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Pre-Hospital Care Management of a Potential Spinal Cord Injured Patient: A Systematic Review of the Literature and Evidence-Based Guidelines

Henry Ahn,[1] Jeffrey Singh,[2] Avery Nathens,[3] Russell D. MacDonald,[4] Andrew Travers,[5]
John Tallon,[6] Michael G. Fehlings,[1] and Albert Yee[1]

Abstract

An interdisciplinary expert panel of medical and surgical specialists involved in the management of patients with potential spinal cord injuries (SCI) was assembled. Four key questions were created that were of significant interest. These were: (1) what is the optimal type and duration of pre-hospital spinal immobilization in patients with acute SCI?; (2) during airway manipulation in the pre-hospital setting, what is the ideal method of spinal immobilization?; (3) what is the impact of pre-hospital transport time to definitive care on the outcomes of patients with acute spinal cord injury?; and (4) what is the role of pre-hospital care providers in cervical spine clearance and immobilization? A systematic review utilizing multiple databases was performed to determine the current evidence about the specific questions, and each article was independently reviewed and assessed by two reviewers based on inclusion and exclusion criteria. Guidelines were then created related to the questions by a national Canadian expert panel using the Delphi method for reviewing the evidence-based guidelines about each question. Recommendations about the key questions included: the pre-hospital immobilization of patients using a cervical collar, head immobilization, and a spinal board; utilization of padded boards or inflatable bean bag boards to reduce pressure; transfer of patients off of spine boards as soon as feasible, including transfer of patients off spinal boards while awaiting transfer from one hospital institution to another hospital center for definitive care; inclusion of manual in-line cervical spine traction for airway management in patients requiring intubation in the pre-hospital setting; transport of patients with acute traumatic SCI to the definitive hospital center for care within 24 h of injury; and training of emergency medical personnel in the pre-hospital setting to apply criteria to clear patients of cervical spinal injuries, and immobilize patients suspected of having cervical spinal injury.

Key words: pre-hospital care; spinal cord injury; systematic review

Introduction

Great care must be taken when providing medical care to an acutely injured patient prior to arrival at hospital. About 2% of all blunt trauma patients will have sustained a spinal cord injury, and these rates are higher in the setting of severe closed head injury (Crosby, 1992, 2006). Patients with acute spinal cord injury (SCI) are at risk of neurologic deterioration due to secondary injury to the spinal cord (Fehlings and Louw, 1996). A potential cause of secondary injury is through inadvertent manipulation of the spinal cord in the setting of an unstable spinal column injury (Crosby, 1992; Eismont et al., 2004; Fehlings and Louw, 1996; Fenstermaker, 1993). Minimizing the chances of secondary injury can be challenging in the pre-hospital setting due to the local and transport environment, a lack of resources, and heterogeneity in health care providers and their skill sets (Hauswald et al., 2000). Furthermore, treatments initiated prior to arrival in the hospital can lead to significant morbidity in other body regions, such as sacral and occipital ulcers (Cordell et al., 1995;

[1]Department of Surgery, [2]Department of Interdepartmental Medicine, Division of Critical Care, [3]Department of Surgery, Health Policy, Management and Evaluation, and [4]Department of Research and Development, Ornge Transport Medicine and Division of Emergency Medicine, Department of Medicine, University of Toronto, Toronto, Ontario, Canada.
[5]Department of Emergency Medicine, and [6]Department of Emergency Medicine, Surgery and Community Health and Epidemiology, Dalhousie University, Halifax, Nova Scotia, Canada.

Davies et al., 1996; De Lorenzo et al., 1996; Hamilton and Pons, 1996; Hauswald et al., 2000; Johnson et al., 1996; Krell et al., 2006; Luscombe and Williams, 2003; Main and Lovell, 1996; Sheerin and de Frein, 2007; Walton et al., 1995). There is tremendous variation in how care is administered prior to arrival at the hospital and during transport from one hospital to another (Armitage et al., 1990; Burney et al., 1989; Flabouris, 2001). Some care models and treatments may provide patients with improved safety and reduce morbidity, and thus improve efficiency of care delivery. These variations of practice served as the impetus to perform a systematic review, in conjunction with a series of other systematic reviews related to SCI care. The purpose of this study was to provide evidence-based guidelines agreed upon by a multi-disciplinary expert panel to identify optimal care in key areas in the pre-hospital setting for patients with potential SCI.

Four questions that were of clinical relevance and that could have significant impact on patient care were determined by a multidisciplinary expert panel. These four questions posed for the systematic review were:

1. What is the optimal type and duration of spinal immobilization in patients with acute SCI?
2. During airway manipulation in the pre-hospital setting, what is the ideal method of spinal immobilization?
3. What is the impact of pre-hospital transport time to definitive care on the outcomes of patients with acute SCI?
4. What is the role of pre-hospital care providers in cervical spine clearance and immobilization?

These four questions then served as the basis of our systematic review of pre-hospital care of potential spinal-cord-injured patients. The systematic review method was utilized to systematically collate and assess the literature, while minimizing bias in the assembly and interpretation of the evidence. Following an exhaustive search of the literature and collation of the identified studies into evidentiary tables, the evidence was graded and synthesized into guidelines that were refined through consensus using Delphi methodology (Hasson et al., 2000; Keeney et al., 2001; Kennedy, 2004).

Methods

Four questions of pertinent interest to a multi-disciplinary committee with expertise in the management of SCI were agreed upon to form the basis of the systematic review. Each of the four questions was amenable to a systematic review. Members of this committee included a traumatologist (Avery Nathens), three trauma triage specialists in emergency medicine (Russell MacDonald, Andrew Tavers, and John Tallon), three spine surgeons (Henry Ahn, Michael Fehlings, and Albert Yee), a critical care intensivist (Jeffrey Singh), and a fundamental scientist in SCI research (Darryl Baptiste).

A primary literature search was performed using the MEDLINE, CINAHL, Embase, and Cochrane databases. A secondary search strategy incorporated articles referred to in meta-analyses, systematic and non-systematic review articles that were found in the primary search. Additional articles that were listed in the references of retrieved original articles could be also included in the secondary search strategy. The literature searches addressed publications produced from 1966 to April 2008. Two reviewers independently selected the articles based on the inclusion and exclusion criteria, determined their level of evidence, and assessed their methodological quality according to the Downs and Black criteria (Downs and Black, 1998). Disagreement between the reviewers was reconciled by a third reviewer. All articles were directly related to pre-hospital care, and limited to human studies by excluding the "animal" Medical Subject Heading (MeSH). The MeSH search terms used were: "pre-hospital care," "spinal trauma," and "spinal cord injury."

Based on this methodology 66 articles were screened, and 47 were eligible based upon criteria utilized for pre-hospital care. These were scored according to the Downs and Black criteria (Downs and Black, 1998). The main results of each article and the reviewers' assessments were summarized in an evidentiary table (Table 1).

Evidence-based responses were then composed for the four questions. A panel of 5 to 10 multi-disciplinary experts (from the Solutions Network [Acute Practice Network]) using the Delphi method scrutinized the evidence-based statements for the specific questions. A level of consensus of 80% or higher was considered to be a strong agreement. Based on the level of agreement and the comments from the expert panel, recommendations were formulated for each question related to pre-hospital care.

Findings from the systematic review

Question 1. What is the optimal type and duration of spinal immobilization in patients with acute SCI?

