine immobilization may benefit only very small fraction of penetrating trauma patients. In an analysis of 1,000 patients with torso gunshot wounds (GSW) in Maryland, Cornwell et al.[9]

demonstrated that 14.1% had vertebral column and/or spinal cord injuries and that only 0.2% required operative vertebral column stabilization. The small proportion of patients who required operative spinal intervention indicates that few patients with torso GSW may benefit from thoracolumbar immobilization.

This study seeks to measure the effect of prehospital spine immobilization on mortality in a large national sample of penetrating trauma patients drawn from the NTDB. We hypothesized that penetrating trauma patients who underwent prehospital spine immobilization would have higher mortality than penetrating trauma patients who did not undergo spine immobilization. In addition, we expected that a very small proportion of penetrating trauma patients potentially benefited from prehospital spine immobilization.

METHODS

This retrospective study used the American College of Surgeons NTDB version 6.2. The NTDB is the largest collection of trauma data, with approximately 1.5 million records from hundreds of U.S. trauma centers. Data from the NTDB is de-identified to comply with Health Insurance Portability and Accountability Act regulations. The Institutional Review Board of The Johns Hopkins Medical Institutions granted exempt status for this retrospective review.

All trauma patients who suffered penetrating injury (stab or a GSW) between 2001 and 2004 were included in the analysis. Any patient who had sustained blunt trauma was excluded. Patients were included only if they had appropriate documentation of "none" or at least one prehospital procedure in the data file. Patients with missing prehospital procedure data were excluded. A sensitivity analysis was performed by excluding patients whose prehospital procedure was recorded as "not documented." Statistical analyses were performed in Stata/Multi-Processor 10.0 (StataCorp, College Station, TX).

The Effect of Prehospital Spine Immobilization on Penetrating Trauma Patient Mortality

The primary outcome variable was inhospital mortality. The primary independent variable was prehospital spine immobilization, as noted in the prehospital procedure file of the NTDB and defined by the application of a cervical collar and/or a spine backboard. We performed a descriptive analysis of our dependent and independent variables, and we conducted an unadjusted analysis that included a comparison of mortality rates among all patients with versus without prehospital spine immobilization.

Multiple logistic regression analysis was performed, with the primary comparison being patients with versus without prehospital spine immobilization. The following variables were included in the multiple logistic regression analysis: gender, race, age, Injury Severity Score (ISS), Revised Trauma Score, insurance status, and year of admission. We also controlled for the performance of five of the most common prehospital procedures: endotracheal intubation, military antishock trousers (MAST), IV fluids, splinting, and chest decompression. We did not adjust for prehospital cardiopulmonary resuscitation (CPR), because the data on prehospital CPR appeared to be biologically implausible: the mean systolic blood pressure of penetrating trauma patients receiving CPR was 118 mm Hg.

Subset analyses were performed on the following groups of penetrating trauma patients: (1) patients who had an ISS <15; (2) ISS >15; (3) ISS >25; (4) hypotensive patients (systolic blood pressure <90 mm Hg); (5) normotensive patients; (6) patients who suffered a GSW; (7) patients who suffered a stab wound; (8) hypotensive patients with GSW; (9) hypotensive patients with stab wounds; (10) hypotensive patients with severe thoracic injury (Abbreviated Injury Scale chest value >3); and (11) hypotensive patients with severe abdominal injury (Abbreviated Injury Scale abdomen value >3).

