Prehospital Cervical Spinal Immobilization After Trauma

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RECOMMENDATIONS

Level II

Spinal immobilization of all trauma patients with a cervical spine or spinal cord injury or with a mechanism of injury having the potential to cause cervical spinal injury is recommended.

- Triage of patients with potential spinal injury at the scene by trained and experienced emergency medical services personnel to determine the need for immobilization during transport is recommended.
- Immobilization of trauma patients who are awake, alert, and are not intoxicated; who are without neck pain or tenderness; who do not have an abnormal motor or sensory examination; and who do not have any significant associated injury that might detract from their general evaluation is not recommended.

Level III

- A combination of a rigid cervical collar and supportive blocks on a backboard with straps is effective in limiting motion of the cervical spine and is recommended.
- The longstanding practice of attempted spinal immobilization with sandbags and tape is insufficient and is not recommended.
- Spinal immobilization in patients with penetrating trauma is not recommended because of increased mortality from delayed resuscitation.

ABBREVIATIONS: EMS, emergency medical services; **HAINES,** high arm in endangered spine; **ICP,** intracranial pressure

RATIONALE

The early management of a patient with a potential cervical spinal cord injury begins at the scene of the accident. The chief concern during the initial management of patients with potential cervical spinal injuries is that neurologic function may be impaired as a result of pathologic motion of the injured vertebrae. It is estimated that 3% to 25% of spinal cord injuries occur after the initial traumatic insult, either during transit or early in the course of management.[1-6] Multiple cases of poor outcome from mishandling of cervical spinal injuries have been reported.[5-8] As many as 20% of spinal column injuries involve multiple noncontinuous vertebral levels; therefore, the entire spinal column is potentially at risk.[9-12] Consequently, complete spinal immobilization has been used in prehospital spinal care to limit motion until injury has been ruled out.[11-19] Over the last 30 years, there has been a dramatic improvement in the neurologic status of spinal cord–injured patients arriving in emergency departments. During the 1970s, the majority (55%) of patients referred to regional spinal cord injury centers arrived with complete neurological lesions. In the 1980s, however, the majority (61%) of spinal cord-injured patients arrived with incomplete lesions.[20] This improvement in the neurologic status of patients has been attributed to the development of emergency medical services (EMS) in 1971 and the prehospital care (including spinal immobilization) rendered by EMS personnel.[13,20-22] Spinal immobilization is now an integral part of prehospital management and is advocated for all patients with potential spinal injury after trauma by EMS programs nationwide and by the American College of Surgeons.[13,23-29]

Recently, the use of spinal immobilization particularly for those patients with a low likelihood of traumatic cervical spinal injury has been questioned. It is unlikely that all patients rescued from the scene of an accident or site of traumatic injury require spinal immobilization.[30-33] Some authors have developed and advocate a triage system based on clinical criteria to select patients for prehospital spinal immobilization.[27,34,35]

Several devices are available for prehospital immobilization of the potential spine-injured patient. However, the optimal device has not yet been identified by careful comparative analysis.[15,36-42] The recommendations of the American College of Surgeons consist of a hard backboard, a rigid cervical collar, lateral support devices, and tape or straps to secure the patient, the collar, and the lateral support devices to the backboard.[23,24] A more uniform, universally accepted method for prehospital spinal immobilization for patients with potential spinal injury after trauma may reduce the cost and improve the efficiency of prehospital spinal injury management.[27,34,35] Although spinal immobilization is typically effective in limiting motion, it has been associated with morbidity in a small percentage of cases, particularly when concomitant head injury exists, in patients with ankylosing spondylitis, and in the setting of delayed resuscitation.[18,24,43-49]

The guidelines author group of the Section on Disorders of the Spine and Peripheral Nerves of the American Association of Neurological Surgeons and Congress of Neurological Surgeons produced a medical evidence-based guideline on this topic in 2002.[50] The purpose of the current review is to update the medical evidence on the spinal immobilization since that early publication.

SEARCH CRITERIA

A National Library of Medicine computerized literature search from 1966 to 2011 was conducted with the terms "spinal injuries" and "immobilization." The search was limited to human subjects and the English language and yielded no articles. A second search combining the terms "spinal injuries" and "transportation of patients" yielded 81 articles. A third search combining the terms "spinal injuries" and "emergency medical services" produced 331 articles. Additional references were culled from the reference lists of the remaining papers. Finally, the author group was asked to contribute articles known to them on the subject matter that were not found by other search criteria. Duplicate references were discarded. The abstracts were reviewed and articles unrelated to the specific topic were eliminated. This process yielded a total of 109 articles for this review, which are listed in the bibliography. Thirty pertinent publications used to formulate this medical evidence-based guideline are summarized in Evidentiary Table format (Table).