In all, 25 studies were reviewed for this particular question (Chan et al., 1996; Chandler et al., 1992; Cordell et al., 1995; Cornwell et al., 2001; Davies et al., 1996, De Lorenzo et al., 1996; Gerling et al., 2000; Graziano et al., 1987; Hamilton and Pons, 1996; Hauswald et al., 2000, 1998; Huerta et al., 1987; Johnson et al., 1996; Krell et al., 2006; Luscombe and Williams, 2003; Main and Lovell, 1996; Mazolewski and Manix, 1994; Nypaver and Treloar, 1994; Peery et al., 2007; Perry et al., 1999; Schafermeyer et al., 1991; Schriger et al., 1991; Sheerin and de Frein, 2007; Walton et al., 1995; Waninger et al., 2001). Most evidence in the literature was based on biomechanical studies with volunteers. The studies showed that immobilization with a board and collar and head immobilization between towels or foam wedges provided the most stable biomechanical immobilization (Huerta et al., 1987; Perry et al., 1999). The addition of the board to the cervical collar provided statistically significantly more immobilization than a collar by itself (Chandler et al., 1992; Graziano et al., 1987). There were not enough studies to recommend exact types of collars. Certain forms of strapping, if applied appropriately in terms of location and tightness may further reduce lateral thoraco-lumbar spinal movement, but the clinical relevance of this reduction is not known (Mazolewski and Manix, 1994; Peery et al., 2007).

The use of rigid boards can lead to discomfort at the occiput and sacrum and increased pressures that can lead to tissue necrosis (Chan et al., 1996; Hauswald et al., 2000; Main and Lovell, 1996; Sheerin and de Frein, 2007; Walton et al., 1995). Cushioning the board can lead to increased comfort and decrease the amount of pressure at the occiput and sacrum without compromising biomechanical immobilization (Chan et al., 1996; Hauswald et al., 2000; Main and Lovell, 1996; Sheerin and de Frein, 2007; Walton et al., 1995). Several studies examined the effects of duration of immobilization on

Table 1. Evidence Table (Pre-Hospital Care in Spinal Cord Injury)

Reference	Journal	Title	Design	Purpose/hypothesis	Sackett rating[a]	D & B score (out of 44)	Results
Armitage et al., 1990	BMJ	Respiratory problems of air travel in patients with SCI	*(Case reports)* **Population:** Age = 50.8 y (24–69 y); level of injury: C = 3, T = 2. **Treatment:** spontaneous respiration through tracheostomy, or intermittent positive pressure ventilation through tracheostomy	To report recommendations for patients at risk during airplane transport	4	8	See text
Armstrong et al., 2007	Emerg. Med. J.	Pre-hospital clearance of the cervical spine: does it need to be a pain in the neck?	*(Observational case series)* **Treatment:** Ambulance personnel were given 3 h of education and training in pre-hospital C-spine clearance and patient information using the algorithm designed by a faculty of emergency care practitioners. After training they were allowed to use the algorithm with the patients and return an audit form. **Outcome measures:** patient data.	To introduce a clinical decision algorithm allowing ambulance personnel to determine who requires cervical immobilization	4	12	See text
Benner, et al., 2006	Air Med. J.	Disagreement between transport team and ED staff regarding the pre-hospital assessment of air medically evacuated scene patients	*(Case series)* **Treatment:** Patient records were reviewed for transport teams' assessment and the final ED diagnosis. Any disagreement between the transport team's assessment and that of the ED was categorized as a difference. If the transport team indicated an actual or potential injury or illness that wasn't found by the ED, this difference was marked overassessment, whereas any injury or illness found by the ED not noted by the transport team was marked underassessment. **Outcome measures:** chart data	To determine the disagreement in assessment of significant illness or injury between air medical transport team and ED diagnosis in patients transferred from the scene	4	15	The transport team assessed 84 potential spinal cord injuries, and 81 injuries were noted as not present and 3 were noted as present. The ED's final diagnosis confirmed the crew's assessment in 81 occurrences (96.4%), and disagreed with assessment in three occurrences (3.6%). Of the three differences, all were underassessment by the transport team.
Brown et al., 1998	Emerg. Med. J.	Can EMS providers adequately assess trauma patients for cervical spinal injury?	*(Case series)* **Treatment:** EMS personnel were instructed to complete a form based on their initial scene review. EPs were instructed to complete the form based on their ED assessment. Participants didn't discuss. No training was given but participants were instructed that vague findings should be recorded as positive findings. After the EMS assessment was performed all the patients were immobilized and transported to the ED.	To determine whether EMS providers can accurately apply the clinical criteria for clearing cervical spines in trauma patients	4	15	See text

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Table 1. Evidence Table (Continued)

Reference	*Journal*	*Title*	*Design*	*Purpose/hypothesis*	*Sackett rating*[a]	*D & B score (out of 44)*	*Results*
Burney et al., 1989	J. Trauma	Stabilization of spinal injury for early transfer	*(Case series)* **Population:** Age = 34 y (13–83 y); M/F = 47/14; level of injury: C = 70.5%; T = 18%; L = 11.5%. **Treatment:** The ambulance, referral hospital, transfer, acute hospital, and rehabilitation hospital records of patients were reviewed and data were obtained. **Outcome measures:** Data from patient records: mode of transfer, distance, and method of spinal stabilization during transfer. Also complications during transfer and type of definitive treatment.	The hypothesis was that patients with spinal fractures and partial or complete neurological deficits could undergo safe early transport to a spinal cord center using basic equipment for spine stabilization	4	18	See text
Burton et al., 2005	Prehosp. Emerg. Care	EMS provider findings and interventions with a state-wide EMS spine-assessment protocol	**Population:** Age = 43.1 y (0–102 y); %M = 46 **Treatment:** A revised spine-assessment protocol was implemented July 1, 2002, outlining a four-step sequence based on patient assessments. Teaching began ~12 months prior to implementation for both ALS and BLS EMS providers. Teaching slides, student learning materials, and a FAQs were placed online and integrated into EMS education activities. The curriculum consists of presentations and patient-based scenario training. **Outcome measures:** EMS provider findings, number of spine immobilizations, and incidence and treatment of spine fracture patients.	To describe the utilization and findings with a state-wide, pre-hospital spine-assessment protocol for EMS providers in a rural state	4	21	Providers reported a decision to immobilize 59% of patients. The incidence of acute spine fractures for the study population was 0.3%. This spine assessment protocol for immobilization of trauma patients with acute spine fracture during the investigational period, rendered a sensitivity of 100.0 (95% CI = 77.2, 100), a negative predictive value of 100 (95% CI = 99.7, 100), a specificity of 41.5 (95% CI = 38.5, 43.5), and a positive-predictive value of 0.5 (95% CI = 0.1, 0.9).
Burton et al., 2006	J. Trauma	A state-wide, pre-hospital EMS selective patient spine immobilization protocol	**Population:** 31,885 patients with mean age of 48.1 ± 26.7 y (0–109 y), 45.2% male. **Treatment:** Pre-hospital providers documented EMS patient encounters. For spine management, data included indicators for spine immobilization. Database was queried for patient encounters with ICD-9 coding specific for the presence of spinal injury. **Outcome measures:** The incidence of spine fractures among EMS-assessed patients and correlation between immobilization and spine fracture.	To evaluate the practices and outcomes associated with a state-wide EMS protocol for trauma patient spine assessment and selective patient immobilization	3	30	12,988 (41%) transported with EMS spine immobilization. Data linkage identified 154 spine fractures with 20 (13%) transported without immobilization; 19 of these were stable spine fractures. The protocol sensitivity for immobilization of any acute spine fracture was 87%. Presence of the protocol affected the decision not to immobilize in more than half of the assessed patients.
Chan, et al., 1996	J. Emerg. Med.	Backboard vs. mattress splint immobilization: a comparison of symptoms generated	*(Prospective RCT)* **Population:** $n = 37$ healthy volunteers. **Treatment:** neck collar + back board versus neck collar versus vacuum splint. **Outcome measures:** self-reported pain levels.	To compare pain levels between neck collar + backboard versus neck collar + vacuum splint	1B	21	Significantly more pain in the back board group ($p < 0.001$), in particular in the occipital region and the lumbosacral region.

