CHAPTER 1

Cervical Spine Immobilization before Admission to the Hospital

RECOMMENDATIONS

STANDARDS: There is insufficient evidence to support treatment standards.
GUIDELINES: There is insufficient evidence to support treatment guidelines.
OPTIONS:

- **All trauma patients with a cervical spinal column injury or with a mechanism of injury having the potential to cause cervical spine injury should be immobilized at the scene and during transport by using one of several available methods.**
- **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 long-standing practice of attempted cervical spine immobilization using sandbags and tape alone is not recommended.**

RATIONALE

Early management of the 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 spine injuries is that neurological function may be impaired by pathological 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 (14, 15, 42, 48, 81, 97). Many cases have been reported that had a poor outcome because of mishandling of cervical spine injuries (12, 51, 81, 97). As many as 20% of spinal column injuries involve multiple noncontinuous vertebral levels; therefore, the entire spinal column is potentially at risk (38, 39, 66, 73). Consequently, complete spine immobilization has been used in spinal care, before admission to the hospital, to limit motion until injury has been ruled out (2, 5, 27, 40, 66, 73, 76, 100, 104). During the last 30 years, the neurological status of spinal cord-injured patients arriving in emergency departments has dramatically improved. During the 1970s, most patients (55%) referred to regional spinal cord injury centers arrived with complete neurological lesions. In the 1980s, however, most spinal cord-injured patients (61%) arrived with incomplete lesions (46). This improvement in the neurological status of patients has been attributed to the development of emergency medical services (EMS) initiated in 1971, and the care (including spine immobilization) rendered by EMS personnel before the patient reaches the hospital (2, 45, 46, 103). Spine immobilization is now an integral part of preadmission management and is advocated, for all patients with potential spine injury after trauma, by EMS programs nationwide and by the American College of Surgeons (1, 2, 5, 6, 16, 32, 70, 93).

Recently, the use of spine immobilization for *all* trauma patients, particularly those 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 spine immobilization (34, 50, 69, 76). Some authors have developed and advocate a triage system based on clinical criteria to select patients for preadmission spine immobilization (13, 32, 74).

Several devices are available for immobilizing the patient with a potential spine injury during transportation to the hospital. However, the optimal device has not yet been identified by careful comparative analysis (17, 21, 27, 53, 61, 64, 94, 99). 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 (3, 5). A more uniform, universally accepted method for spine immobilization for trauma patients with potential spine injury may reduce the cost and improve the efficiency of preadmission spinal injury management (13, 32, 74). Although spine immobilization is typically effective in limiting motion, it has been associated with morbidity in a small percentage of cases (4, 9, 18, 19, 26, 55, 90, 100). These issues are the subject of this review on the use and effectiveness of preadmission spine immobilization.

SEARCH CRITERIA

A computerized search of the National Library of Medicine database of literature published from 1966 to 2001 was performed. The search was limited to the English language and human studies. The medical subject heading "spinal immobilization" produced 39 articles. A second search, combining the exploded terms "spinal injuries" and "immobilization," yielded 122 articles. A third search, combining the exploded terms "spinal injuries" and "transportation of patients," yielded 47 articles. A fourth search, combining the exploded terms "spinal injuries" and "emergency medical services," produced 119 articles. Additional references were culled from the reference lists of the articles. Finally, members of the author group were asked to contribute articles known to them on the subject matter that were not found by other search methods. Duplicate references were discarded. The abstracts were reviewed, and articles unrelated to the specific topic were eliminated. This process yielded 101 articles for this review, which are listed in the reference list. Articles used to formulate this guideline are summarized in *Table 1.1*.

SCIENTIFIC FOUNDATION

Pathological motion of the injured cervical spine may create or exacerbate cervical spinal cord or cervical nerve root injury (38–40, 66, 73, 96). This potential has led to the use of spine 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 (5, 6, 27, 33, 34, 40, 66, 73, 74, 76, 104).