SCIENTIFIC FOUNDATION

Pathologic motion of the injured cervical spine may create or exacerbate cervical spinal cord or cervical nerve root injury.[9-11,16,51,52] This potential has led to the use of spinal immobilization for trauma patients who have sustained a cervical vertebral column injury or experienced a mechanism of injury that could result in cervical spinal column injury.[11,12,15-17,19,24,27,30,35,53]

Kossuth[54,55] is credited with pioneering the currently accepted methods of protection and immobilization of the cervical spine during extrication of acute injury victims. Farrington[56,57] championed the concept of prehospital immobilization. Dick and Land[58] note in their review of spinal immobilization devices that techniques of prehospital spinal immobilization appeared in standard EMS texts and in the American Academy of Orthopedic Surgeons Committee on Injuries Emergency text as early as 1971.[13] Initially, the preferred method to immobilize the cervical spine was the use of a combination of a soft collar and a rolled-up blanket.[37] This was followed by the introduction of a more rigid extrication collar by Hare in 1974. Hare's contribution launched an era of innovation for devices for spinal immobilization.[15]

Currently, spinal immobilization is one of the most frequently performed procedures in the prehospital care of acute trauma patients in North America.[9,11-13,15-17,19,25,53,59] Although clinical and biomechanical evidence demonstrates that spinal immobilization limits pathologic motion of the injured spinal column, there is no Class I or Class II medical evidence to support spinal column immobilization in all patients after trauma. Although immobilization of an unstable cervical spinal injury makes good sense and Class III medical evidence reports exist of neurological worsening with failure of adequate spinal immobilization, there have been no randomized trials or case-control studies that address the impact of spinal immobilization on clinical outcomes after cervical spinal column injury.[3,4,6,11,12,15,16,27,31,32,53] The issue of who should be immobilized is important; tens of thousands of trauma victims are treated with spinal immobilization each year, yet few actually have spinal column injuries or instability.[10,35,60]

Other considerations in the use of prehospital spinal immobilization include the cost of equipment, the time and training of EMS personnel to apply the devices, and the unnecessary potential morbidity for patients who do not need spinal immobilization after trauma.[15,18,24,45-49,53,61,62] As with many interventions in the practice of medicine, spinal immobilization has been instituted in the prehospital management of trauma victims with potential spinal injuries based on the principles of neural injury prevention and years of clinical experience but without supportive scientific evidence from rigorous clinical trials. For a variety of both practical and ethical reasons, it is likely impossible to obtain this information in prospective, randomized clinical trials in contemporary times.

In 1989, Garfin et al[16] stated, "No patient should be extricated from a crashed vehicle or transported from an accident scene without spinal stabilization." In that review, they credited stabilization of the cervical spine as a key factor in the decline in the percentage of complete spinal cord injury lesions from 55% in the 1970s to 39% in the 1980s and in the significant reduction in the mortality of multiple injury patients with cervical spinal injuries. Unfortunately, there is no Class I medical evidence to support these claims.

TABLE. Evidentiary Table: Immobilization[a]

Author, Reference	Description of Study	Data Class	Conclusions
Haut et al,[103] *The Journal of Trauma*, 2010	The assessment of spinal immobilization in patients with cervical spine injury associated with penetrating trauma	III	Prehospital spine immobilization is associated with higher mortality in the settings of penetrating trauma and should not be routinely used.
Burton et al,[70] *The Journal of Trauma,* 2006	Evaluation of the practice and outcomes associated with statewide EMS protocol for trauma patient spine assessment and selective prehospital immobilization	II	EMS providers were able to evaluate injured prehospital trauma patients with a 4-step clinical assessment protocol and to accurately discriminate between patients likely to benefit from immobilization and patients with unstable spine injury.
Del Rossi et al,[105] *The Spine Journal*, 2004	Biomechanical study testing 3 cervical collars on a cadaveric model of cervical spine injury	II	When transferring patients to a spine board, the key remains the combination of manual stabilization and the controlling effect of the cervical collar.
Domeier et al,[106] *The Journal of Trauma*, 2002	Evaluation of clinical criteria to identify prehospital trauma patients who may safely have rigid spine immobilization withheld	II	Altered mental status, focal neurologic deficit, evidence of intoxication, spine pain or tenderness, or suspected extremity fracture were clinical criteria that identified the presence of spine injury, therefore justifying immobilization.
Stroh and Braude,[68] *Annals of Emergency Medicine*, 2001	Determination of the sensitivity of Fresno/Kings/Madera EMS selective spine immobilization protocol in identifying patients with potential cervical injuries	II	Fresno/Kings/Madera protocol is 99% sensitive in identifying patients with cervical surgeries for immobilization, suggesting that selecting immobilization may be safely applied in the out-of-hospital setting.
Markenson et al,[39] *Pre-Hospital Emergency Care*, 1999	Evaluation of the Kendrick extrication device for pediatric spinal immobilization.	III	Kendrick extrication device provides excellent static and dynamic immobilization.
Perry et al,[33] *Spine*, 1999	Laboratory evaluation of 3 immobilization devices compared during simulated vehicle motion	III	Substantial amounts of head motion can occur during simulated vehicle motion regardless of the method of immobilization.
	Neck motion was judged by 3 physicians.		Movement of trunk can have an effect equal to head motion on motion across the neck.
Bauer and Kowalski,[44] *Annals of Emergency Medicine*, 1998	Effect of spinal immobilization devices on pulmonary function in 15 men	III	Significant restriction of pulmonary function was seen.
Mawson et al,[99] *American Journal of Physical Medicine and Rehabilitation/Association of Academic Physiatrists,* 1998	Evaluation of risk factors for pressure ulcers after spinal cord injury	III	Time spent on a backboard is significantly associated with pressure ulcers developing within 8 d.