Potential Benefit of Prehospital Spine Immobilization

We examined patients with penetrating spine injury to assess the proportion of patients who may have benefited from prehospital spine immobilization. Patients were considered to have potentially benefited from prehospital spine immobilization if they had an incomplete spine injury and required an operative spine procedure (including vertebral spine repair, spine fusion, laminectomy, and/or halo placement). An incomplete spine injury was defined using International Classification of Diseases, Ninth Revision (ICD-9) diagnosis codes of open vertebral column injuries (806.1×, 806.3×, 806.5, 806.71, 806.72, 806.79, 806.9, and 852.0–852.59) without complete spinal cord lesions (806.11, 806.16, 806.31, 806.36, 806.71, 952.01, 952.06, 952.11, and 952.16). Operative spine procedure was defined using ICD-9 procedure codes of 81.0×, 81.3×, 03.01, 03.02, 03.09, 03.53, 02.94, and 93.41. The number needed to treat to achieve one potential benefit of prehospital spine immobilization was calculated as the number of patients immobilized, divided by the number of patients who might have benefited (which we defined as patients with incomplete spinal cord injury that underwent operative repair). The number needed to harm (NNH) was calculated based on the adjusted risk reduction from the multiple logistic regression analysis and is the inverse of the attributable risk associated with prehospital spine immobilization. The NNH represents the number of patients who would need to undergo spinal immobilization to be associated with one potential death.

RESULTS

A total of 45,284 penetrating trauma patients were identified with complete prehospital procedure data. The patient population was predominantly young (median age, 29 years) and men (87.8%). The highest proportion of patients were black (41.8%), followed by white (34.6%) and Hispanic (19.3%). About one third (32.0%) of injuries were to the neck or torso, and 22.0% of patients had an ISS >15; 4.3% of penetrating trauma patients underwent prehospital spine immobilization. The overall mortality rate for all penetrating patients was 8.1% (Table 1).

On unadjusted bivariate analysis (Table 2), patients who underwent spine immobilization were twice as likely to

TABLE 1. Descriptive Analysis of Penetrating Trauma Patients in Study

	Percentage
Race	
Whites	34.6
Blacks	41.8
Hispanics	19.3
Asians	1.5
Native Americans	0.66
Other race	2.2
Age (yr), (mean ± SD)	31.4 ± 13.3
Age (yr), median	29
Male	87.8
Female	12.3
Gunshot wound (GSW)	42.3
Stab wound	57.7
ISS	
<9	49.5
9–15	28.5
16–25	9.4
>25	12.6
Revised Trauma Score (RTS) (± SD)	7.1 ± 1.9
Yr of admission	
2001	21.9
2002	23.9
2003	29.4
2004	24.8
Insurance	
Private insurance	24.4
Medicaid	64.7
Medicare	4.2
Other insurance	6.6
Open spine injury	1.6
Complete spine injury	0.34
Incomplete spine injury	1.4
Spine Surgery	0.34
Prehospital procedures	
Spine immobilization	4.3
Intubation	3.3
IV fluids	64.1
MAST	36.7
Chest decompression	17.5
Splint	0.49
Neck, and/or torso injury	32.0
Hypotensive	9.9
Immediate disposition to operating room	37.6
Death (in-hospital)	8.1
Dead on arrival (DOA)	4.6

die as patients who did not (14.7% vs. 7.2%, $p < 0.001$). Prehospital spine immobilized patients were more likely to have moderate-severe injuries with ISS >15 (31.2% vs. 20.4%, $p < 0.001$). Patients younger than 18 years and older than 60 years were more likely to be spine immobilized ($p < 0.001$). Immobilized patients were more likely to have a complete spine injury (1.4% vs. 0.26%, $p < 0.001$) and undergo spine surgery (0.79% vs. 0.30%, $p = 0.011$). GSW

TABLE 2. Bivariate (Unadjusted) Comparison of Penetrating Trauma Patients With vs. Without Spine Immobilization

