PRELIMINARY REPORTS

Out-of-hospital Spinal Immobilization: Its Effect on Neurologic Injury

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ABSTRACT

Objective: To examine the effect of emergency immobilization on neurologic outcome of patients who have blunt traumatic spinal injuries.
Methods: A 5-year retrospective chart review was carried out at 2 university hospitals. All patients with acute blunt traumatic spinal or spinal cord injuries transported directly from the injury site to the hospital were entered. None of the 120 patients seen at the University of Malaya had spinal immobilization during transport, whereas all 334 patients seen at the University of New Mexico did. The 2 hospitals were comparable in physician training and clinical resources. Neurologic injuries were assigned to 2 categories, disabling or not disabling, by 2 physicians acting independently and blinded to the hospital of origin. Data were analyzed using multivariate logistic regression, with hospital location, patient age, gender, anatomic level of injury, and injury mechanism serving as explanatory variables.
Results: There was less neurologic disability in the unimmobilized Malaysian patients (OR 2.03; 95% CI 1.03–3.99; $p = 0.04$). This corresponds to a <2% chance that immobilization has any beneficial effect. Results were similar when the analysis was limited to patients with cervical injuries (OR 1.52; 95% CI 0.64–3.62; $p = 0.34$).
Conclusion: Out-of-hospital immobilization has little or no effect on neurologic outcome in patients with blunt spinal injuries.
Key words: injury; trauma; morbidity; spine; immobilization; back board; emergency medical services; spinal cord.

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Immobilization of the spine in blunt trauma is thought to be a crucial intervention almost as essential as management of the airway.[1] Failure to diagnose and appropriately manage spinal injuries is a major concern for emergency physicians. A large number of papers address immobilization and management of spinal injuries in the emergency setting. Much is now known about these issues. Immobilization is improved by using a firm surface; addition of a hard cervical collar,[2] head blocks,[3] and lateral restraint[4,5] provides progressively more stability. The clinical importance of immobilization remains unknown. That is, how much spinal motion is permissible without harm during transport and during the initial workup remains unknown.

This issue is complex. The definition of instability is not standardized. The most conservative view is: "... the loss of the ability of the spine under physiologic conditions to maintain relationships between vertebra in such a way that there is neither damage nor subsequent irritation to the spinal cord or nerve root and, in addition there is no development of incapacitating deformity or pain from structural changes."[6] This definition, while appropriate to guide long-term management, is of little use in the emergency setting, where the question generally is: will motion

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make the neurologic lesion worse? Furthermore, neurologic lesions are dynamic, some deteriorate due to swelling and microvascular injury,[7,8] and some improve as edema and neuropraxia resolve, irrespective of immobilization. Other neurologic injuries are irrevocable at the time of the injury, and not affected by subsequent movement. In the face of these uncertainties and considerable medicolegal pressure, physicians have opted for extraordinarily conservative management. Patients are fully immobilized at the injury site if there is any suggestion that the neck or back could be injured.[1] Immobilization is usually continued in the ED until the spine is "cleared" by multiple imaging procedures.[9,10] Authors have claimed that without adequate long-term immobilization, 10% to 25% of all patients with spine injuries will deteriorate.[5,11] These claims, however, have little scientific support.

Conservative treatment is not necessarily benign. Immobilization is uncomfortable,[12,13] takes time, and delays transport. Immobilized patients are difficult to examine and treat. Immobilization increases the risk of aspiration and pressure sores. Cervical collars increase intracranial pressure.[14] Given these problems, it would be useful to know how often not immobilizing patients would result in increased neurologic injury. A low incidence of these "acutely unstable" injuries would justify more liberal guidelines for allowable spinal motion following trauma. A high incidence of injuries that might benefit from immobilization would require more a conservative approach.