Kossuth (56, 57) is credited with pioneering the currently accepted methods of protecting and immobilizing the cervical spine during extrication of patients with acute injury. Farrington (36, 37) championed the concept of preadmission immobilization. Dick and Land (30) noted in their review of spine immobilization devices that techniques of preadmission spine immobilization appeared as early as 1971 in standard EMS texts and in the American Academy of Orthopedic Surgeons Committee on Injuries Emergency text (2). Initially, the preferred method for immobilizing the cervical spine was to use a combination of a soft collar and a rolled-up blanket (21). Later, in 1974, Hare introduced a more rigid extrication collar. Hare's contribution launched an era of innovation for spine immobilization devices (27).

Currently, in North America, spine immobilization is one of the most frequently performed procedures in the preadmission care of patients with acute trauma (2, 6, 7, 27, 38, 40, 66, 73, 76, 98, 104). Although clinical and biomechanical evidence demonstrates that spine immobilization limits pathological 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 evidence reports exist of neurological worsening with failure of adequate spine immobilization, no case-control studies or randomized trials address the effect of spine immobilization on clinical outcomes after cervical spinal column injury (6, 27, 32, 40, 42, 48, 50, 66, 69, 73, 96). The issue is important; tens of thousands of patients with trauma are treated with spine immobilization each year, but few of them will have spinal column injuries or instability (39, 74, 83).

Other considerations in the use of preadmission spine 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 spine immobilization (4, 9, 18, 19, 26, 27, 55, 58, 84, 90, 100). As with many interventions in the practice of medicine, spine immobilization has been instituted in preadmission management of trauma patients with potential spinal injuries on the basis of 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 may be impossible to obtain this information in clinical trials.

In 1989, Garfin et al. stated that no patient should be extricated from a crashed vehicle or transported from an accident scene without spinal stabilization (40). The authors credited stabilization of the cervical spine as a key factor in declining percentages of complete spinal cord injury lesions, from 55% in the 1970s to 39% in the 1980s, and in the significant reduction of mortality in patients with multiple injuries that include cervical spine injuries. Unfortunately, no Class I or Class II medical evidence supports their claims.

Few articles have directly evaluated the effect of preadmission spine immobilization on neurological outcome after injury. Several Class III evidence reports cite lack of immobilization as a cause of neurological deterioration among acutely injured trauma patients transported to medical facilities for definitive care (12, 40, 51, 62, 81). The most pertinent study is Toscano's (96) retrospective case series report. Toscano, in 1988, reported that 32 (26%) of 123 trauma patients sustained major neurological deterioration in the period between injury and admission at the hospital. The author attributed neurological deterioration to patient mishandling and cited the lack of spine immobilization after traumatic injury as the primary cause. The report supports the need for spine immobilization of trauma patients with potential spinal column injuries before admission to the hospital.

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. (50) analyzed only patients with acute blunt spine or spinal cord injuries. At the University of Malaya, none of the 120 patients they managed were immobilized with spinal orthoses during transport. All 334 patients managed at the University of New Mexico were initially treated with spine immobilization. The hospitals were reportedly comparable in physician training and clinical resources. Two independent physicians, blinded to the participating hospital, characterized the neurological injuries into two groups: disabling and nondisabling. Data were analyzed by 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 patients with spinal injuries in Malaya, who were not treated with formal spine immobilization during transport (odds ratio, 2.03; 95% confidence interval, 1.03–3.99; $P = 0.04$), than in patients in New Mexico, who were managed with spinal column immobilization techniques. Even with the analysis limited to cervical spine injuries, no significant protective effect from spine immobilization was identified. The authors theorized that because the initial injury is of tremendous force, additional movement of the spine by the patient or rescuers is insufficient to cause further injury. However, they noted that because of the small sample size, the benefit of spine immobilization might not be statistically measurable in their study.

This report has been challenged, and several flaws have been identified. Patients who died at the scene or during transport were excluded from analysis. Injuries were not matched by severity of neurological injury or by type of spinal column injury. The mechanisms of injury differed dramatically in the two populations. Malayan patients were immobilized or held immobile during transport, but spinal orthoses as immobilization devices were not used. For these reasons and others, the conclusions drawn by the authors are questionable (27, 76).