	Nonspine Immobilized	Spine Immobilized	*p*
Race			<0.001
Whites	35.7	29.6	
Blacks	41.6	42.5	
Hispanics	18.6	21.6	
Asians	1.4	2.5	
Other race	2.8	3.8	
Age (yr)			<0.001
<18	13.2	29.0	
18–24	27.0	24.8	
25–29	14.7	11.9	
30–34	11.0	8.6	
35–39	10.2	7.5	
40–44	8.8	7.0	
45–49	6.2	4.3	
50–54	3.8	2.4	
55–59	2.1	1.2	
60–89	3.0	3.5	
Gender			0.014
Male	87.5	89.5	
Female	12.5	10.5	
GSW	40.1	56.8	<0.001
Stab	59.9	43.2	<0.001
ISS			<0.001
<9	50.5	43.0	
9–15	29.2	25.9	
16–25	8.9	12.4	
>25	11.5	18.8	
Revised Trauma Score (mean ± SD)	7.17 ± 1.83	6.83 ± 2.26	<0.001
Year admitted			<0.001
2001	22.3	21.5	
2002	24.2	22.2	
2003	28.9	35.5	
2004	24.6	20.9	
Insurance			<0.001
Private insurance	25.2	17.9	
Medicaid	63.7	70.2	
Medicare	4.3	3.5	
Other insurance	6.8	8.5	
Open spine injury	1.4	2.0	0.061
Complete spine injury	0.26	1.4	<0.001
Incomplete spine injury	1.3	1.6	0.292
Spine surgery	0.30	0.79	0.011
Prehospital procedures			
Intubation	3.0	22.1	<0.001
IV fluids	63.1	85.8	<0.001
MAST	38.4	0.11	<0.001
Chest decompression	18.0	8.1	<0.001
Splint	0.46	1.1	0.001
Neck and/or torso injury	31.8	33.6	0.112
Hypotensive	9.6	15.0	<0.001
Immediate to the operating room	37.9	33.6	<0.001
Death	7.2	14.7	<0.001
Death on arrival (DOA)	4.4	8.1	<0.001

patients were more likely to be spine immobilized, whereas stab wound patients were less likely to be spine immobilized ($p < 0.001$). Spine-immobilized patients were more likely to be intubated, receive IV fluids, and be splinted (all $p < 0.001$), whereas they were less likely to have MAST and chest decompression ($p < 0.001$).

On multiple logistic regression controlling for confounders (Table 3), spine-immobilized penetrating trauma patients were twice as likely to die [odds ratio (OR) of death 2.06, 95% CI 1.35–3.13] as those who did not undergo prehospital spine immobilization. Other prehospital procedures were also associated with inhospital mortality, with IV fluid administration predicting mortality (OR of death 1.95, 95% CI 1.55–2.47), whereas both MAST (OR of death 0.64, 95% CI 0.52–0.80) and chest decompression (OR of death 0.63, 95% CI 0.52–0.77) were correlated with survival. ISS, age, insurance status, and Revised Trauma Score were also associated with mortality ($p < 0.001$). The magnitude and direction of the results from the regression analyses did not significantly change when patients whose prehospital procedures were "not documented" were excluded from the analysis.

On subset analysis of specific patient populations, no group of penetrating trauma patients had any survival benefit with prehospital spine immobilization (Fig. 1) Even for patients with the least severe injuries (ISS <15), spine immobilization was independently associated with significantly decreased survival (OR of death 3.40, 95% CI 1.48–7.81). The OR of death was significantly elevated for GSW patients (OR 2.12; 95% CI 1.33–3.37) and for hypotensive patients (OR of death 2.42, 95% CI 1.37–4.27). Patients who were hypotensive and suffered a GSW had over a threefold increased risk of death with spine immobilization (OR of death of 3.19, 95% CI 1.62–6.28). There was no statistically significant effect of spine immobilization on mortality for patients with stab wounds (OR of death 2.17, 95% CI 0.79–5.96), although the trend remained in the same direction.

TABLE 3. Multiple Logistic Regression Showing Odds Ratio of Death for Penetrating Trauma Patients With Pre-Hospital Spine Immobilization