Some spinal injuries are undoubtedly truly biomechanically and neurologically unstable and will develop increased neurologic injury with movement. Others are undoubtedly biomechanically stable but neurologically fragile; these will suffer more neurologic injury by delaying resuscitation. Standard practice assumes that immobilization is generally protective and that patients with spinal fractures will have a higher incidence of neurologic injuries if immobilization is not carried out. However, this hypothesis has never been tested. It is no longer possible to derive a meaningful estimate of effect of spinal immobilization in the developed world because of the universal adoption of early, preventive immobilization and widespread publicity regarding the "need" to protect the spine until ambulance personnel arrive. We derive this estimate by comparing the percentages of spine-injured patients who had neurologic injuries from 2 sites: the University Hospital, University of Malaya in Kuala Lumpur, Malaysia, which is not served by an out-of-hospital emergency medical services (EMS) system, and the University of New Mexico Hospital in Albuquerque, NM, which is served by an extensive EMS system.

METHODS

Study Design: A retrospective chart review of all patients admitted to the inpatient service or ED of our 2 hospitals with spinal or spinal cord injuries between January 1988 and January 1993 was performed. Permission for the study was provided by the Ethical Sub-Committee of the Medical Advisory Board of the University Hospital, Kuala Lumpur, Malaysia, and by the institutional review board of the University of New Mexico, School of Medicine, Albuquerque, NM.

Setting and Population: Study cases were identified by searching for bony spine or spinal cord injuries by International Classification of Disease Version 9 (ICD-9) codes contained in hospital computerized databases. Compression fractures due to osteopenia or other disease were excluded. Patients who died were included unless the cause of death was clearly unrelated to the spinal injury; these cases were almost exclusively patients with massive head or other injuries who died in the first 24 hours.

During the period 1988 through 1993, approximately 12,700 trauma patients were admitted to inpatient services at the U.S. hospital and 16,600 to the University of Malaysia. Both statistics include transfer patients. The U.S. figures exclude patients with burns, drownings, and isolated injuries who were admitted to services other than the trauma service. The Malaysian data include the latter cases. All the patients taken to the U.S. hospital, but none of those taken to the Malaysian hospital, had their spines immobilized at the injury site. The catchment area of the University of Malaya Hospital lacks emergency ambulance coverage. The hospital operates an ambulance, but it is used almost exclusively for medical patients. Trauma patients are transported by passersby, police, and coworkers, none of whom have training in spinal immobilization. None of the ED staff could remember any patients who had been immobilized in Malaysia. Other differences between our sites are small. The level of training of Malaysian physicians is comparable to that of their counterparts in the United States, particularly in the essential specialties where training was commonly outside of Malaysia until recently. The 2 hospitals have similar radiologic, resuscitative, and surgical abilities. All patients who were admitted to either facility after June 1990 with a neurologic deficit were treated with high-dose methylprednisolone.[15]

Study Protocol: All patients with blunt injuries to the spine or spinal cord who were transported directly from the injury scene to a study hospital were entered into the database. Compression fractures due to osteopenia or disease were excluded. Information regarding hospital, patient age, gender, level of deficit, mechanism of injury, and type of neurologic injury was collected. Ages were grouped by decade for use in the regression model. The level of injury was classified into cervical, thoracic, or lumbosacral depending on the highest vertebra injured. The mechanism of injury was grouped into 1 of 4 cate-

TABLE 1 Anatomic Distribution of Injuries

	Disability	No	Total
Cervical			
Immobilized (United States)	34 (30%)	79 (70%)	113 (100%)
Unimmobilized (Malaysia)	10 (25%)	30 (75%)	40 (100%)
Thoracic			
Immobilized (United States)	22 (21%)	85 (79%)	107 (100%)
Unimmobilized (Malaysia)	2 (6%)	31 (94%)	33 (100%)
Lumbosacral			
Immobilized (United States	14 (12%)	99 (88%)	113 (100%)
Unimmobilized (Malaysia)	1 (2%)	46 (98%)	47 (100%)

gories: falls from a height; motor vehicle crashes (MVCs); high-velocity–low-mass impacts (primarily patients assaulted with blunt objects and those struck by falling objects); and other.