Chandler et al., 1992	Ann. Emerg. Med.	Emergency cervical-spine immobilization	*(Experimental)* **Population:** Age = 29.6; %M = 100. **Treatment:** Unrestrained cervical motion was compared with motion in a cervical extrication collar and an Ammerman halo orthosis with and without a spine board. In 10 subjects the range of motion was measured in the Ammerman halo orthosis and cervical extrication collar alone. In the other 10 subjects the range of motion was determined with the cervical extrication collar in place and the head taped to a supine spine board, and also with the Ammerman halo orthosis attached to a supine spine board. **Outcome measures:** Photographic measurement of head and neck motion during maximal flexion extension/lateral bending/rotation. Radiological measurement of maximal intervertebral flexion-extension.	To determine the effectiveness of a cervical spine immobilization using a rigid cervical extrication collar and an Ammerman halo orthosis with and without spine boards	Bench-side experimental study	17	Both the cervical extrication collar and the Ammerman halo orthosis significantly reduced motion in all planes ($p < 0.001$), with the Ammerman halo orthosis reducing these motions significantly more ($p < 0.001$). The use of a spine board restricted motions even more ($p < 0.001$). The Ammerman halo orthosis with a spine board provided the greatest immobilization, equivalent to that provided by a halo-vest. A rigid cervical collar and a spine board provided significantly better immobilization than the collar alone. Further immobilization was provided by an Ammerman halo orthosis.
Cordell et al., 1995	Ann. Emerg. Med.	Pain and tissue interface pressures during spine board immobilization	*(Experimental RCT)* **Population:** M/F = 8/12; Age = 29.9 y (16–50 y); Height = 66.2 in; Weight = 165.7 lb; Average pound-to-inch ratio = 2.5 **Treatment:** Pre-hospital transport conditions were simulated by immobilizing healthy volunteers with hard cervical collars and single-buckle chest straps on wooden spine boards with or without commercially available medical air mattresses. The crossover order was randomized. After 80 min, the subjects were allowed to get off the boards for a recovery period of 60 min. Subjects were then studied for a second 80-min period with the opposite intervention. To standardize, volunteers were instructed to wear comfortable, loose-fitting clothing. Belts, shoes, and all objects in pockets were removed. At baseline and at 20-min intervals, the level of pain was rated with a 100-mm visual analog scale. Tissue interface pressures were measured at the occiput, sacrum, and left heel. **Outcome measures:** Differences in pain and pressure levels between the two treatments.	To investigate the level of pain and tissue-interface pressures in volunteers immobilized on spine boards with and without interposed air mattresses	1B	28	The two treatment types did not differ significantly in age ($p = 0.30$), height ($p = 0.88$), weight ($p = 0.68$), or pounds-to-inch ratio ($p = 0.5$). Pain levels changed significantly over time ($p = 0.0001$) and the two treatments differed in amount of pain ($p = 0.0001$) and pattern of pain change over time ($p = 0.0009$). No significant difference in pain between the two treatments at time-point 0; subjects reported significantly more pain during the no-mattress period at 20 ($p = 0.003$), 40 ($p = 0.0001$), 60 ($p = 0.0001$), and 80 min ($p = 0.0001$). Interface pressure levels were significantly less for mattress than no-mattress at the occiput ($p = 0.0001$), sacrum ($p = 0.0001$), and heel ($p = 0.0001$). Pressure was significantly less during the mattress period at all time points ($p = 0.0001$). Pain levels for the mattress and no-mattress groups were not significantly different on the basis of order of treatment group assignment ($p = 0.41$ and $p = 0.93$). Total pressure was related to height ($p = 0.008$), and not significantly related to weight ($p = 0.11$). Total pressure was not significantly related to pain ($p = 0.76$).

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Table 1. Evidence Table (Continued)

Reference	*Journal*	*Title*	*Design*	*Purpose/hypothesis*	*Sackett rating*[a]	*D & B score (out of 44)*	*Results*
Cornwell et al., 2001	Arch. Surg.	Thoracolumbar immobilization for trauma patients with torso gunshot wounds	*(Observational case reports)* **Population:** Median age = < 25 y; Male = 90.8%. **Treatment:** Patients who could have theoretically benefited from spinal immobilization were those who did not have complete neurological deficits, and who required a vertebral column stabilization procedure while in the hospital. Patients (1) with no vertebral column injury, (2) with less-than-complete neurological deficits but with stable vertebral columns and who did not require vertebral column stabilization while in the hospital, or (3) with complete neurological deficits who were considered to not have benefited from thoracolumbar immobilization. **Outcome measures:** A patient was considered to have benefited from immobilization if he or she had less-than-complete neurological deficits in the presence of an unstable vertebral column, as shown by the need for operative stabilization of the vertebral column; mortality.	To look at the potential benefits and negative effects of time required for EMS protocol in patients with torso gunshot wounds	4	19	In 1000 patients with torso gunshot wounds, 141 patients had vertebral column or spinal cord injury. Two patients required operative vertebral column stabilization, while six others required other spinal operations (decompression/foreign body removal). The two patients are the only ones who would have benefited from thoracolumbar immobilization in the field. Placement on a long board without formal four-point fixation for patients in this category would allow a shorter injury-to-treatment time, while preserving the benefit to these two patients. Formal immobilization would not have benefited the 73 survivors who had complete lesions of their spinal cords nor the 859 patients who had no vertebral column injury. The presence of vertebral column injury was actually associated with lower mortality (7.1%, $p < 0.02$) than patients with no vertebral column injury (14.8%, $p < 0.02$).
Davies et al., 1996	Injury	The effect of a rigid collar on intracranial pressure (ICP)	*(Observational case series)* **Treatment:** The assessment of collar fitment was done by a single operator familiar with spinal immobilization and with the manufacturer's recommended guidelines. Measurements of intracranial pressure, mean arterial pressure (MAP), heart rate (HR), and central venous pressure (CVP) were made 20 min before the collar was applied, 20 min after, and 20 min after it was removed. **Outcome measures:** patient report data.	To measure changes in ICP in patients who required spinal immobilization by protocol, and who could have disturbed cerebral autoregulation	4	19	A mean ICP rise of 4.5 mm Hg (SD 4.1 mm Hg) was found. A paired analysis of ICP readings with and without the collar showed a significant rise when the collar was used ($p = < 0.001$). Paired analysis of HR, CVP, and MAP with and without the collar showed no significant difference. There was no correlation between changes in ICP and MAP ($r = 0.17$), starting ICP ($r = 0.03$), change in CVP ($r = 0.06$), or change in HR ($r = 0.02$).