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TABLE. *Continued*

Author, Reference	Description of Study	Data Class	Conclusions
Hauswald et al,[31] *Academic Emergency Medicine*, 1998	A 5-year retrospective chart review 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 at the University of Malaya had spinal immobilization with orthotic devices during transport; all 334 patients at the University of New Mexico did. The hospitals were comparable. Neurological injuries were assigned to 2 categories, disabling or not disabling, by 2 blinded physicians. Data were analyzed using multivariate logistic regression. There was less neurological disability in the Malaysian patients (odds ratio, 2.03; 95% confidence interval, 1.03-3.99; $P = .04$). Results were similar when the analysis was limited to patients with cervical injuries (odds ratio, 1.52; 95% confidence interval, 0.64-3.62; $P = .34$).	III	Out-of-hospital immobilization has little effect on neurological outcome in patients with blunt spinal injuries.
			The association between spinal column movement and the potential for spinal cord injury remains unclear.
Blaylock,[100] *Ostomy Wound Management*, 1996	Evaluation of pressure ulcers resulting from cervical collars	III	
Johnson et al,[75] *American Journal of Emergency Medicine*, 1996	Measured immobilization and comfort on 10-point scale; vacuum splint was compared with backboard	III	Vacuum splints are more comfortable and faster to apply than backboards and provide a similar degree of immobilization.
			Vacuum splints are not rigid enough for extrication and are more expensive.
Rodgers and Rodgers,[62] *Journal of Orthopaedic Trauma*, 1995	Marginal mandibular nerve palsy resulting from compression by a cervical hard collar	III	
Chan et al,[46] *Annals of Emergency Medicine*, 1994	Prospective study of the effects of spinal immobilization on pain and discomfort in 21 volunteers after 30 min; all subjects developed pain	III	Duration of time on backboard was minimized.
Liew and Hill,[107] *The Austrian and New Zealand Journal of Surgery*, 1994	Complication of hard cervical collars in multitrauma patients	III	
Mazolewski and Manix,[40] *Annals of Emergency Medicine*, 1994	Tests the effectiveness of strapping techniques in reducing lateral motion on a backboard in the laboratory in adults	III	Strapping should be added to the torso to reduce lateral motion on a backboard.
Plaisier et al,[78] *Journal of Trauma Injury Infection and Critical Care*, 1994	Prospective evaluation of craniofacial pressure of 4 different cervical orthoses	III	
Raphael and Chotai,[108] *Anaesthesia*, 1994	Effects of the cervical collar on cerebrospinal fluid pressure	III	
Chandler et al,[71] *Annals of Emergency Medicine*, 1992	Compared rigid cervical extrication collar with Ammerman halo orthosis in 20 men	III	Ammerman halo orthosis and spine board provided significantly better immobilization, equivalent to halo vest.

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TABLE. ***Continued***

Author, Reference	Description of Study	Data Class	Conclusions
Rosen et al,[89] *Annals of Emergency Medicine*, 1992	Compares 4 cervical collars in 15 adult volunteers by goniometry	III	Vacuum splint cervical collar restricted the range of motion of the cervical spine most effectively.
Schafermeyer et al,[109] *Annals of Emergency Medicine*, 1991	Respiratory effects of spinal immobilization in children	III	Mean reduction in FVC to 80% of baseline
Schriger et al,[84] *Annals of Emergency Medicine*, 1991	Compares flat backboard with occipital padding in achieving neutral position in 100 healthy volunteers	III	Occipital padding places the cervical spine in more neutral alignment
Cohen,[91] *Paraplegia*, 1990	A new device for the care of acute spinal injuries: the Russell extrication device	III	Russell extrication device is an effective spinal immobilization device.
Toscano,[52] *Paraplegia*, 1988	Prevention of neurological deterioration before admission to hospital	III	Appropriate handling of patients with spinal injury after trauma can reduce major neurological deterioration caused by pathological motion of the vertebral column.
	Retrospective review of 123 patients, 32 of 123 sustained major neurological deterioration from injury to admission		
Graziano et al,[90] *Annals of Emergency Medicine,* 1987	A radiographic comparison of prehospital cervical immobilization methods with the short board in 45 volunteers	III	The short board proved to be significantly better ($P < .05$).
Linares et al,[98] *Orthopedics,* 1987	Evaluation of pressure sores and immobilization.	III	Strong association between 1 to 2 h of immobilization and the development of pressure sores.
McGuire et al,[93] *Spine*, 1987	Radiographic evaluation of motion of the thoracolumbar spine in a cadaver with an unstable thoracolumbar spine and a patient with a T12-L1 fracture dislocation	III	Extreme motion at an unstable thoracolumbar spine segment can occur during the logroll maneuver. The backboard and the Scoop stretcher offered adequate stabilization for thoracolumbar spine instability.
McCabe and Nolan,[76] *Annals of Emergency Medicine*, 1986	Radiographic comparison of the 4 cervical collars in 7 adults	III	Polyethylene-1 provides the most restriction in flexion.
Cline et al,[37] *Journal of Trauma,* 1985	A radiographic comparison of 7 methods of cervical immobilization in 97 adults	III	The short-board technique appeared to be superior to all the 3 collars studied. The collars provided no augmentation of immobilization over that provided by the short board alone.
Podolsky et al,[86] *Annals of Emergency Medicine*, 1983	Static trial using goniometry	III	Hard foam and plastic collars were superior to soft collars.
			Sandbags and tape provide an advantage in addition to the cervical collar.

[a]EMS, emergency medical services; FVC, forced vital capacity.

Few articles have directly evaluated the effect of prehospital spinal immobilization on neurological outcome after injury. Several Class III medical evidence reports cite the lack of immobilization as a cause of neurological deterioration among acutely injured trauma patients transported to medical facilities for definitive care.[5,7,16,21,63] The most pertinent study is the retrospective case series of Toscano et al,[52] who in 1988 reported that 32 of 123 trauma patients (26%) they managed sustained major neurological deterioration in the period of time between injury and admission. The authors attributed neurological deterioration to patient mishandling and cited the lack of spinal immobilization after traumatic injury as the primary cause. Their report supports the need for prehospital spinal immobilization of trauma patients with potential spinal column injuries.