The dependent variable, neurologic injury, was classified as disabling or not disabling based on the last hospital note. Patients with complete quadriplegia or paraplegia, inability to ambulate without assistance, incontinence, or the need for chronic catheterization, and those who died were classified as having disability. Patients with no neurologic injury were classified as not having disability. The remaining charts were reviewed by 2 physicians acting independently and blinded to the hospital of origin. These patients were classified into the 2 groups based on whether the physicians thought the injury would interfere with normal functioning.

Data Analysis: Comparison between patients from the United States (all who had spinal immobilization) and Malaysia (none of whom had spinal immobilization) was performed using χ^2 and 1-way analysis of variance as appropriate. Multivariate logistic regression of the association between the collected variables and disability was used for analysis.[16,17] The level of deficit and the mechanism of injury were coded as separate binary variables. All of the independent variables were included in the model. Odds ratios (ORs) and 2-sided 95% confidence intervals (CIs) were calculated. We also repeated the analysis using only patients with cervical injuries.

Data management was carried out using Quattro Pro version 5.00 spreadsheet software (Borland International, Scotts Valley, CA). Statistical computations were performed with Statgraphics Plus version 7.0 (Manugistics Inc., Rockville, MD) and LogXact-Turbo version 1.1 (Cytel Software Corporation, Cambridge, MA). We used 2-tailed tests and an α of 0.05 throughout.

RESULTS

The anatomic distributions of injuries were similar in the 2 sites and to that published in the literature (Table 1).[18]

Malaysian and US patients were similar in terms of age and level of injury. Patients in Malaysia were more likely to be male and to have been injured in a fall rather than an MVC (Table 2).

There were 24 patients who had injuries that required physician classification. The 2 physicians grouped these with complete agreement (Table 3), resulting in 21% of the patients (70/334) from the United States and 11% of the Malaysian patients (13/120) being classified as having disabling injuries.

The OR for disability was higher for patients in the United States (all with spinal immobilization) after adjustment for the effect of all other independent variables (2.03; 95% CI 1.03–3.99; p = 0.04). The estimated probability of finding data as extreme as this if immobilization has an overall beneficial effect is only 2%. Thus, there is a 98% probability that immobilization is harmful or of no value. The level of neurologic deficit was the only independent predictor of bad outcome (Table 4). We repeated this analysis using only the subset of patients with isolated cervical level deficits. We again failed to show a protective effect of spinal immobilization (OR 1.52; 95% CI 0.64–3.62; p = 0.34).

DISCUSSION

These results undoubtedly seem counterintuitive to most physicians who have been taught that spinal motion

TABLE 2 Characteristics of the Patients from the United States and Malaysia

	Immobilized	Unimmobilized	p-value
Number of patients	334	120	
Average age	34 yr	35 yr	0.31
Gender—male	256 (77%)*	106 (88%)	0.009
Level of injury			0.52
Cervical	113 (34%)	40 (33%)	
Thoracic	107 (32%)	33 (28%)	
Lumbosacral	113 (34%)	47 (39%)	
Mechanism			0.0001
Fall	66 (20%)	63 (53%)	
Vehicle crash	248 (74%)	45 (38%)	
Low-mass impact	9 (3%)	8 (7%)	
Other	11 (3%)	4 (3%)	
Significant disability	70 (21%)	13 (11%)	0.02

*Percentages are relative to each hospital's total.