De Lorenzo et al., 1996	Ann. Emerg. Med.	Optimal positioning for cervical immobilization	*(Experimental non-RCT)* **Population:** M/F = 8/11; Age = 33.6 y (20–54 y). **Treatment:** Subjects were asked to lie on a rigid plastic board. The neck was flexed and extended by raising and lowering the head relative to the coccyx-scapular plane in 2-cm increments. The magnetic field isocenter was aligned with the subject's cricoid membrane. Once the subject was in position, imaging was obtained with a Phillips 1.5 T scanner. Transverse images through the center of the vertebral bodies from C2 to T2 were obtained. The imaging process was repeated with the occiput sequentially elevated and lowered by 2 and 4 cm to the plane of the plastic board. **Outcome measures:** The ratio of spinal canal and spinal cord areas at each spinal level C2 to T1 was calculated for each position of flexion and extension. The cross-sectional area was determined.	To determine the optimal position for cervical spine immobilization using magnetic resonance imaging (MRI), and to define this optimal position in a clinically reproducible fashion	4	19	The mean ratio of spinal canal and spinal cord cross-sectional areas was smallest at C6, but exceeded 2.0 at all levels from C2 to T1 ($p < 0.05$). At C4–C7 the zero position ratio of spinal canal area to spinal cord area was minimum for 78% of subjects. Small canal-to-cord ratios represent the lowest margin of safety for injury to the spinal cord potentially swollen by injury or ischemia, or impinged on by displaced vertebral structures. At the C5 and C6 levels the maximal area ratio was most consistently obtained with slight flexion (cervical-thoracic angle of 14°; $p < 0.05$). For a patient lying flat on a backboard, this corresponds to raising the occiput 2 cm. At + 4 elevation significant variability was obtained among the subjects such that at this extreme degree of flexion, some individuals had maximal spinal canal/spinal cord area ratios at a given level, whereas others had minimal spinal canal/spinal cord area ratios. In healthy adults, 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 spine injuries.
Domeier et al., 1997	Acad. Emerg. Med.	Prospective validation of out of hospital spinal clearance criteria: a preliminary report	*(Observational study)* **Population:** M/F = 1035/1061; Level of injury: C = 19; T = 22; L = 25. **Treatment:** Out of hospital transport ambulance personnel completed a questionnaire for patients. All participating personnel were trained on the study and questionnaires. They were told to verify the presence or absence of each data point based on the initial patient evaluation. The personnel were instructed to detail any potential DPI. Outcome data points were determined by medical record review. **Outcome measures:** Presence or absence of a spinal fracture or SCI, location of fracture and treatment.	To prospectively assess whether the absence of all of the above retrospectively identified criteria can be used to identify out of hospital trauma patients without significant spinal fracture	4	17	See text

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Table 1. Evidence Table (Continued)

Reference	*Journal*	*Title*	*Design*	*Purpose/hypothesis*	*Sackett rating*[a]	*D & B score (out of 44)*	*Results*
Domeier et al., 1999	Prehosp. Emerg. Care	The reliability of pre-hospital clinical evaluation for potential spinal injury is not affected by the mechanism of injury	*(Case series)* **Treatment:** Pre-hospital transporting ambulance providers completed a data questionnaire for all the patients who met the study population inclusion criteria. All participating pre-hospital personnel were provided brief didactic training designed for orientation to the study and data collection sheet. Participants were instructed to determine the presence or absence of each data point based on the initial patient evaluation. The data questionnaires were left in the ED of the receiving facility, or given to the ambulance supervisor for distribution and outcome determination. **Outcome measures:** Presence or absence of spinal fracture or SCI, location of fracture and treatment.	To examine the effect of the severity of the mechanism of injury on the ability of clinical criteria to select patients with spinal injury	4	27	See text
Domeier, et al., 2002	J. Trauma	Multicenter prospective validation of pre-hospital clinical spinal clearance criteria	*(Case series)* **Population:** %M/F = 49.5/50.5; Age = 39.3 y; Level of injury: C = 109; T = 86; L = 100. **Treatment:** Pre-hospital transporting ambulance providers were instructed to complete a standardized data questionnaire for all patients who met inclusion criteria. All participating pre-hospital personnel were provided a brief didactic training session designed for orientation to the study and data collection sheet before enrolling patients. **Outcome measures:** Patient report data.	To prospectively validate that the absence of specific criteria can be used to identify pre-hospital trauma patients without a spinal injury, and who do not require pre-hospital rigid immobilization	4	15	See text
Domeier et al., 2005	Ann. Emerg. Med.	Prospective performance assessment of an out of hospital protocol for selective spine immobilization using clinical spine clearance criteria	*(Case series)* **Population:** Age = < 1–104 y; Level of injury: 27% C, 10% T, 2.5% L. **Treatment:** EMS personnel were trained to perform and document a spine injury assessment for out-of-hospital trauma patients with a mechanism of injury judged sufficient to cause a spine injury. **Outcome measures:** Based on hospital records and spine injury assessment table completed by EMS personnel. Outcome characteristics included the presence or absence of spine injury and spine injury management.	To determine whether the use of an EMS protocol for selective spine immobilization would result in appropriate immobilization without SCI associated with no immobilization	4	15	See text

Doran et al., 1995	Prehosp. Disaster Med.	Factors influencing successful intubation in the pre-hospital setting	*(Prospective review)* **Population:** 4691 patients transported; 236 with intubation attempts; 78% male, mean age 51.4 ± 22.10 y. **Treatment:** Data abstracted from run reports and paramedics asked in structured interviews to describe difficulties in OETI/ETI. **Outcome measures:** Success or failure of pre-hospital intubation	To explore the determinants influencing oral/nasal endotracheal intubation; to determine which cognitive, therapeutic, and technical interventions may assist pre-hospital airway management	2B	25	88% successful intubation; position and spinal immobilization were reported to increase difficulty in 39.6% of trauma patients.
Flabouris, 2001	Injury	Clinical features, patterns of referral and out of hospital transport events for patients with suspected isolated spinal injury	*(Case series)* **Population:** Age = 31 y; %M = 68; Level of injury: C = 41%; L = 10%; T = 8%; mixed = 2%; normal = 39%. **Treatment:** Medical transport records of patients transported were reviewed. Relevant data were collated onto a study-specific database. **Outcome measures:** Patient demographics, type and mode of transport, and transport incidents. Scene, pre-referral, and outcome clinical data.	To describe the pattern of utilization of a patient transportation service by patients with suspected isolated spinal injuries who are transported from hospital/scene, document the impact of the service on scene management and the clinical cost of modes of transportation	4	19	See text
Gerling et al., 2000	Ann. Emerg. Med.	Effects of cervical spine immobilization technique and laryngoscope blade selection on an unstable cervical spine in a cadaver model of intubation	*(Experimental)* **Treatment:** A C5–C6 surgical transection was created to standardize the model of injury. An anterior approach was selected, with a vertical incision made along the medial aspect of the clavicular head of the sternocleidomastoid muscle. Complete instability of the injury was confirmed through fluoroscopy as defined by angular displacement $> 11°$ and AP displacement $> 20\%$ of C5 vertebral body width during manipulation. An OTI was performed with each of the three laryngoscope blades. Each of the two different immobilization techniques (manual in-line stabilization and cervical collar immobilization) were also used. A cross-over design was used in which three blades and both immobilization techniques were used in random order for each cadaver. Intubators were not blinded to either the blade type or immobilization technique. **Outcome measures:** Amount of movement across the unstable cervical spine lesion in three planes, axial distraction, and angular rotation	To evaluate the effects of manual in-line stabilization and cervical collar immobilization and three different laryngoscope blades on cervical spine movement during OTI in a cadaver model of cervical spine injury	Biomechanical study, not applicable	16	Significantly less movement during OTI was observed with the use of manual in-line stabilization than cervical collar immobilization with regard to AP displacement into the spinal canal (7.5% versus 13.7% of C5 body width; $p = 0.03$). There were no significant differences in axial distraction/angular rotation; Significantly less movement during OTI with the use of the Miller straight blade versus the McIntosh or CLM blades in axial distraction ($p = 0.009$). There were no differences among the blades in AP displacement or angular rotation. The Cormack-Lehane grade obtained during laryngoscopy was significantly better with manual in-line stabilization versus cervical collar immobilization ($p < 0.05$), but no difference in grade between the Miller, Macintosh, and CLM laryngoscope blades.