	OR of Death	95% CI	*p*
Prehospital procedures			
Spine immobilization	2.06	1.35–3.13	0.001
Intubation	1.31	0.97–1.77	0.079
IV fluids	1.95	1.55–2.47	<0.001
MAST	0.64	0.52–0.80	<0.001
Chest decompression	0.63	0.52–0.77	<0.001
Splint	3.83	0.30–48.96	0.301
Race			
White	Reference		
Black	0.99	0.82–1.19	0.889
Hispanic	1.08	0.83–1.41	0.549
Asian	0.96	0.39–2.34	0.926
Native American	1.40	0.53–3.71	0.503
Other race	0.77	0.37–1.60	0.480
Age (yr)			
<18	Reference		
18–24	0.98	0.74–1.30	0.894
25–29	0.98	0.71–1.34	0.882
30–34	0.91	0.65–1.26	0.558
35–39	0.99	0.70–1.40	0.954
40–44	1.27	0.88–1.82	0.196
45–49	1.28	0.87–1.88	0.215
50–54	1.55	0.99–2.42	0.056
55–59	1.62	0.95–2.74	0.074
60–64	1.30	0.65–2.62	0.456
65–69	1.19	0.48–2.97	0.713
70–74	3.22	1.45–7.17	0.004
75–79	6.09	2.54–14.62	<0.001
80–84	9.13	3.84–21.67	<0.001
85–89	18.33	4.71–71.37	<0.001
Gender			
Male	Reference		
Female	1.03	0.80–1.31	0.844
ISS			
<9	Reference		
9–15	2.82	2.05–3.87	<0.001
16–25	9.13	6.69–12.48	<0.001
>25	27.11	20.49–35.89	<0.001
Revised Trauma Score	0.63	0.61–0.65	<0.001
Yr admitted			
2001	Reference		
2002	1.11	0.87–1.42	0.391
2003	0.99	0.78–1.25	0.933
2004	0.97	0.76–1.23	0.796
Insurance			
Private insurance	Reference		
Medicaid	1.45	1.17–1.80	0.001
Medicare	1.49	0.95–2.33	0.086
Other insurance	1.17	0.80–1.70	0.414

Potential Benefit of Spine Immobilization in Penetrating Trauma

Of 30,956 penetrating trauma patients with complete inhospital procedure data, 443 (1.43%) had an open spine injury. There were 116 (0.38%) patients who underwent surgery (n = 105, 0.34%) or halo placement (n = 11, 0.04%). Of these 116 patients, 86 (74%) had complete spinal cord injury and would not have benefitted from spine immobilization. Only 30 (0.01%) of the 30,956 patients had incomplete spinal cord injury and underwent operative spine stabilization. The number needed to treat with spine immobilization to potentially benefit one penetrating trauma patient was 1,032. The NNH with spine immobilization to potentially contribute to one death was 66.

DISCUSSION

Although the intention behind conservative prehospital spine immobilization protocols is to protect the minority of patients who suffer spine injuries, this study demonstrates that spine immobilization is associated with higher mortality in penetrating trauma patients and may harm more penetrating trauma patients than it helps. Prehospital spine immobilization was associated with higher odds of death in all