Evidence in the literature evaluating the effectiveness of preadmission spine immobilization is sparse. The article by Hauswald et al. (50) was published in 1998 after a period during which universal spine immobilization after trauma had been applied in the United States and North America. Ethical and practical issues preclude a contemporary clinical trial designed to study the effectiveness of preadmission spine immobilization compared with no immobilization, primarily because spine immobilization for trauma patients is perceived as essential with minimal risk and is already widely used. Intuitively, the use of preadmission spine immobilization is a rational means of limiting spinal motion in spine-injured patients in an effort to reduce the likelihood of neurological deterioration caused by pathological motion at the site(s) of injury.

The consensus from all articles reviewed (Class III evidence), from an anatomic and biomechanical perspective and from time-tested clinical experience with traumatic spinal injuries, is that all patients with cervical spinal column injuries, or those with the potential for a cervical spinal injury after trauma, should be treated with spinal column immobilization until injury has been excluded or definitive management has been initiated. Although there is insufficient medical evidence to support a treatment standard or a treatment guideline, practitioners are strongly encouraged to provide spine immobilization to spine-injured patients (or those with a likelihood of spinal injury) until definitive assessment can be accomplished.

Orledge and Pepe (76) in their commentary on the Hauswald findings (50) point out some limitations of the article, but they also suggest that it raises the issue of a more selective evidence-based protocol for spine immobilization. Should all trauma patients be managed with spine immobilization until spinal injury has been excluded, or should immobilization be selectively used for patients with potential spinal injury on the basis of well-defined clinical criteria? Which clinical criteria should be used? After the Hauswald report, several prospective studies supported the use of clinical findings as indicators of the need for preadmission spine immobilization after trauma (33–35). Several EMS systems now use clinical protocols to help decide which patients should be managed with spine immobilization after trauma (43, 102).

Domeier et al. (32–34), in a multicenter prospective study of 6500 trauma patients, found that the application of clinical criteria (altered mental status, focal neurological deficit, evidence of intoxication, spinal pain or tenderness, or suspected extremity fracture) was predictive of most patients with cervical spinal injuries that required immobilization. The predictive value of their criteria held true for patients with high- or low-risk mechanisms of injury. They suggested that clinical criteria, rather than the mechanism of injury, be evaluated as the standard for the use of spine immobilization.

Brown et al. (13) examined whether EMS providers could accurately apply clinical criteria to evaluate 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 one of six criteria was present. The clinical assessment of trauma patients by EMS providers was compared with the clinical assessment provided by emergency physicians. The providers (EMS technicians and emergency physicians) were blinded to each other's assessments. Agreement between EMS and physician providers was analyzed by κ statistic. Five hundred seventy-three patients were included in the study. The assessments matched in 79% of the cases (n = 451). For 78 patients (13.6%), the EMS clinical assessment indicated spine immobilization but the physician assessment did not. For 44 patients (7.7%), the physician's clinical assessment indicated spine immobilization but the EMS assessment did not. For the individual components, κ ranged from 0.35 to 0.81. For the decision to immobilize, κ was 0.48. The EMS clinical assessments were generally more in favor of immobilization than the physician's clinical assessments. Brown et al. 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. Meldon et al. (71), in an earlier study, found significant disagreement between the clinical assessments and subsequent spine immobilization of patients by EMS technicians and physicians. They recommended further research and education before widespread implementation of this practice.

Clinical criteria to select appropriate patients for spine immobilization are being studied in Michigan (102) and have been implemented in Maine (43) and San Mateo County, CA (88). Recommendations regarding the adoption of EMS protocols for preadmission spine immobilization await definitive studies of safety and efficacy (23). EMS personnel who make these assessments require intensive education and careful, quality-assurance scrutiny to ensure that trauma patients with potential spinal injuries are appropriately triaged and managed. Until further studies can be undertaken, the available Class III studies support the use of spine immobilization for all patients with potential cervical spinal injury after trauma.