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Table 1. Evidence Table (Continued)

Reference	Journal	Title	Design	Purpose/hypothesis	Sackett rating[a]	D & B score (out of 44)	Results
Graziano et al., 1987	Ann. Emerg. Med.	A radiographic comparison of prehospital cervical immobilization methods	*(Experimental RCT)* **Population:** Age = 25 y (18–61 y) **Treatment:** All volunteers were tested in the sitting position to approximate the condition frequently encountered in the prehospital setting. All immobilization techniques were administered according to the manufacturer's recommended procedure. Each volunteer underwent nine radiographic views. Three views were obtained in each of the following conditions studied: unrestricted for baseline comparison, the short-board technique, and one of the three test devices to which the subject was randomly assigned. The efficacies of these techniques were compared. **Outcome measures:** Efficacy of the different test devices	To evaluate the efficacy of three newer commonly used cervical immobilization devices (CSC, a one-piece wrap-around collar; KED, a factory-fabricated short board; and XP-One, a factory-fabricated short board-collar combination) for which there are no objective data published in the medical literature	4	20	The short board technique (SBT) was superior to the CSC in rotation and the KED in extension; the KED was superior to the SBT in flexion. For total range of motion in the sagittal plane the SBT proved significantly better ($p < 0.05$) than the CSC, while the KED and XP-One approached SBT efficacy. The SBT was significantly different than the controls ($p < 0.001$) in all planes. Thus where differences were significant ($p < 0.05$) the SBT was superior when compared to all test devices. The SBT was superior in all planes of cervical spine motion. Of the three devices compared against the SBT, the short-board devices (KED and XP-One) provided the greatest immobilization with logistical advantages over the SBT.
Hamilton and Pons, 1996	J. Emerg. Med.	The efficacy and comfort of full body vacuum splints for cervical-spine immobilization	**Population:** Age = 28.9 y; M/F = 22/4; Height = 174.5 cm; Weight = 75.6 kg. **Treatment:** Each measurement was repeated three times and the average was used. Subjects were asked to perform the desired motion by moving as far as possible without causing pain/discomfort. C-spine ROM was recorded, a Stifneck cervical collar was applied, and ROM was repeated. Subjects were then randomized to be immobilized on a standard long spine board or on the VacBoard, both with and without a cervical collar. Each subject was then crossed over to the other device. During each immobilization, a full set of cervical spine ROM measurements was made, and after 10 min of immobilization, each subject was asked to grade overall immobilization on a 10-point visual analog scale, with 0 as "no restriction" and 10 as "completely immobilized." Subjects were also asked to grade discomfort both overall and in seven specific body regions on a 10-point visual analog scale, with 0 as "no discomfort" and 10 as "severe pain." **Outcome measures:** Significance of each immobilization system on motion, overall immobilization, and discomfort	To determine whether or not vacuum splints provide cervical spine immobilization comparable to that obtained with the rigid backboard, and to compare the subjective comfort between the two systems	2B	16	In flexion, there was no significant difference between the VS + CC (vacuum splint and cervical collar) and the BB + CC (back board and cervical collar), and both these systems provided better immobilization than either without the CC. Without the CC, the VS provided significantly better immobilization for flexion than the BB. For extension, the BB alone and the VS with or without a CC provided comparable immobilization, and all three combos were better than the BB + CC. In lateral bending, the vacuum splint in general provided better immobilization than the backboard, with or without a CC. In rotation, there were no significant differences in immobilization. Significant differences in subject perception of overall immobilization were found, with the VS + CC providing the best immobilization, followed by the BB + CC and VS alone, followed by the BB alone. The vacuum splint was also found to be significantly more comfortable than the backboard, both in subjective perception of overall and occipital region comfort, with or without a CC.

Hauswald et al., 1998	Acad. Emerg. Med.	Out of hospital spinal immobilization: its effect on neurologic injury	*(Observational case series)* **Population:** Age: = 34 y (USA), (Malaysia) = 35 y; %M (USA) = 77, (Malaysia) = 88; Level of injury: (USA) C = 34%, T = 32%, L = 34%; Malaysia: C = 33%, T = 28%, L = 39%. **Treatment:** A retrospective chart review was conducted on all patients admitted to the inpatient service or ED for the two hospitals. None of the patients seen at the University of Malaya had spinal immobilization during transport, whereas all the patients seen at the University of New Mexico did. Neurological injuries were assigned to two categories (disabling or not disabling), by two physicians acting independently and blinded to the hospital of origin. Data were analyzed using multivariate logistic regression. **Outcome measures:** Chart data	To examine the effect of emergency immobilization on neurological outcome of patients who have blunt traumatic spinal injuries	4	23	OR for disability was higher for patients in the USA after adjustment for the effect of independent variables ($p = 0.04$). The level of neurological deficit was the only independent predictor of bad outcome. There was less neurological disability in the unimmobilized Malaysian patients (OR 2.03; 95% CI 1.03, 3.99; $p = 0.04$). This corresponds to a < 2% chance that immobilization is beneficial. Results were similar when limited to patients with cervical injuries (OR 1.52; 95% CI 0.64, 3.62; $p = 0.34$). Out-of-hospital immobilization has little or no effect on neurological outcome in patients with blunt spinal injuries.
Hauswald et al., 2000	Prehosp. Emerg. Care	Maximizing comfort and minimizing ischemia: A comparison of four methods of spinal immobilization	*(Experimental RCT)* **Treatment:** Students were asked to lay supine on four different surfaces without being secured with straps. Devices (traditional backboard; backboard padded with a folded blanket; backboard padded with a 3-cm gurney mattress; and a backboard and mattress padded with a 6-cm egg crate foam pad) were assigned in random order. After lying for 10 min, students rated comfort. All four methods were evaluated using the same scale to allow comparison of responses. Each participant evaluated all four devices and was given a 15-min rest interval between trials. Each marked 10-cm visual analog scale was measured on two separate occasions to the closest 0.1 cm by the same observer and the mean of these two estimates was recorded. **Outcome measures:** Device comfort scores	To determine which of four methods of spinal immobilization causes the least ischemic pain	2B	29	Comfort scores were significantly different for all methods ($F = 101$, $p < 0.001$). A backboard padded with a gurney mattress and egg crate foam caused the least ischemic pain (9.6 cm, 95% CI 8.9, 9.8 cm). A backboard padded with a gurney mattress was the second most comfortable device (7.0 cm, 95% CI 6.4, 7.4 cm). A backboard padded with a folded blanket was the third most comfortable (3.3 cm, 95% CI 2.6, 4.9 cm). The backboard alone caused the most pain (0.8 cm, 95% CI, 0.7 to 2.1 cm). Increasing the amount of padding on a backboard decreased the amount of ischemic pain caused by immobilization.
Huerta et al., 1987	Ann. Emerg. Med.	Cervical spine stabilization in paediatric patients: evaluation of current techniques	*(Experimental Non-RCT)* **Population:** Age = 5–9 y. **Treatment:** Each child was instructed to exert maximum pressure with his or her head against a stationary hand-held blood pressure cuff inflated to a baseline pressure of 20 mm Hg. Average pressures were determined for each direction and these pressures were subsequently reproduced the mannequins. With the mannequin in the supine position, each cervical collar was placed with manual axial traction and immobilization was maintained. **Outcome measures:** Pressures were recorded in four directions: flexion, extension, torsion, and laterally. Overall effectiveness of the collar was assessed	This study was conducted to evaluate the efficacy of commercially available cervical spine stabilization devices designed for paediatric patients	4	17	Collars of rigid plastic construction performed better than foam. When used alone none of the collars provided acceptable immobilization; the best allowed 17° of flexion, 19° of extension, 4° of rotation, and 6° of lateral motion, but combined with other devices, immobilization to 3° or less in any direction was achieved. Overall, combination methods were better than cervical collars alone ($p < 0.001$) or supplemental devices alone ($p < 0.05$). The modified half spine board used with a rigid collar and tape was the most effective combination method.