In contrast, a collaborative 5-year retrospective chart review reported by the University of New Mexico and the University of Malaya challenges this position. Hauswald et al[31] analyzed only patients with acute blunt spinal or spinal cord injuries. At the University of Malaya, none of the 120 patients they managed were treated with spinal immobilization during transport. All 334 patients managed at the University of New Mexico were initially treated with spinal immobilization. Both hospitals were reportedly comparable with respect to physician training and clinical resources. Two independent physicians blinded to the participating hospital characterized the neurological injuries into 2 groups: disabling and nondisabling. Data were analyzed with logistic regression techniques, with hospital, patient age, sex, anatomic level of injury, and injury mechanism as variables. Neurological deterioration after injury was less frequent in Malayan patients with spinal injuries who were not treated with formal spinal immobilization during transport (odds ratio, 2.03; 95% confidence interval, 1.03-3.99; $P = .04$) compared with patients in New Mexico who were managed with spinal column immobilization techniques. Even when the analysis was limited to cervical spine injuries, no significant protective effect from spinal immobilization was identified. For multiple reasons, the conclusions drawn by the authors of this study are considered spurious at best.[15,31,33]

Evidence in the literature evaluating the effectiveness of prehospital spinal immobilization is sparse. Ethical and practical issues preclude the execution of a contemporary, randomized clinical trial designed to study the effectiveness of prehospital spinal immobilization compared with no immobilization, primarily because spinal immobilization for trauma patients is perceived as essential with minimal risk and is already widely used. Intuitively, the use of prehospital spinal immobilization is a rational means of limiting spinal motion in spine-injured patients in an effort to reduce the likelihood of neurological deterioration resulting from pathological motion at the site(s) of injury.

The medical evidence (Class III) derived from all of the articles reviewed for the first iteration of this guideline published in 2002 supports that, from an anatomic and biomechanical perspective and from time-tested clinical experience with traumatic spinal injuries, all patients with cervical spinal column injuries or those with the potential for a cervical spinal injury after trauma should be treated with cervical spinal cord immobilization until an injury has been excluded or definitive management has been initiated.

Orledge and Pepe[17] in their commentary on the Hauswald et al findings point out some limitations of their article but also suggest that it raises the issue of a more selective evidence-based protocol for spinal immobilization. Should all trauma patients be managed with spinal immobilization until spinal injury has been excluded, or should immobilization be selectively used for patients with potential spinal injury based on well-defined clinical criteria? Which clinical criteria should be used? Since the Hauswald et al report, prospective studies in support of the use of clinical findings as indicators for the need for prehospital spinal immobilization after trauma have been reported.[27,30,64] Several EMS systems now use clinical protocols to help guide which patients should be managed with spinal immobilization after trauma.[65,66]

In 2002, Domeier et al,[27,30] in a multicenter prospective study of 6500 trauma patients, found that the application of clinical criteria (altered mental status, focal neurologic deficit, evidence of intoxication, spinal pain or tenderness, or suspected extremity fracture) was predictive of the majority of patients who sustained cervical spinal injuries requiring immobilization. The predictive value of their criteria held for patients with high- or low-risk mechanisms of injury. Their study offers Class II medical evidence suggesting that clinical criteria, rather than the mechanism of injury, be evaluated as the standard by which spinal immobilization should be used.

Brown et al[34] examined whether EMS providers could accurately apply clinical criteria to clear the cervical spines of trauma patients before transport to a definitive care facility. The criteria included the presence of pain or tenderness of the cervical spine, the presence of a neurological deficit, an altered level of consciousness, evidence of drug use or intoxication (particularly alcohol, analgesics, sedatives, or stimulants), and/or the presence of other significant trauma that might act as a distracting injury. Immobilization of the cervical spine was initiated if any 1 of 6 criteria was present. The clinical assessment of trauma patients by EMS providers was compared with the clinical assessment provided by emergency physicians. The providers (emergency medical technicians and emergency room physician) were blinded to each other's assessments. Agreement between EMS staff and physicians was analyzed by the κ statistic. Five hundred seventy-three patients were included in the study. The assessments matched in 79% of the cases (n = 451). There were 78 patients (13.6%) for whom the EMS clinical assessment indicated spinal immobilization, but the physician assessment did not. There were 44 patients (7.7%) for whom the physician's clinical assessment indicated spinal immobilization, but the EMS assessment did not. The κ for the individual components ranged from 0.35 to 0.81. The κ value for the decision to immobilize was 0.48. The EMS clinical assessments were generally more in favor of immobilization than the physician clinical assessments. The authors concluded that EMS and physician clinical assessments to rule out cervical spinal injury after trauma have moderate to substantial agreement. The authors recommended, however, that systems that allow EMS personnel to decide whether to immobilize patients after trauma should provide attentive follow-up of those patients to ensure appropriate care and to provide immediate feedback to the EMS providers.[34] Meldon et al,[67] in an earlier study, found significant disagreement between the clinical assessments and subsequent spinal immobilization of patients between EMS technicians and physicians. They recommended further research and education before widespread implementation of this practice.