Devices and techniques for preadmission spine immobilization

Preadmission spine immobilization is effective in limiting spinal motion during transportation of the patient (7, 27, 40,

TABLE 1.1. Summary of Reports on Preadmission Cervical Spine Immobilization[a]

Series (Ref. No.)	Description of Study	Evidence Class	Conclusions
Markenson et al., 1999 (61)	An evaluation of the Kendrick extrication device[b] for pediatric spinal immobilization.	III	Kendrick extrication device provides excellent static and dynamic immobilization.
Perry et al., 1999 (77)	An experimental evaluation of 3 immobilization devices compared during simulated vehicle motion. Neck motion was judged by 3 physicians.	III	Substantial amounts of head motion can occur during simulated vehicle motion, regardless of the method of immobilization. Movement of the trunk can have the same effect as head motion on motion across the neck.
Bauer and Kowalski, 1998 (9)	A study of the effect of spinal immobilization devices on pulmonary function in 15 men.	III	Significant restriction of pulmonary function may result from spinal immobilization.
Mawson et al., 1998 (63)	A prospective study to determine the association between immobilization and pressure ulcers in 39 SCI patients.	III	Time spent on backboard is significantly associated with pressure ulcers developing within 8 d.
Hauswald et al., 1998 (50)	5-yr retrospective chart review of patients with acute traumatic SCI from 2 centers. 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 (OR, 2.03; 95% CI, 1.03–3.99; $P = 0.04$). Results were similar when the analysis was limited to patients with cervical injuries (OR, 1.52; 95% CI, 0.64–3.62; $P = 0.34$).	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 SCI remains unclear.
Blaylock, 1996 (11)	A prospective study to determine the association between immobilization and pressure ulcers in 32 SCI patients.	III	Pressure sores developed, mostly in patients who were turned after 3 h. Most of those without sores were turned <2 h after immobilization.
Johnson et al., 1996 (52)	Measured immobilization and comfort on 10-point scale. The 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, 1995 (84)	Case report of marginal mandibular nerve palsy due to compression by a cervical hard collar.	III	The collar was removed; the palsy resolved uneventfully during the next 2 d.
Chan et al., 1994 (19)	A prospective study of the effects of spinal immobilization on pain and discomfort in 21 volunteers after 30 min. All subjects developed pain.	III	Standard spinal immobilization may be a cause of pain in an otherwise healthy subject.
Liew and Hill, 1994 (59)	2 case reports of significant occipital pressure ulceration associated with the use of hard cervical collar.	III	Pressure ulcers may occur with the use of hard cervical collars.
Mazolewski, 1994 (64)	A study to test the effectiveness of strapping techniques in reducing lateral motion on a backboard in laboratory in 19 adults.	III	Strapping should be added to the torso to reduce lateral motion on a backboard.
Plaisier et al., 1994 (78)	A prospective evaluation of craniofacial pressure of four different cervical orthoses in 20 adults. Pressure was measured at the occiput, mandible, and chin. Opinions on comfort were also collected.	III	The Newport or Miami-J collars have favorable skin pressure patterns and superior patient comfort.
Raphael and Chotai, 1994 (82)	A randomized, single-blind, crossover study of 9 patients scheduled for elective spinal anesthesia. The cerebrospinal fluid pressure in the lumbar subarachnoid space was measured with and without a Stifneck cervical collar applied.	III	There was a significant elevation of cerebrospinal fluid pressure in 7 of the patients studied when the cervical collar was applied ($P < 0.01$).
Chandler et al., 1992 (20)	A comparison of the 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.
Rosen, 1992 (87)	A comparison of 4 cervical collars in 15 adult volunteers, by goniometry.	III	Vacuum splint cervical collar restricted range of motion of the cervical spine most effectively.