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Table 1. Evidence Table (Continued)

Reference	*Journal*	*Title*	*Design*	*Purpose/hypothesis*	*Sackett rating*[a]	*D & B score (out of 44)*	*Results*
Johnson et al., 1996	Am. J. Emerg. Med.	Comparison of a vacuum splint device to a rigid backboard for spinal immobilization	*(Experimental)* **Treatment:** To evaluate the comfort/speed of application of each device, students were given training in the use of each device and allowed 4–6 h of practice. An instructor timed each procedure and students were randomly assigned for placement on the vacuum splint or the wood backboard first. After lying on each device for 30 min the students rated comfort. Each participant had the opportunity to evaluate both devices. The second phase compared immobilization of subjects in each of the devices. When immobilization was measured, each device was evaluated both with and without the application of a rigid cervical collar. **Outcome measures:** Comfort, lateral tilt, movement	To compare a vacuum splint mattress to a standard wooden backboard with respect to patient comfort; also to compare the two devices with regard to the adequacy of immobilization and speed of application using human volunteers	4	17	The vacuum splint was significantly more comfortable on a 10-point scale than the rigid backboard after subjects had been lying on each device for 30 min ($p < 0.001$). The vacuum splint was also faster to apply ($p < 0.001$). Vacuum splints provided better immobilization of the torso and less slippage on a gradual lateral tilt. The rigid backboard with head blocks was slightly better at immobilizing the head; Vacuum splints offer a significant improvement in comfort over the traditional backboard for the patient with possible spinal injury.
Krell et al., 2006	Prehosp. Emerg. Care	Comparison of the Ferno Scoop stretcher with the long backboard for spinal immobilization	*(Experimental)* **Population:** Age = 26 y (18–47 y); Height = 175 cm (155–196 cm); Weight = 79 kg (48–121 kg). **Treatment:** The movement of the spine during immobilization and lifting between the Ferno Scoop Stretcher Model 65 EXL (FSS) and the long backboard (LBB) were evaluated. Each device was also evaluated for comfort and sense of security. **Outcome measures:** Sagittal/lateral flexion and axial rotation ROM were measured on both the LBB and FSS	To compare the traditional LBB with the FSS	4	20	There was about 6–8° greater motion in the sagittal, lateral, and axial planes during the application of the LBB compared with the FSS ($p < 0.001$). No significant difference was found during a secured logroll maneuver. The FSS induced more sagittal flexion during the lift than the LBB ($p < 0.001$). The FSS showed superior comfort and perceived security over the LBB.
Luscombe and Williams, 2003	Emerg. Med. J.	Comparison of a long spinal board and vacuum mattress for spinal immobilisation	*(Experimental)* **Population:** M/F = 8/1; Weight M/F = 79 kg/58 kg. **Treatment:** Volunteers wore a Wizloc rigid cervical collar and standardized clothing. Each was then placed on both the backboard and the vacuum mattress and securely strapped to the device. Body movements and comfort levels were determined. **Outcome measures:** Mean body movements and comfort levels	To compare the stability and comfort afforded by the long spinal board and the vacuum mattress	4	21	The mean body movements in the head-up position, head-down position, and lateral tilt were significantly greater on the backboard than on the vacuum mattress ($p < 0.01$). The vacuum mattress was significantly more comfortable than the backboard ($p < 0.01$).

Main and Lovell, 1996	J. Accident Emerg. Med.	A review of seven support surfaces with emphasis on their protection of the spinally injured.	*(Experimental RCT)* **Treatment:** Subjects were randomly placed on six well-established support surfaces and the prototype support surface. Readings for each surface were taken and the mean pressures/standard deviations were calculated to measure the variability of sacral and thoracic pressures between the subjects and surfaces. The subjects were asked about comfort and acceptability of the surfaces. **Outcome measures:** Mean sacral and thoracic pressure readings	To evaluate seven evacuation support surfaces: conventional spinal board, two vacuum stretchers, a prototype (combination of both principles), and three conventional stretchers	1B	15	See text
Maruyama et al., 2008	Br. J. Anaesthesia	Randomized cross-over comparison of cervical-spine motion with Airway Scope or Macintosh laryngoscope with in-line stabilization: a video fluoroscopic study	*(Prospective RCT)* **Population:** 13 patients with normal cervical spines. **Treatment:** Patients underwent laryngoscopy with a Macintosh blade or an Airway scope, then vice versa. **Outcome measures:** Upper cervical spine motion assessed with live video fluoroscopy in the lateral plane	To compare the C-spine movement required for laryngoscopy and intubation with the Airway Scope and the Macintosh laryngoscope	1B	30	C-spine motion was significantly less with use of the Airway Scope compared to direct laryngoscopy with the Macintosh blade. Time to intubation was similar.
Mazolewski and Manix, 1994	Ann. Emerg. Med.	The effectiveness of strapping techniques in spinal immobilization	*(Experimental)* **Population:** Height: 70.20 in; Weight: 171.74 lb; %M = 100. **Treatment:** Subjects restrained on a wooden back board using a control and three strapping techniques: #1 (control)—two straps over the chest with a third strap placed just below the axilla; #2—the same straps as #1 with an abdominal strap across the umbilicus; #3—the same straps as #2, with a strap around the chest/arms; #4—no cross straps, but abdominal/arm straps. The backboard was rolled 90° and lateral motion of the torso was measured. Volunteers judged ease of breathing once the straps were tightened, and each was asked which method they thought allowed the least amount of lateral motion. **Outcome measures:** lateral motion	To test the effectiveness of strapping techniques in reducing lateral motion of volunteers restrained on a backboard	1B	15	Technique #2, which added an abdominal strap to the control technique, reduced 26% of the lateral motion. Techniques #2, #3, and #4 were found to be statistically significantly different than technique #1, but not from each other ($p < 0.05$). When asked which technique they thought reduced lateral motion best, 6% of volunteers chose technique #1, 6% technique #2, 73% technique #, and 15% technique #4.
McGuire et al., 1987	J. Trauma	Spinal instability and the log rolling manoeuvre	*(Case reports)* **Treatment:** The motion of the thoracolumbar spine in a volunteer with a stable spine, a cadaver with a unstable thoracolumbar spine, and a patient with a T12–L1 fracture dislocation were radiographically examined. **Outcome measures:** Stabilization efficiency	To evaluate the motion of the thoracolumbar spine in various individuals	4	12	Both the backboard and the scoop stretcher offered adequate stabilization for throracolumbar spine instability. The logroll maneuver presented the greatest possibility for movement of the spine at the unstable thoracolumbar segment.