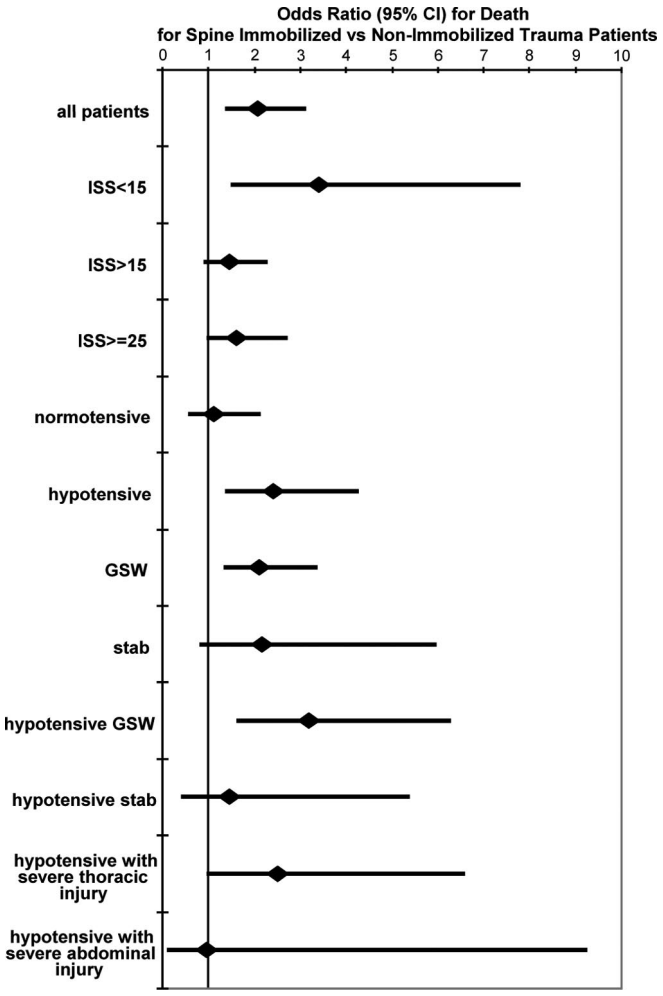

Figure 1. Multiple logistic regression showing odds ratio of death for prehospital spine-immobilized penetrating trauma patients—subset analyses.

penetrating trauma patients, and this association was qualitatively robust across all subsets of penetrating trauma patients. Spine-immobilized patients were more likely to have moderate-severe injuries (ISS >15); this is exactly the cohort of patients for whom delay in transport may be critically detrimental. Our findings confirm those previously reported by Cornwell et al.,[9] who found that only a small proportion of GSW patients might have potentially benefited from spine immobilization. The proportion of penetrating trauma patients in the NTDB found to have the potential to benefit from spine immobilization (0.08%) was consistent with this earlier finding.

In light of the debate over the role of prehospital providers in the care of trauma patients, the benefit of any prehospital procedure must be carefully weighed against the risk of delaying definitive care. Trauma practitioners have agreed that transport time is paramount when considering the utility of prehospital procedures.[10] The merits of IV fluid administration, endotracheal intubation, and now spine immobilization (in penetrating trauma patients) have been called into question, because their clinical benefit may not be worth the extra time on scene.

Several studies have shown that trauma patients may have improved outcomes with less prehospital care. Demtriades et al.[11] demonstrated that patients who had sustained severe trauma had a better chance of survival if they were transported by private vehicles rather than being treated and transported by EMS providers. One potential reason for this finding is the delay to definitive care in EMS-transported patients. Similarly, trauma patient survival has been shown to be higher when patients receive basic life support instead of ALS care.[12] In a large Canadian study, system-wide implementation of full ALS programs did not improve outcomes and worsened outcomes for patients with severe traumatic brain injury.[8] The underlying implication of these studies is that the additional time required to perform prehospital procedures may be detrimental to patient outcome.

The growing body of evidence against the performance of prehospital procedures on trauma patients supports the "limited scene intervention" approach to prehospital care, as taught by PHTLS.[5] This approach assumes that the most effective treatment can be performed at a trauma center and that the principal goal of prehospital trauma care may simply be the safe and rapid transport of patients with attention to the airway, breathing, and circulation en route. Prehospital procedures may delay necessary surgical intervention for patients with potentially survivable injuries.[13] Seamon et al.[14] concluded that the performance of prehospital procedures was associated with lower survival in patients undergoing emergency department thoracotomy.

Like many of the other prehospital procedures that have become more scrutinized, complete spine immobilization can be time consuming, with published literature estimating that the procedure takes more than 5 minutes to complete.[15] Even in the best of hands, if the procedure takes only 2 minutes or 3 minutes, this precious time may be better used on other procedures or by not delaying transport. Spine immobilization is a two-person procedure, which often precludes other prehospital procedures from being performed simultaneously.[15] Spine immobilization may also pose specific challenges to other important patient care. In patients with penetrating neck trauma, spine immobilization may conceal life-threatening complications like tracheal deviation and subcutaneous emphysema.[16] Multiple studies have concluded that c-spine immobilization in not warranted in patients with isolated GSWs to the head and may complicate and delay emergency airway management.[17–20]

The conventional wisdom on spine immobilization has underscored a conservative approach under which prehospital providers cannot distinguish patients who have spine injuries from those who do not. Recent studies of selective immobilization strategies demonstrate that prehospital providers can reduce the number of unnecessary immobilizations without missing a significant number of patients who could have benefited from immobilization.[2,3] Such strategies use indicators like altered mental status, cervical tenderness, and abnormal sensory/motor function to decide whether spine immobilization is necessary.[2,3]