Clinical criteria to select appropriate patients for spinal immobilization have been studied in Michigan[65] and have been implemented in Maine[66] and San Mateo County, California.[45] In Fresno, California, there has been a selective spine immobilization clearance protocol in place since 1990.[45] EMS Policy Number 530, as it is known, calls for spinal immobilization in the following circumstances:

1. Spinal pain or tenderness, including any neck pain with a history of trauma
2. Significant multiple system trauma
3. Severe head or facial trauma
4. Numbness or weakness in any extremity after trauma
5. Loss of consciousness caused by trauma
6. If mental status is altered (including drugs, alcohol, trauma) and no history is available, or the patient is found in a setting of possible trauma (eg, lying at the bottom of stairs or in the street); or the patient experienced near drowning with a history or probability of diving
7. Any significant distracting injury

In 2001, Stroh and Braude[68] reported a retrospective series of all cases of cervical spine trauma in a 6-year period from 1990 to 1996 at 5 trauma-receiving hospitals in Fresno County, California. There were 861 patients with cervical injuries during this period, 504 of whom were transported to the hospital by EMS personnel. Of those, 495 arrived with cervical spine immobilization. Of the 9 remaining patients, 2 refused immobilization and 2 could not be immobilized. Three injuries were missed by the protocol criteria and 2 secondary to protocol violations. Of the last 5 patients, only 1 patient had an adverse outcome; 2 patients were considered unstable, 4 patients were $>$ 67 years of age, and 1 patient was 9 months old. The protocol was found to be 99% sensitive in identifying trauma patients with cervical injuries requiring immobilization (95% confidence interval, 97.7-99.7).[68] The criteria for immobilization are similar to those used to identify patients who require imaging of the cervical spine after trauma.[69] The authors' retrospective review of prospectively collected data provides convincing Class II medical evidence that prehospital criteria to select which patients need spinal immobilization after trauma can be successfully applied by EMS personnel in the field. The authors pointed out that the missed injuries identified in their series occurred in very old and very young patients; therefore, caution should be exercised in these age ranges.

In 2004, Burton et al[70] reported a prospective series of trauma patients in Maine who were evaluated by EMS personnel in the field with a "NEXUS-like" decision instrument, originally designed for physicians in the evaluation of trauma patients to determine which trauma patients require imaging of the cervical spine. This included an algorithmic approach excluding patients from immobilization if they were reliable (no alcohol or drugs, loss of consciousness, or altered sensorium), had no distracting injuries, had no normal motor and sensory examinations, and had no spinal tenderness. If any 1 of the 4 criteria was present, the patient was immobilized.[70]

Before the study was initiated, all EMS personnel underwent training on the evaluation system. The protocol was initiated in 2002, and the first year's data were reported in 2004. During that period, there were 207 545 EMS encounters with 41 885 transports to an emergency department. There were 12 988 patients transported with spinal immobilization (41%). Acute spinal fractures were identified in 154 patients; 20 patients were transported without spinal immobilization (13%). Of these 20 patients, 19 patients had stable fractures and 1 patient had an unstable thoracic injury. The sensitivity for immobilization was 87% (95% confidence interval, 81.7-92.3), with a negative predictive value of 99.9% (95% confidence interval, 99.8-100). The only missed injury was in the thoracic spine; there were no missed cervical injuries. The protocol ensured that more than half of the trauma patients evaluated did not unnecessarily receive spinal immobilization.[70]

On the basis of the report by Domeier et al[64] and the more recent experiences in Fresno and Maine, both of which have robust protocols in place guiding EMS personnel in the application of spinal immobilization, it appears that these criteria can safely and effectively be applied to predict which patients require cervical spinal immobilization after blunt trauma. There have been no subsequent reports of significant missed spinal injuries in settings where these protocols are used. These 3 studies provide Class II medical evidence on this subject.

EMS personnel who make the assessments to immobilize trauma victims require intensive education and vigilant, quality-assurance scrutiny to ensure that trauma patients with potential spinal injuries are appropriately triaged and managed. Available studies support the use of selective "NEXUS-like" criteria to guide EMS personnel in the field to determine the need for spinal immobilization in patients with potential cervical spinal injuries after trauma.

METHODS OF PREHOSPITAL SPINAL IMMOBILIZATION

Prehospital spinal immobilization is effective in limiting spinal motion during patient transport.[25] Various devices and techniques exist to provide immobilization of the cervical spine. Attempts to define the best method of spinal immobilization for prehospital transport have been hampered by physical and ethical constraints.[15,36,38-42]

The methods of measuring the efficacy of spinal immobilization devices vary among investigators. Comparative studies of the various devices have been performed on normal human volunteers, but none has been tested in a large number of patients with spinal injuries. It is difficult to extrapolate normative data to injured patients with potential spinal instability.[15,36,38,41,42,59,61,71-78]

Several methods have been used to measure movement of the cervical spine. They range from clinical assessment to plumb lines, photography, radiography, cinematography, and computed tomography and magnetic resonance imaging. Roozmon et al[79] and Bourn et al[80] summarized the problems inherent in each method and concluded that there was no satisfactory noninvasive means of studying neck motion, particularly if one is to quantify movement between individual vertebral segments.