(*Continued*)

Table 1. Evidence Table (Continued)

Reference	Journal	Title	Design	Purpose/hypothesis	Sackett rating[a]	D & B score (out of 44)	Results
Meldon et al., 1998	J. Trauma	Out of hospital cervical spine clearance: Agreement between emergency medical technicians and emergency physicians	*(Case series)* **Population:** Age = 34 y (6–98 y); %M = 59. **Treatment:** Patient data were prospectively collected in order to determine inter-rater agreement between EMTs and EPs regarding out-of-hospital clinical CSI clearance. **Outcome measures:** Inter-rater agreement between EMTs and EPs	To determine agreement between EMTs and EPs when applying an EMS/fire department protocol for out-of-hospital CSI clearance in blunt trauma patients	4	27	Overall disagreement between EMTs and EPs regarding CSI pre-hospital clearance occurred in 23% of patients (kappa = 0.29; 95% CI 0.15, 0.43; $p < 0.01$). CSI was detected in 2.6% of patients, and all of them were immobilized in the out-of-hospital setting.
Muhr et al., 1998	Prehosp. Emerg. Care	Paramedic use of a spinal injury clearance algorithm reduces spinal immobilization in the out of hospital setting	*(Case series)* **Population:** Age: standard = 34.1 y; %M/F: standard = 48/52. **Treatment:** Paramedics received training on the algorithm. They were instructed to assess patient level of consciousness, drug/alcohol use, loss of consciousness, spinal pain/tenderness, neurological deficit, concomitant serious injury, and pain with ROM. If all criteria were negative, the algorithm indicated that patients didn't need spinal immobilization (SI). Paramedics completed a tracking form and followed the patient to the ED. Data were then gathered to determine the presence of spinal fracture, neurological deficit, or a combination of the two	To determine whether paramedics can safely use a spinal clearance algorithm to reduce unnecessary SI in the out-of-hospital setting	4	21	11.7% of patients were immobilized despite their not meeting immobilization criteria. None of these patients were diagnosed as having spinal injury. Comparison of pre-study data and study data indicated a 33% reduction in utilization of SI (95% CI 27.2, 38.8). An out-of-hospital spinal clearance algorithm administered by paramedics can reduce SI by one-third.
Nypaver and Treloar, 1993	Ann. Emerg. Med.	Neutral cervical spine positioning in children	*(Experimental)* **Population:** Age = 33 months (1 month–7 y). **Treatment:** The two observers independently placed children in a neutral position using standard-sized padding with or without shims to raise the back off a backboard. **Outcome measures:** Inter-observer agreement, height of elevation	To determine the elevation of back/shoulders needed to put children in neutral cervical spine position, and determine if observers could agree on the height required	4	20	The inter-observer agreement kappa = 0.56. No correlation was noted between the age and height of elevation ($r = 0.114$, $p > 0.05$). When children > 4 y old were compared with those ≥ 4 y old, it was found that the younger group required more elevation for correct positioning than older children ($p < 0.05$).
Peery et al., 2007	Prehosp. Emerg. Care	Pre-hospital spinal immobilization and the Backboard Quality Assessment Study	*(Case series)* **Population:** M/F = 23/26; Weight = 172 lb; Height = 68 in. **Treatment:** Patients who were spinally immobilized were evaluated for the number and occasion of restraining straps and their degree of tightness to assess quality of immobilization. **Outcome measures:** Number and location of restraining straps and their degree of tightness	To quantify how often immobilization is inadequate	4	25	30% had at least one unattached strap or piece of tape that should have attached their head to the board; 88% were found to have > 2 cm of slack between their body and at least one strap; among those with any straps looser than 2 cm, the average number of loose straps was 3.4.

Perry et al., 1999	Spine	The efficacy of head immobilization techniques during simulated vehicle motion	*(Experimental)* **Population:** Age = 25 y; Height = 168 cm; Weight = 69 kg. **Treatment:** Three different head-immobilization methods were compared in six healthy adults using a computer-controlled platform to simulate movements that occur during transport; 5/6 volunteers were tested using each of the three different methods: (1) towels, (2) wedges, and (3) headbed; 1 volunteer was tested on the first two methods; 3 volunteers were tested for 8 min (4 exposures for 2 min each), and the other three for 14 min (7 exposures for 2 min each). **Outcome measures:** Efficacy of head immobilization	To compare the efficacy of different head-immobilization techniques during motion simulating ambulance transport	4	30	The range of lateral bending was significantly larger when this motion was referenced to the trunk rather than to the fracture board ($p < 0.001$); Styrofoam wedges led to consistently lower ranges of motion for absolute axial rotation ($p = 0.0004$) and absolute lateral bending ($p = 0.016$) than the Headbed; There were no statistically significant differences between the techniques in terms of relative motion occurring across the neck (axial rotation $p = 0.13$; lateral bending $p = 0.31$).
Sahni et al., 1997	Prehosp. Emerg. Care	Paramedic evaluation of clinical indicators of cervical spinal injury	*(Experimental)* **Population:** Healthy volunteers. **Treatment:** The EPs and EMSs were paired. Each pair evaluated five randomly assigned patients for six clinical criteria: alteration in consciousness, evidence of intoxication, complaint of neck pain, cervical tenderness, neurologic deficit/complaint, and distracting injury. If any criterion was positive, clinical clearance was considered to have failed and the patient would have been immobilized. **Outcome measures:** Kappa coefficients	To compare paramedic assessments of indicators of cervical spinal injury with those of attending emergency physicians	4	16	Kappas for the six criteria were: altered consciousness = 0.77; intoxication = 0.68; neck pain = 0.62; cervical tenderness = 0.73; neurologic deficit = 0.68; and distracting injury = 0.62. Kappa = 0.90 for the immobilization decision. In one case the decisions differed: the paramedic indicated immobilization, whereas the physicians did not. No patient requiring immobilization would have been clinically cleared by the paramedics.
Scannell et al., 1993	Arch. Surg.	Orotracheal intubation in trauma patients with cervical fractures	*(Case series)* **Treatment:** Senior resident or faculty anesthesiologists performed intubations. Peripheral neurological examination was performed before and after each intubation, and neurological deficits were documented **Outcome measures:** Number of neurologic deficits	To evaluate orotracheal intubation with in-line stabilization of the cervical spine for emergency airway treatment of patients	4	8	There were unstable cervical fractures in 38 patients with no neurological deficits, and 23 patients were neurologically intact with fractures that were later judged stable. In no instance was there a deterioration of neurological status following intubation. Peripheral neurological deficits improved after intubation in four patients.
Schaefermeyer, et al., 1991	Ann. Emerg. Med.	Respiratory effects of spinal immobilization in children	*(Experimental)* **Population:** Age = 10.6 y; M/F = 22/29; Height = 57.5 in. **Treatment:** Participants' forced vital capacity (FVC) measurements were first obtained with children standing and lying supine, and then in full spinal immobilization using two different strapping configurations: cross straps and lateral straps. Straps were tightened to allow one hand to fit snugly between the strap and the child. **Outcome measures:** Supine FVC	To assess the restrictive effects of two spinal immobilization strapping techniques on the respiratory capacity of normal healthy children	4	19	Supine FVC was less than upright FVC ($p < 0.001$). FVC in spinal immobilization ranged from 41–96% of supine FVC. There was no difference in FVC between strapping techniques ($p = 0.83$). Spinal immobilization significantly reduced respiratory capacity as measured by FVC in healthy patients 6–15 y old. There was no significant benefit of one strapping technique over the other.