TABLE 1.1. *Continued*

Series (Ref. No.)	Description of Study	Evidence Class	Conclusions
Schafermeyer et al., 1991 (89)	A study to assess the restrictive effects of 2 spinal immobilization strapping techniques on the respiratory capacity and forced vital capacity of 51 children.	III	Spinal immobilization significantly reduced respiratory capacity as measured by FVC in healthy patients 6–15 yr old. There is no significant benefit of one strapping technique over the other.
Schriger et al., 1991 (91)	A study comparing the 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 et al., 1990 (22)	A study analyzing the RED in 64 patients.	III	RED is an effective spinal immobilization device with advantages over currently available devices.
Barney and Cordell, 1989 (8)	Evaluated pain and discomfort during immobilization on rigid spine boards in 90 patients.	III	Spine boards may cause discomfort.
Toscano, 1988 (96)	Prevention of neurological deterioration before admission to hospital. Retrospective review of 123 patients; 32 of 123 sustained major neurological deterioration from injury to admission.	III	Appropriate handling of patients with spinal injury after trauma can reduce major neurological deterioration due to pathological motion of vertebral column.
Graziano et al., 1987 (44)	A radiographic comparison of preadmission cervical immobilization methods with the short board technique in 45 volunteers.	III	The short-board technique proved to be significantly better ($P < 0.05$) than Kendrick extrication device and collars.
Linares et al., 1987 (60)	A study of 32 SCI patients to determine whether pressure sores are associated with prolonged immobilization.	III	There is a strong association between 1–2 h of immobilization and the development of pressure sores.
McGuire et al., 1987 (68)	A 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, 1986 (65)	A radiographic comparison of the 4 cervical collars in 7 adults.	III	Polyethylene-1 provided most restriction in flexion.
Cline et al., 1985 (21)	A radiographic comparison of 7 methods of cervical immobilization in 97 adults.	III	The short-board technique appeared to be superior to the 3 collars studied. The collars provided no augmentation of immobilization over that provided by the short board alone.
Podolsky et al., 1983 (79)	Static trial using goniometry comparing soft collar, hard collar, extrication collar, Philadelphia collar, bilateral sandbags and tape, and the combination of sandbags, tape, and the Philadelphia collar in 25 normal adult volunteers.	III	Hard foam and plastic collars were superior to soft collars. Sandbags and tape in combination 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 ($P < 0.01$), from 15 to 7.4 degrees, a change of 49.3%. The combination of sandbags and tape alone does not allow sufficient restriction of motion, particularly in extension.

[a] SCI, spinal cord injury; FVC, forced vital capacity; RED, Russell extrication device; OR, odds ratio; CI, confidence interval.

[b] Kendrick extrication device, Ferno-Washington, Inc., Wilmington, OH; Newport collar (now known as Aspen collar), Fiji Manufacturing, Inc., Long Beach, CA; Scoop stretcher, Ferno-Washington, Wilmington, OH; Miami-J, Jerome Medical, Moorestown, NJ; Stifneck rigid collar, Alliance Medical, Russelville, MO; Polyethylene-1, Alliance Medical, Russelville, MO; Ammerman halo orthosis, Ammerman Trauma Systems, Pacific Palisades, CA; Russell extrication device, Milla Mitchell & Co., New South Wales, Australia; Philadelphia collar, Philadelphia Collar Co., Westville, NJ.

66, 73, 104). Various devices and techniques are available to provide immobilization of the cervical spine. Attempts to define the best method have been hampered by physical and ethical constraints (17, 27, 53, 61, 64, 94, 99).

Ways of measuring the efficacy of spine immobilization devices vary among investigators. Comparative studies of the various devices have been performed on healthy volunteers, but none have been tested in a large number of patients with spinal injury. It is difficult to extrapolate normative data to injured patients with spinal instability (17, 20, 24, 27, 29, 49, 52, 53, 58, 65, 67, 77, 94, 98, 99).

Several methods have been used to measure movement of the cervical spine. They include clinical assessment, plumb lines, photography, radiography, cinematography, computed tomography, and magnetic resonance imaging. Roozmon et al. (85) 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 (25, 28, 75, 88, 92). Schriger defined the neutral position as the normal anatomic position of the head and torso that one assumes when standing and looking ahead (90). This position correlates to 12 degrees of cervical spine extension on a lateral radiograph. Schriger comments that the extant radiographic definition of neutral position was based on radiographic study of patients who were visually observed to be in the neutral position. Schriger et al. (91) used this position in their evaluation of occipital padding on spine immobilization backboards. De Lorenzo et al. (28), in their magnetic resonance imaging study of 19 adults, found that a slight degree of flexion equivalent to 2 cm of occiput elevation produces a favorable increase in spinal canal/spinal cord ratio at levels C5 and C6, a region of frequent unstable cervical spine injuries. Backboards have been used for years in extricating and immobilizing spine-injured patients. Schriger et al. (91) questioned the ability of a flat board to allow neutral positioning of the cervical spine. They compared spine immobilization by using 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 occipital padding combined with a rigid backboard places the cervical spine in a better neutral position than a flat backboard alone (91, 93). McSwain (70) determined that more than 80% of adults require 1.3 to 5.1 cm of padding to achieve neutral positioning of the head and neck relative to the torso and noted that physical characteristics and muscular development alter the cervical-thoracic angle, thus affecting positioning. This makes it impossible to dictate specific recommendations for padding.