causes neurologic injury. However, technically only the transfer of energy can physically alter material. Acute neurologic injury occurs when excessive energy is deposited in the spinal cord or its vascular structures. This energy is a product of force multiplied by time. "Excessive" energy is directly related to the failure strength of the material. Over the length of time experienced during an injurious event, the spine is quite strong and massive amounts of energy are required to fracture or otherwise significantly injure it. The cervical spine will fracture when >2,000–6,000 N (Newton or meter-kg/sec^2, 1 N = 0.225 pounds of force)[19] is applied; the lumbar spine requires >4,200 N to fracture, even in elder individuals.[20] Muscles and ligaments[21] reinforce the bone. Even the spinal cord itself is capable of absorbing significant energy without suffering damage.[22] Energy deposition during an injury is a complex process. Subjects ejected from vehicles, the most common cause of disability in our sample, undergo repetitive impacts. In most cases the maximal impact is early in the event as the victim contacts the vehicle structure or the ground. It is presumably at these times that most of the injury is inflicted. Subsequently, multiple impacts occur between the subject and the ground. Even in the simple case of a restrained subject and direct linear deceleration while in a sitting position, the initial acceleration is followed by a series of repetitive oscillatory movements.[23] In these circumstances the energy deposited by moving the patient after the event will be much less than the energy deposited at the scene by secondary impacts.

There are good physical and biomechanical reasons why immobilization immediately after the injurious event has little effect. Movement within the spine's normal range of motion requires little energy and is hence unlikely to result in significant energy deposition to the cord. Even the force generated across the spine by hanging a completely unimmobilized 4-kg head off the end of a stretcher is only equal to approximately 40 N, which is orders of magnitude less than that experienced during the original event.

As the spine is moved, changes in force vectors occur. The spinal elements (bone, ligament, muscle, and disc) interact to transfer energy to all the component parts.[24] This serves to minimize energy deposition to any one component. When force is applied rapidly, the energy is focused due to wave effects, thus enhancing injury.[25] However, the definition of instability that is used to guide long-term care of the patient is based on the risk of gradual slippage due to gravity and active motion. It is hardly surprising that this definition has little relevance in the acute setting when the biomechanical factors are completely different.

The difference in neurologic disability between immobilized patients in the United States and unimmobilized patients in Malaysia was statistically significant. It may be that immobilization increases the risk of neurologic injury secondary to tissue hypoxia, perhaps by delaying resuscitation or perhaps the benefit of immobilization is so small that it is unmeasurable given our sample size.

Previous studies have estimated that three fourths of cervical fractures are potentially unstable[26,27] based on ra-

TABLE 3 Physician-classified Patients—Verbatim Discharge Diagnosis

Neurologic Finding	Location
Injuries judged not disabling	
Moderate leg weakness, ambulatory	United States
Hypoesthetic thumb	United States
Paresthesias only	United States
Mild hypaesthesia 1/3 right leg	United States
Mild hand weakness	United States
Decreased right arm sensation	United States
Almost normal at discharge	United States
Weak deltoids	United States
Weak toe	United States
Mild diffuse hypaesthesia	United States
Paresthesias	United States
Mild weakness left leg	United States
Sacral 1 root injury	United States
Right foot drop	Malaysia
Slight right arm weakness	Malaysia
Right arm partial brachial palsy	Malaysia
Slight left arm weakness	Malaysia
Sensory change, no objective findings	Malaysia
Injuries judged disabling	
Right arm paralysis and anesthesia	United States
Severe right arm weakness	United States
Right hemiparesis	United States
Anesthetic left leg	United States
Severe hypoesthesia left leg	United States
Complete left cervical plexus injury	United States

TABLE 4 Logistic Regression Analysis

	Odds Ratio	95% Confidence Interval	p-value
Spinal immobilization	2.03	1.03–3.99	0.04
Gender—male	1.69	0.86–3.32	1.13
Age (by decade)	0.96	0.81–1.14	0.65
Level of injury			
Cervical	3.82	1.98–7.37	0.0001
Thoracic	1.99	0.98–4.00	0.06
Lumbosacral	0.34	0.19–0.62	0.0005
Mechanism			
Fall	0.60	0.14–2.54	0.49
Vehicle crash	0.91	0.23–3.56	0.90
Low-mass impact	0.38	0.03–4.77	0.45
Other	1.32	0.34–5.08	0.69

diographic criteria. The actual percentage of injuries that are likely to be made worse by lack of immobilization during the immediate post-injury period is much smaller. The risk of neurologic deterioration is greatly exaggerated.