The position in which the injured spine should be placed and held immobile, the "neutral position," is poorly defined.[15,45,80-82] Schriger[83] defined the neutral position as "the normal anatomic position of the head and torso that one assumes when standing and looking ahead." This position correlates to 12° cervical spine extension on a lateral radiograph. The extant radiographic definition of neutral position was based on the radiographic study of patients who were visually observed to be in the neutral position.[83] Schriger et al[84] used this position in their evaluation of occipital padding on spinal immobilization backboards. De Lorenzo,[15] in a magnetic resonance imaging study of 19 adults, found that a slight degree of flexion equivalent to 2 cm occiput elevation produces a favorable increase in spinal canal/spinal cord ratio at levels C5 and C6, a region of frequent unstable spinal injuries. Backboards have been used for years for extrication and immobilization of spine-injured patients. Schriger et al[84] questioned the ability of a flat board to allow neutral positioning of the cervical spine. They compared spinal immobilization with the flat backboard with and without occipital padding in 100 adults. Clinical observation and assessment were used to determine the neutral position of the cervical spine. The authors found that the use of occipital padding in conjunction with a rigid backboard places the cervical spine in the optimal neutral position compared with positioning on a flat backboard alone.[83,84] McSwain[28] determined that > 80% of adults require 1.3 to 5.1 cm of padding to achieve neutral positioning of the head and neck with respect to the torso and noted that body habitus and muscular development alter the cervical-thoracic angle, thus affecting positioning. These variables make it impossible to dictate specific or routine recommendations for padding.

In general, spinal immobilization consists of a cervical collar, supports on either side of the head, and either long or short backboards with associated straps to attach and immobilize the entire patient's body to the board.[15] Garth[85] proposed performance standards for cervical extrication collars, but these standards have not been uniformly implemented. There are a variety of different cervical collars. Several studies compare collars alone or in combination with other immobilization devices using a wide range of assessment criteria.[36,41,42,46,71,72]

In 1983, Podolsky et al[86] evaluated the efficacy of cervical spine immobilization techniques using goniometric measures. Twenty-five healthy volunteers lying supine on a rigid emergency department resuscitation table were asked to actively move their necks as far as possible in 6 ways: flexion, extension, rotation to the right and left, and lateral bending to the right and left. Control measurements were made with no device, and measurements were repeated after immobilization in a soft collar, hard collar, extrication collar, Philadelphia collar, bilateral sandbags joined with 3-in-wide cloth tape across the forehead attached to either side of the resuscitation table, and the combination of sandbags, tape, and a Philadelphia collar. Hard foam and hard plastic collars were superior at limiting cervical spine motion compared with soft foam collars. Neither collars alone nor sandbags and tape in combination provided satisfactory restriction of cervical spine motion. Immobilization with sandbags and tape was significantly better than with any of the other methods used alone for all 6 cervical spinal movements. The authors found that the combination of sandbags and tape with a rigid cervical collar was the best means of those evaluated to limit cervical spine motion. The addition of a Philadelphia collar was significantly more effective in reducing neck extension ($P < .01$), from 15° to 7.4°, a change of 49.3%. Collar use had no significant additive effect for any other motion of the cervical spine.

Sandbags as adjuncts to cervical spine immobilization require more rather than less attention from care providers.[87] Sandbags are heavy, and if the extrication board is tipped side to side during evacuation and transport, the sandbags can slide, resulting in lateral displacement of the patient's head and neck with respect to the torso. Sandbags can be taped to the extrication board, but because they are small compared with the patient, this can be difficult and/or ineffective. Finally, sandbags must be removed before initial lateral cervical spine x-ray assessment because they can obscure the radiographic bony anatomy of the cervical spine. For these reasons and because of the findings of Podolsky et al,[88] the use of sandbags and tape alone to attempt to immobilize the cervical spine is not recommended.

In 1985, Cline et al[37] compared methods of cervical spinal immobilization used in prehospital transport. They found that strapping the patient to a standard short board was superior to cervical collar use alone. They noted no significant differences between the rigid collars they tested. McCabe and Nolan[76] compared 4 different collars for their ability to restrict motion in flexion-extension and lateral bending using radiographic assessment. They found that the polyethylene-1 collar provided the most restriction of motion of the cervical spine, particularly with flexion. Rosen et al[89] in 1992 compared the limitation of cervical spinal movement of 4 rigid cervical collars in 15 adults using goniometric measurements. The vacuum splint cervical collar provided the most effective restriction of motion of the cervical spine of the 4 devices they tested.

Graziano et al[90] compared prehospital cervical spine immobilization methods by measuring cervical motion radiographically in the coronal and sagittal planes in 45 immobilized adults. The Kendricks extrication device and the Extrication Plus-One device were nearly as effective in limiting cervical motion as the short immobilization board in their study. Both devices were superior to a rigid cervical collar alone.

In 1990, Cohen[91] described the Russell extrication device for immobilization of patients with potential spine injuries. The Russell extrication device was comparable to the short immobilization board for prehospital spinal immobilization. Chandler et al[71] compared a rigid cervical extrication collar with the Ammerman halo orthosis in 20 male patients. The Ammerman halo orthosis combined with a rigid spine board provided significantly better cervical spinal immobilization than a cervical collar and spine board. The Ammerman halo orthosis and spine board was equivalent to the standard halo vest immobilization device.