Penetrating trauma patients who may benefit from immobilization might not be difficult to recognize. Connell et al.[1] found that all penetrating trauma patients with spinal cord injuries were either in traumatic arrest or had clear clinical signs of spine injury. Historically, penetrating and blunt patients have been considered equally eligible for spine immobilization, but there is significant evidence to support immobilization protocols that distinguish eligibility by mechanism.[1] Numerous studies demonstrate that spine immobilization is unnecessary for patients with isolated penetrating trauma to the neck,[1,2,16] head,[17–20] and face.[21] Burkana et al.[16] speculated that penetrating injury is unlikely to cause spinal instability without causing a complete spine injury. Such complete injuries would cause irreversible neurologic consequences regardless of spine immobilization.[16] Our conservative estimate of the benefit is possibly exaggerated as not all patients with an incomplete spinal cord injury who underwent surgery truly benefitted from spinal immobilization. Some likely underwent other types of surgical procedures on the spine (i.e., decompression or repair of cerebrospinal fluid leaks) rather than spine stabilization procedures. Our results support the evidence that prehospital spine immobilization is both unnecessary and potentially hazardous for penetrating trauma patients.

This retrospective study suffers some significant limitations, mainly because of the data available. The NTDB does not report prehospital scene or transport times or differentiate urban versus rural care. Thus, we could not demonstrate that the excess mortality in patients who underwent spine immobilization was associated with delays in transport to definitive care. In addition, a long spine board is often used to facilitate moving a patient (i.e., down a flight of steps) as opposed to for the intent of true spine immobilization. The submission of data to the NTDB is voluntary and not all trauma centers report data in all fields. The voluntary data reporting also means that the NTDB cannot be considered a representative sample of trauma care nationwide. Many patients had no data on prehospital procedures. We assumed that the error resulting from the missing data were nondifferential and, thus, did not affect the direction of the observed associations. However, the significant advantage of using the NTDB is that it is the largest collection of trauma registry data ever assembled, which allows this study to examine data from a sizeable national sample of penetrating trauma patients. Ideally, a prospective randomized study in a large EMS system would be optimal to determine the impact of prehospital spine immobilization in penetrating trauma. However, in reality, a study such as this with enough power to determine any effect is likely unfeasible.

In summary, this study demonstrates that the risks associated with prehospital spine immobilization outweigh the potential benefits in victims of penetrating trauma. Given these results, we support the current recommendations of PHTLS, which suggest that the practice of prehospital providers immobilizing all patients with penetrating trauma be discontinued in favor of a more selective approach. Our data suggest that, even with providers' best intentions, some patients may be harmed by prehospital spinal immobilization.

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EDITORIAL COMMENT

This is an important article. The authors performed a retrospective analysis of the National Trauma Databank to inves-

tigate their hypothesis that penetrating trauma patients who underwent prehospital spine immobilization would have higher mortality than penetrating trauma patients who did not undergo spine immobilization. In addition, they sought to investigate whether there was a very small proportion of penetrating trauma patients who potentially benefited from prehospital spine immobilization.

There are two main points that come from this study. First, taking time to place spinal precautions wastes precious time that could be spent transporting patients with penetrating injuries to definitive treatment centers. Those who underwent immobilization were more than twice as likely to die. Second, the increased mortality seen in those patients who underwent spinal precautions also underscores the low prevalence of unstable spinal injuries whose immobilization would impact outcomes in this population.

Of note, no group of penetrating trauma patients had any survival benefit with prehospital spine immobilization. The number needed to treat with spine immobilization to potentially benefit one penetrating trauma patient was 1,032. The number needed to harm with spine immobilization to potentially contribute to one death was 66.

Issues related to spinal immobilization continue to be a source of controversy. This article adds to our growing knowledge of when to immobilize and when not to immobilize the trauma patient.

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