LIMITATIONS AND FUTURE QUESTIONS

Our study has several shortcomings. Patients who died at the injury site or during transport are excluded. It is possible that some of these died as a result of high cord injuries, attendant loss of diaphragmatic function, and asphyxia. Most of these cord injuries are probably complete at the time of the injury and many of these patients have other fatal injuries, but it is possible that some partial lesions could have been completed during transport in Malaysia and resulted in death prior to admission. However, there were no survivors in Albuquerque with complete lesions above C_4 during this period, either.

We did not attempt to match patients for the severity of their nonspinal injuries. The University of Malaya does not routinely use injury severity scores, and retrospective calculation of them would have been difficult. The use of mechanism of injury in our regression analysis partly corrects for this omission as does our entry criteria, which required that adequate energy be deposited to injure the spine.

It is possible that the injuries from New Mexico were more unstable or more severe. Indeed, our initial plan was to match injuries from our 2 sites and then compare outcomes. This proved impossible. Spinal injuries are idiosyncratic and no 2 are identical. Many injuries were merely described verbally in the radiologic and discharge notes. The severity of injury was poorly predicted by the description; for example, some "compression fractures" were associated with severe neurologic injuries, while others caused no neurologic injury at all. Fracture classification schemes are not well standardized and systems of classification are based on estimates of long-term instability which may, as noted above, be unrelated to short-term stability. Even those injuries that were placed in discrete diagnostic categories were not matchable.

The number of patients available for comparison is relatively small. We chose to analyze only patients with injuries to the spine presenting to a single pair of medium-sized hospitals over a 5-year period. Inclusion of patients seen prior to 1988 or at other facilities would increase the differences in hospital treatment in our samples and make direct comparison more difficult. Although resources and clinical capabilities are similar in the 2 hospitals, they are not identical. We doubt that hospital care in Malaysia is significantly superior to that in the United States, but if this were the case, it would complicate our analysis. An important source of bias in our study is that only patients who proved to have spinal injuries were entered. The vast majority of trauma patients do not have a spinal injury and hence cannot benefit from spinal immobilization. As a result, our study design would tend to exaggerate any potential benefit of current protocols that require the immobilization of almost all trauma patients.

It is doubtful that this study can be duplicated in the future because Malaysia is now developing an EMS system and considerable publicity has recently been given to spinal immobilization in the mass media. Other population-based studies are urgently needed to confirm our data. Current spinal immobilization protocols have been developed without supporting clinical efficiency data. They may be overly conservative.

CONCLUSION

Comparison of spine injury patients from 2 study populations, one with out-of-hospital spinal immobilization and the other without, showed a higher rate of neurologic injury in the immobilized group. Acute spinal immobilization may not have significant benefit for the prevention of neurologic deterioration from unstable spinal fractures.

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REFERENCES

1. Alexander RH, Proctor HJ. Advanced Trauma Life Support Course for Physicians. Chicago, IL: Committee on Trauma, American College of Surgeons, 1993, pp 21–2.

2. Rosen PB, McSwain NE Jr, Arata M, Stahl S, Mercer D. Comparison of two new immobilization collars. Ann Emerg Med. 1992; 21:1189–95.

3. Chiles BW III, Cooper PR. Acute spinal injury. N Engl J Med. 1992; 334:514–20.

4. Graziano AF, Scheidel EA, Cline JR, Baer LJ. A radiographic comparison of prehospital cervical immobilization methods. Ann Emerg Med. 1987; 16:1127–31.

5. Podolsky S, Baraff LJ, Simon RR, Hoffman JR, Larmon B, Ablon W. Efficacy of cervical spine immobilization methods. J Trauma. 1983; 23:461–5.

6. White AA, Panjabi MM. Clinical Biomechanics of the Spine. Philadelphia, PA: J. B. Lippincott, 1978.

7. Tator CH, Fehlings MG. Review of the secondary injury theory of acute spinal cord trauma with emphasis on vascular mechanisms. J Neurosurg. 1991; 75:15–26.