Perry et al[33] evaluated 3 cervical spine immobilization devices during simulated vehicle motion in 6 adults. Neck motion was assessed by 3 neurologists and neurosurgeons as to whether motion was "clinically significant." They found that substantial head motion occurred during simulated vehicle motion regardless of the method of immobilization. They observed that the efficacy of cervical spine immobilization was limited unless the motion of the head and the trunk was also controlled effectively. Mazolewski and Manix[40] tested the effectiveness of strapping techniques to reduce lateral motion of the spine of adults restrained on a backboard. Subjects were restrained on a wooden backboard with 4 different strapping techniques. The backboard was rolled to the side, and lateral motion of the torso was measured. The authors found that additional strapping securing the torso to the backboard reduced lateral motion of the torso. Finally, the traditional method of moving a patient onto a long backboard has typically involved the logroll maneuver. The effectiveness of this transfer technique has been questioned.[89,92] Significant lateral motion of the lumbar spine has been reported to occur.[93,94] Alternatives to the logroll maneuver include the HAINES (high arm in endangered spine) method and the multihand or fireman lift method.[14,23] In the HAINES method, the patient is placed supine, the upper arm away from the kneeling rescuer is abducted to 180°, the near arm of the patient is placed across the patient's chest, and both lower limbs are flexed. The rescuer's hands stabilize the head and neck and the patient is rolled away onto an extrication board or device.[95] The multihand or fireman lift method involves several rescuers on either side of the patient, each of whom slides his or her arms underneath the patient and lifts the patient from 1 position to the other onto an extrication board or device.

The above review describes the evolution of and underscores the diversity of techniques available for providing prehospital spinal immobilization of spine-injured patients during transport. These studies are limited by the fact that none of the studies evaluates the full range of available devices using similar criteria. Overall, it appears that a combination of rigid cervical collar immobilization with supportive blocks on a rigid backboard with straps to secure the entire body of the patient is most effective in limiting motion of the cervical spine after traumatic injury.[14] The longstanding practice of attempted spinal immobilization with sandbags and tape with a rigid backboard is insufficient and is not recommended.

SAFETY OF PREHOSPITAL SPINAL IMMOBILIZATION DEVICES

Despite obvious benefits, cervical spinal immobilization has a few potential drawbacks. Immobilization can be uncomfortable; it can be difficult to apply properly; it takes time to apply; application may delay transport; and it is associated with modest morbidity.[14,18,44-48]

Chan et al[46] studied the effects of spinal immobilization on pain and discomfort in 21 uninjured adults. Subjects were placed in backboard immobilization for 30 minutes, and symptoms were chronicled. All subjects developed pain, which was described as moderate to severe in 55% of volunteers. Occipital headache and sacral, lumbar, and mandibular pain were the most frequent complaints. In a later study, Chan and others[47] compared spinal immobilization on a backboard with immobilization with a vacuum mattress-splint device in 37 normal adults. They found that the frequency and severity of occipital and lumbosacral pain were significantly greater during backboard immobilization than on the vacuum mattress-splint device. Johnson et al[75] performed a prospective, comparative study of the vacuum splint device and the rigid backboard. The vacuum splint device was significantly more comfortable than the rigid backboard and was faster to apply. The vacuum splint device provided better immobilization of the torso. The rigid backboard with head blocks was slightly better at immobilizing the head. Vacuum splint devices, however, are not recommended for extrication because they are reportedly not rigid enough, and they are more expensive. At a cost of approximately $400, the vacuum splint device is roughly 3 times more expensive than a rigid backboard.

Hamilton and Pons[74] studied the comfort level of 26 adults on a full-body vacuum splint device compared with a rigid backboard with and without cervical collars. Subjects graded their immobilization and discomfort. No statistically significant difference was found between the vacuum splint device–collar combination compared with the backboard-collar combination for flexion and rotation. The vacuum splint–collar combination provided significantly superior immobilization in extension and lateral bending than the backboard-collar combination. The vacuum splint device alone provided superior cervical spinal immobilization in all neck positions except extension compared with the rigid backboard alone. A statistically significant difference in subjective perception of immobilization was noted, with the backboard alone less effective than the other 3 alternatives. In conclusion, the vacuum splint device, particularly when used with a cervical collar, is an effective and comfortable alternative to a rigid backboard (with or without a collar) for cervical spinal immobilization.

Barney et al[96] evaluated pain and discomfort during immobilization on rigid spine boards in 90 trauma patients and found that rigid spine boards cause discomfort. Padding the rigid board improves patient comfort without compromising cervical spine immobilization.[97] Minimizing the pain of immobilization may decrease voluntary movement and therefore decrease the likelihood of secondary injury.[46]

Cervical collars have been associated with elevations in intracranial pressure (ICP). Davies et al[48] prospectively analyzed ICP in a series of injured patients using the Stifneck rigid collar. ICP rose significantly ($P < .001$; mean, 4.5 mm Hg) when the collar was firmly in place. They cautioned that because head-injured patients may also require cervical spinal immobilization, it is essential that secondary insults producing raised ICP are minimized. Kolb and coinvestigators[49] also examined changes in ICP after the application of a rigid Philadelphia collar in 20 adult patients. ICP averaged 176.8 mm H_2O initially and increased to an average of 201.5 mm H_2O after collar placement. Although the difference in ICP of 24.7 mm H_2O was statistically significant (P = .001), it remains uncertain that it has clinical relevance. Nonetheless, this modest increase in pressure may be important in patients who already have elevated ICP. Plaisier et al[78] in 1994 prospectively evaluated craniofacial pressure with the use of 4 different cervical orthoses. They found small changes in craniofacial pressure (increases) but no significant differences between the 4 collar types.