In general, spine immobilization consists of a cervical collar, supports on either side of the head, and the long and short backboards with associated straps to attach and immobilize the entire body to the board (27). Garth (41) proposed performance standards for cervical extrication collars, but these standards have not been uniformly implemented. A variety of different cervical collars is available. Several studies compare collars alone or combined with other immobilization devices by a wide range of assessment criteria (17, 19, 20, 24, 94, 99).

Podolsky et al. (79), in 1983, evaluated the efficacy of cervical spine immobilization techniques by using goniometric measurements. 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 six 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 then measurements were repeated after immobilization in a soft collar, hard collar, extrication collar, Philadelphia collar (Philadelphia Collar Co., Westville, NJ), bilateral sandbags joined with 3-inch-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 better at limiting cervical spine motion than soft foam collars. Neither collars alone nor sandbags and tape in combination provided satisfactory restriction of cervical spine motion. For all six cervical spine movements, sandbags and tape immobilization were significantly better than any of the other methods of attempted cervical spine immobilization used alone. The authors found that sandbags and tape combined with a rigid cervical collar were the best means of those evaluated to limit cervical spine motion. Adding a Philadelphia collar to the sandbag and tape construct significantly reduced neck extension ($P < 0.01$), from 15 degrees to 7.4 degrees, 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 (54). 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 (54) and the findings by Podolsky et al. (79), use of sandbags and tape alone to attempt to immobilize the cervical spine is not recommended.

In 1985, Cline et al. (21) compared methods of cervical spine immobilization used in preadmission transport. The authors found that strapping the patient to a standard short board was more effective than cervical collar use alone. They noted no significant differences among the rigid collars they tested. McCabe and Nolan (65) used radiographic assessment to compare four different collars for their ability to restrict motion in flexion-extension and lateral bending. They found that the Polyethylene-1 collar (Alliance Medical, Russelville, MO) provided the most restriction of motion of the cervical spine, particularly for flexion. Rosen (87), in 1992, used goniometric measurements to compare limitation of cervical spine movement of four rigid cervical collars on 15 adults. Of the four devices they tested, the vacuum splint cervical collar provided the most effective restriction of motion of the cervical spine.

Graziano et al. (44) compared preadmission cervical spine immobilization methods by measuring cervical motion radiographically in the coronal and sagittal planes in 45 immobilized adults. In this study, the Kendrick extrication device (Ferno-Washington, Inc., Wilmington, OH) and the Extrication Plus-One device (Medical Specialties, Inc., Charlotte, NC) were nearly as effective in limiting cervical motion as the short immobilization board. Both devices were more effective than a rigid cervical collar alone.

Cohen et al. (22), in 1990, described the Russell extrication device (RED) (Milla Mitchell & Co., New South Wales, Australia) for immobilization of patients with potential spine injuries. The RED was comparable to the short immobilization board for preadmission spine immobilization. Chandler et al. (20) compared a rigid cervical extrication collar with the Ammerman halo orthosis (Ammerman Trauma Systems, Pacific Palisades, CA) in 20 men. The Ammerman halo orthosis combined with a rigid spine board provided significantly better cervical spine 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. (77) evaluated three cervical spine immobilization devices during simulated vehicle motion in six adults. Neck motion was assessed by three neurologists and neurosurgeons as to whether motion was "clinically significant." The authors found that substantial head motion occurred during simulated vehicle motion regardless of the method of immobilization. The authors observed that the efficacy of cervical spine immobilization was limited unless the motion of the head and the trunk was also effectively controlled. Mazolewski (64) 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 four different strapping techniques. The backboard was rolled to the side, and lateral motion of the torso was measured. The author found that additional strapping securing the torso to 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 (31, 87). Significant lateral motion of the lumbar spine has been reported (68, 95). Alternatives to the logroll maneuver include the HAINES method and the multihand or fireman lift method (4, 5, 47). In the HAINES method (acronym for High Arm IN Endangered Spine), the patient is placed supine, the upper arm away from the kneeling rescuer is abducted to 180 degrees, 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 (47). The multihand or fireman lift method involves several rescuers on either side of the patient; the rescuers slide their arms underneath the patient and lift the patient from one position to another onto an extrication board or device.