8. Tator CH. Review of experimental spinal cord injury with emphasis on the local and systemic circulatory effects. Neurochirurgie. 1991; 37: 291–302.

9. Davis JW, Phreaner DL, Hoyt DB, Mackersie RC. The etiology of missed cervical spine injuries. J Trauma. 1993; 34:342–6.

10. Terregino CA, Ross SE, Lipinski MF, Foreman J, Hughes R. Selective indications for thoracic and lumbar radiography in blunt trauma. Ann Emerg Med. 1995; 26:126–9.

11. Reid DC, Henderson R, Saboe L, Miller JD. Etiology and clinical course of missed spine fractures. J Trauma. 1987; 27:980–6.

12. Cordell WH, Hollingsworth JC, Olinger ML, Stroman SJ, Nelson

DR. Pain and tissue-interface pressures during spine-board immobilization. Ann Emerg Med. 1995; 26:31–6.
13. Chan D, Goldberg R, Tascone S, Chan L. The effect of spinal immobilization on healthy volunteers. Ann Emerg Med. 1994; 23:48–51.
14. Raphael JH, Chotai R. Effects of the cervical collar on cerebrospinal fluid pressure. Anaesthesia. 1994; 49:437–9.
15. Bracken MB, Shepard MJ, Collins WF, et al. A randomized, controlled trial of methylprednisolone or naloxone in the treatment of acute spinal-cord injury. N Engl J Med. 1990; 322:1405–11.
16. Kleinbaum DG. Analysis of matched data using logistic regression. In: Kleinbaum DG (eds). Logistic Regression: A Self-learning Text. New York, NY: Springer-Verlag, 1994, pp 227–52.
17. Hirji KF, Mehta CR, Patel NR. Computing distributions for exact logistic regression. J Am Stat Assoc. 1987; 82:1110–7.
18. Riggins RS, Kraus JF. The risk of neurologic damage with fractures of the vertebrae. J Trauma. 1977; 17:126–33.
19. Maiman DJ, Sances A Jr, Myklebust J, et al. Compression injuries of the cervical spine: a biomechanical analysis. Neurosurgery. 1983; 13: 254–60.
20. Percy O. Fractures of the vertebral end-plate in the lumbar spine—an experimental biomechanical investigation. Acta Orthop Scand. 1957; 25(suppl):1–101.
21. Pintar FA, Myklebust JB, Yoganandan N, Mainan DJ, Sances A. Biomechanics of human spinal ligaments. In: Sances A, Thomas DJ, Ewing CL, Larson SJ, Unterharnscheidt F (eds). Mechanisms of Head and Spine Trauma. Goshen, NY: Aloray, 1986, pp 505–27.
22. Fernandez E, Pallini R, Marchese E, Talamonti G. Experimental studies on spinal cord injuries in the last fifteen years. Neurol Res. 1991; 13:138–59.
23. Stapp JP. Human and chimpanzee tolerance to linear decelerative force. In: Sances A, Thomas DJ, Ewing CL, Larson SJ, Unterharnscheidt F (eds). Mechanisms of Head and Spine Trauma. Goshen, NY: Aloray, 1986, pp 1–46.
24. Noyes FR, DeLucas JL, Torvik PJ. Biomechanics of anterior cruciate ligament failure: an analysis of strain-rate sensitivity and mechanisms of failure in primates. J Bone Joint Surg. 1974; 56(A):236–53.
25. Fung YC. The application of biomechanics to the understanding and analysis of trauma. In: Nahum AM, Melvin J (eds). The Biomechanics of Trauma. Norwalk, CT: Appelton-Century-Crofts, 1985, pp 1–18.
26. O'Malley KF, Ross SE. The incidence of injury to the cervical spine in patients with craniocerebral injury. J Trauma. 1988; 28:1476–8.
27. Wright SW, Robinson GG, Wright MB. Cervical spine injuries in blunt trauma patients requiring emergent endotracheal intubation. Am J Emerg Med. 1992; 10:104–9.