Spinal immobilization increases the risk of pressure sores. Linares and associates[98] found pressure sores were associated with immobilization (patients who were not turned during the first 2 hours after injury). The development of pressure sores was not related to mode of transportation to hospital or the use of a spinal board and sandbags during transportation. Mawson et al[99] prospectively assessed the development of pressure ulcers in 39 spinal cord-injured patients who were immobilized immediately after injury. The length of time on a rigid spine board was significantly associated with the development of decubitus ulcers within 8 days of injury (P = .01). Rodgers and Rodgers[62] reported a marginal mandibular nerve palsy resulting from compression by a hard collar. The palsy resolved uneventfully during the next 2 days. Blaylock[100] found that prolonged cervical spinal immobilization may result in pressure ulcers. Improved skin care (keeping the skin dry), proper fitting (avoiding excessive tissue pressure), and the appropriate choice of collars (those that trap or do not absorb moisture or that exert significant tissue pressure) can reduce this risk.[100,101] Skin breakdown is another potential complication of spinal immobilization. This can occur within 48 hours of application of a cervical collar.[102]

Cervical spinal immobilization may also increase the risk of aspiration and may limit respiratory function. Bauer and Kowalski[44] examined the effect of spinal immobilization with the Zee Extrication Device and the long spinal board on pulmonary function. They tested pulmonary function in 15 healthy, nonsmoking men using forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), the FEV1:FVC ratio, and forced midexpiratory flow (25%-75%). They found a significant difference ($P < .05$) between preimmobilization strapping and poststrapping values for 3 of the 4 functions tested when on the long spinal board. Similarly significant differences were found for 3 of the 4 parameters using the Zee Extrication Device. These differences reflect a marked pulmonary restrictive effect of appropriately applied entire-body spinal immobilization devices.

Totten and Sugarman[6] evaluated the effect of whole-body spinal immobilization on respiration in 39 adults. Respiratory function was measured at baseline, once immobilized with a Philadelphia collar on a rigid backboard, and when immobilized on a Scandinavian vacuum mattress with a vacuum collar. The comfort levels of each of the 2 methods were assessed on a visual analog scale. Both immobilization methods restricted respiration by an average of 15%. The effects were similar with the 2 methods, although the FEV_1 was lower on the vacuum mattress. The vacuum mattress was significantly more comfortable than the wooden backboard.

Haut et al[103] conducted a retrospective analysis comparing patients with and without prehospital spine immobilization after penetrating trauma (knife stab and gunshot). Their study revealed that patients with penetrating injuries to the spine rarely have spinal instability even when the penetrating trauma specifically injures the spine and that spine-immobilized penetrating trauma patients were twice as likely to die as those who were not treated with spinal immobilization. They estimated that the number of patients with a penetrating spinal injury needed to treat with spinal immobilization to potentially benefit 1 patient was 1032. They estimated that the number of patients needed to harm 1 patient with the use of spinal immobilization, potentially contributing to death, was 66. The time required for the proper application of spinal immobilization devices in patients who have suffered stab and gunshot wounds delays patient resuscitation, resulting in increased morbidity and mortality.

Other potential problems with spinal immobilization have been reported in patients with ankylosing spondylitis. In 1 series, 15 patients with ankylosing spondylitis were followed up after sustaining spinal trauma. Twelve of the 15 patients deteriorated neurologically after presentation. In more than one of these patients, neurological deterioration was felt to be secondary to spinal immobilization protocols.[104]

In conclusion, cervical spine immobilization devices are generally effective at limiting spinal motion but may be associated with increased morbidity in certain instances. Cervical spinal immobilization devices should be used to achieve the goals of safe extrication and transport yet should be removed as soon as it is safe to do so. Spinal immobilization for patients with penetrating injuries does not appear to be efficacious.

SUMMARY

Spinal immobilization can reduce untoward movement of the cervical spine and can reduce the likelihood of neurological deterioration in patients with unstable cervical spinal injuries after trauma. Immobilization of the entire spinal column is necessary in these patients until a spinal cord injury (or multiple injuries) has been excluded or until appropriate treatment has been initiated. Although immobilization of the cervical spine after trauma is not supported by Class I or II medical evidence, this effective, time-tested practice is based on anatomic and mechanical considerations in an attempt to prevent spinal cord injury and is supported by years of cumulative trauma and triage clinical experience.

Not all trauma patients must be treated with spinal immobilization during prehospital resuscitation and transport. Many patients do not have spinal injuries and therefore do not require such intervention. The development of specific selection criteria for those patients for whom immobilization is indicated remains an area of investigation. Current publications on the use of contemporary, well-defined EMS triage protocols provide Class II medical evidence for their utility.

The variety of techniques used and the lack of definitive evidence to advocate a uniform device for spinal immobilization make immobilization technique and device recommendations difficult. It appears that a combination of a rigid cervical collar with supportive blocks on a rigid backboard with straps and tape to immobilize the entire body is effective at achieving safe, effective spinal immobilization for transport. The longstanding practice of attempted spinal immobilization with sandbags and tape with the patient strapped to a rigid backboard is not sufficient and is not recommended.

Cervical spine immobilization devices are effective but can result in patient morbidity. Spinal immobilization devices should be used to achieve the goals of spinal stability for safe extrication and transport. They should be removed as soon as a definitive evaluation is accomplished and/or definitive management is initiated. Spinal immobilization of trauma patients with penetrating injuries is not recommended.

KEY ISSUES FOR FUTURE INVESTIGATION

The optimal device for immobilization of the cervical spine after traumatic vertebral injury should be studied in a prospective fashion.

A sensitive, reliable, and valid in-field triage protocol to be applied by EMS personnel for patients with potential cervical spine injuries after trauma should be studied in greater detail.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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