This review depicts the evolution of techniques available for providing preadmission spine immobilization of spine-injured patients during transport and underscores their diversity. These studies are limited by the fact that none of the studies evaluates the full range of available devices using similar criteria. Overall, it seems 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 (5). The long-standing practice of attempted spine immobilization using sandbags and tape alone is insufficient.

Safety of preadmission spine immobilization devices

Despite obvious benefits, cervical spine immobilization has a few potential drawbacks. Immobilization can be uncomfortable, it takes time to apply, application may delay transport, and it is associated with modest morbidity (4, 9, 18, 19, 26, 90, 100).

Chan et al. (19) studied the effects of spine immobilization on pain and discomfort in 21 healthy 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 et al. (18) compared spine immobilization on a backboard to immobilization with a vacuum mattress-splint device in 37 healthy adults. The authors found that the frequency and severity of occipital and lumbosacral pain was significantly higher during backboard immobilization than on the vacuum mattress-splint device. Johnson et al. (52) performed a prospective, comparative study of the vacuum splint device versus the rigid backboard. The vacuum splint device was significantly more comfortable than the rigid backboard and could be applied more quickly. 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 three times more expensive than a rigid backboard (18).

Hamilton and Pons (49) 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 and collar combination and the backboard and collar combination for flexion and rotation. The vacuum splint-collar combination provided significantly better immobilization in extension and lateral bending than the backboard-collar combination. The vacuum splint alone provided better cervical spine immobilization in all neck positions except extension than the rigid backboard alone. A statistically significant difference in subjective perception of immobilization was noted; the backboard alone was less effective than the three 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 the collar) for cervical spine immobilization.

Barney and Cordell (8) 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 (101). Minimizing the pain of immobilization may decrease voluntary movement and therefore decrease the likelihood of secondary injury (19).

Cervical collars have been associated with elevated intracranial pressure (ICP). Davies et al. (26) prospectively analyzed ICP in a series of injured patients managed with the Stifneck rigid collar (Alliance Medical). ICP rose significantly ($P < 0.001$; mean, 4.5 mm Hg) when the collar was firmly in place. The authors cautioned that because head-injured patients may also require cervical spine immobilization, it is essential that secondary insults producing raised ICP be minimized. Kolb et al. (55) 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 ($P = 0.001$), 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 four different cervical orthoses. The authors found small changes in craniofacial pressure (increases) but no significant differences among the four collar types.

Spine immobilization increases the risk of pressure sores. Linares et al. (60) found that 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 to the use of a spinal board and sandbags during transportation. Mawson et al. (63) 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 ($P = 0.01$). Rodgers and Rodgers (84) reported a marginal mandibular nerve palsy caused by compression by a hard collar. The palsy resolved uneventfully during the next 2 days. Blaylock (11) found that prolonged cervical spine immobilization may result in pressure ulcers. Improved skin care (keeping the skin dry), proper fitting (avoid excessive tissue pressure), and the appropriate choice of collars (those that do not trap moisture and do not exert significant tissue pressure) can reduce this risk (10, 11).

Cervical spine immobilization may also increase the risk of aspiration and may limit respiratory function. Bauer and Kowalski (9) examined the effect of the Zee Extrication Device (Zee Medical Products, Irvine, CA) and the long spinal board on pulmonary function. They tested pulmonary function in 15 healthy, nonsmoking men by using forced vital capacity, forced expiratory volume in 1 second, the ratio of forced expiratory volume in 1 second to the forced vital capacity, and forced midexpiratory flow (25–75%). They found a significant difference ($P < 0.05$) between before-strapping and after-strapping values for three of the four functions tested when on the long spinal board. Similarly, significant differences were found for three of the four parameters when using the Zee Extrication Device. These differences reflect a marked pulmonary restrictive effect of appropriately applied entire-body spine immobilization devices.

Totten and Sugarman (97) evaluated the effect of whole-body spine 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 two methods were assessed on a visual analog scale. Both immobilization methods restricted respiration by an average of 15%. The effects were similar under the two methods, although the forced expiratory volume in 1 second was lower on the vacuum mattress. The vacuum mattress was significantly more comfortable than the wooden backboard (4).

In conclusion, cervical spine immobilization devices are generally effective in limiting motion of the cervical spine but may be associated with important but usually modest morbidity. Cervical spine immobilization devices should be used to achieve the goals of safe extrication and transport but should be removed as soon as it is safe to do so.

SUMMARY

Spine immobilization can reduce untoward movement of the cervical spine and can reduce the likelihood of neurological deterioration in patients with unstable cervical spine injuries after trauma. Immobilization of the entire spinal column is necessary in these patients until a spinal column injury (or multiple injuries) or a spinal cord injury has been excluded, or until appropriate treatment has been initiated. Although not supported by Class I or Class 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.

It is unclear whether the spines of all patients with trauma must be immobilized during preadmission 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.

The variety of techniques used and the lack of definitive evidence to advocate a uniform device for spine immobilization make it difficult to formulate recommendations for immobilization techniques and devices. It seems that a combination of rigid cervical collar with supportive blocks on a rigid backboard with straps is effective at achieving safe, effective spine immobilization for transport. The long-standing practice of attempting to immobilize the cervical spine with sandbags and tape alone is not recommended.

Cervical spine immobilization devices are effective but can result in patient morbidity. Spine immobilization devices should be used to achieve the goals of spinal stability for safe extrication and transport. They should be removed as soon as definitive evaluation is accomplished and/or definitive management is initiated.

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 reliable in-field triage protocol to be applied by EMS personnel for patients with potential cervical spine injuries after trauma needs to be developed.

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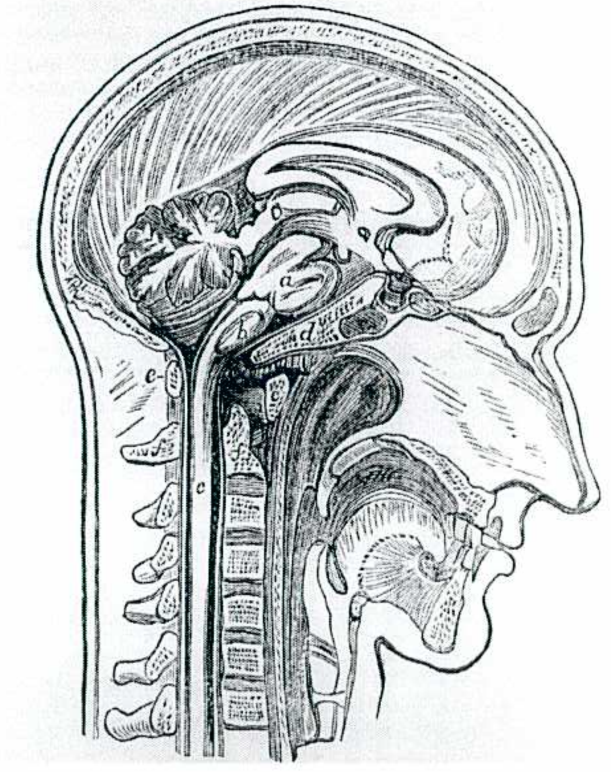

Sketch of a dissection showing the head falling forward, as happens in some cases of destruction of the ligaments, associated with disease of the joints between the atlas and axis and occipital bones. From, Hilton J: *On Rest and Pain: A Course of Lectures on the Influence of Mechanical and Physiological Rest in the Treatment of Accidents and Surgical Diseases, and the Diagnostic Value of Pain.* New York, Wood, 1879, 2nd ed.