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Table 1. Evidence Table (Continued)

Reference	*Journal*	*Title*	*Design*	*Purpose/hypothesis*	*Sackett rating*[a]	*D & B score (out of 44)*	*Results*
Schriger et al., 1991	Ann. Emerg. Med.	Spinal immobilization on a flat backboard: Does it result in neutral position of the cervical spine?	*(Experimental)* **Population:** M/F = 50/50; Age = 24.4 y. **Treatment:** Neutral position was defined as the normal anatomic position of the head and torso that one assumes when standing looking straight ahead **Outcome measures:** Intra-observer reliability, occipital offset	To determine the amount of occipital padding required to achieve neutral position of the cervical spine when immobilized on a flat backboard	4	23	Intra-observer reliability showed a multi-observer kappa = 0.99 and intra-class correlation coefficient of 0.98. The amount of occipital offset required for neutral position varied from 0–3.75 in (mean = 1.49 in; 95% CI 1.37, 1.60). Mean occipital offset for men (1.67 in) was significantly greater than that for women (1.31 in; $p = 0.0016$). Mean occipital offset significantly differed from zero ($p < 0.0001$). Body measurements did not accurately predict occipital offset. Immobilization on a flat backboard would place 98% of subjects in cervical extension. Occipital padding would place a greater percentage of patients in neutral position and increase patient comfort.
Sheerin and de Frein, 2007	J. Emerg. Nurs.	The occipital and sacral pressures experienced by healthy volunteers under spinal immobilization: a trial of three surfaces	*(RCT)* **Population:** Age = 41 and 23 y; M = 2; Weight = 82 and 67 kg; Height = 1.68 and 1.77 m; BMI = 29.05 and 21.39 kg/m^2. **Treatment:** The two volunteers were immobilized on three spinal support surfaces to assess the differences in occipital and sacral tissue interface pressure. **Outcome measures:** Reduction of pressure experienced at the occipital and sacral regions	To identify whether or not the pressure experienced by individuals at two anatomical locations were dependent on the support surface used	2B	20	See text
Stroh and Braude, 2001	Ann. Emerg. Med.	Can an out-of-hospital cervical spine clearance protocol identify all patients with injuries? An argument for selective immobilization	*(Retrospective chart review)* **Population:** 861 patients with significant cervical injuries discharged from five trauma hospitals between July 1, 1990 and June 30, 1996	To determine the sensitivity of an EMS spine immobilization protocol in identifying patients with cervical injuries, and to determine whether it was safe in an out-of-hospital setting	4	23	Of the 861 total patients, 504 were brought to hospital by EMS, with 495 arriving in spine immobilization. The EMS spinal immobilization protocol was 99% sensitive in identifying patients with significant cervical injuries for immobilization. Prospective validation addressing limitations is needed.
Turkstra et al., 2005	Anesth. Analg.	Cervical spine motion: a fluoroscopic comparison during intubation with lighted stylet, GlideScope, and Macintosh laryngoscope	*(Prospective RCT cross-over)* **Population:** ASA I–III, elective noncardiac surgery, without difficult airway or unstable C-spine. **Treatment**: Lightwand versus Macintosh ($n = 18$), and GlideScope versus Macintosh ($n = 18$), all with simulated manual in-line immobilization. **Outcome measures:** Extension-flexion of neck under digital video fluoroscopy	To determine C-spine movement during use of the GlideScope or Lightwand versus direct laryngoscopy with the Macintosh blade	1B	30	C-spine motion was significantly less during bag-and-mask ventilation than direct laryngoscopy. Lightwand use resulted in significantly less C-spine motion along all segments, from occipital-cervical to cervicothoracic regions ($p < 0.03$). GlideScope use resulted in reduced motion from C2–C5, but no change in motion at other regions versus the Macintosh blade. Time to intubation was similar for the Lightwand and the blade, but was increased with the use of the GlideScope versus the blade ($p < 0.01$).

Walton et al., 1994	Acad. Emerg. Med.	Padded vs. unpadded spine board for cervical spine immobilization	*(RCT)* **Population:** Age = 32.5 y; M/F = 26/4; Weight = 72 kg. **Treatment:** Subjects were randomized to either padded or unpadded long spine board immobilization with serial measurements of discomfort and transcutaneous tissue oxygen tension. The subjects were then asked to return after at least 3 days to be immobilized with the other spine board. **Outcome measure:** Discomfort, flexion, extension, rotation, lateral bending, and sacral transcutaneous oxygen tension	To determine whether padding the long spine board improves patient comfort, affects cervical spine immobilization, or increases sacral transcutaneous oxygen tension	2B	23	Subject discomfort was significantly reduced in the padded group compared with the unpadded group ($p = 0.024$). There was no significant difference in flexion ($p = 0.410$), extension ($p = 0.231$), rotation ($p = 0.891$), or lateral bending ($p = 0.230$) for the two groups. There was no significant difference in the actual drop in sacral transcutaneous oxygen tension from time zero to 30 min for the padded and the unpadded groups ($p = 0.906$).
Waninger et al., 2001	Clin. J. Sport Med.	An evaluation of head movement in backboard-immobilized helmeted football, lacrosse, and ice hockey players	*(Prospective)* **Population:** 30 volunteer collegiate athletes (12 ice hockey, 9 football, 9 lacrosse) with no history of cervical spine injury or pathology. **Treatment:** Athletes were immobilized on backboards per protocol. Three retro-reflective markers were attached to the helmet. Measurements were obtained during a period when the backboard was perturbed in order to stimulate jostling during transportation. **Outcome measures:** Helical angles determine the relative range of motion of the head inside the helmet	Compares the amount of head movement in American football, lacrosse, and ice hockey helmets during head and neck stabilization procedures	4	16	Mean range of head motion for football players was 4.88° ($n = 9$, SD 2.07), lacrosse players 6.56° ($n = 9$, SD 1.61), and ice hockey players 5.54° ($n = 12$, SD 1.19). Results were not significantly different ($p > 0.05$). Supports the policy of stabilization with helmet and shoulder pads in place. The amount of movement that is safe to prevent iatrogenic injury has yet to be determined.

Source: Sackett et al., 2000.

[a]Sackett rating.

EMS, emergency medical services; ED, emergency department; EP, emergency physicians; C, cervical; T, thoracic; M, male; F, female; T, thoracic; L, lumbar; BLS, basic life support; ALS, advanced life support; FAQ, frequently asked question; CI, confidence interval; ICD-9, International Classification of Disease, 9th edition; RCT, randomized controlled trial; SD, standard deviation; DPI, distracting painful injury; SCI, spinal cord injury; OETI/ETI, orotracheal intubation/endotracheal intubation; AP, anteroposterior; ROM, range of motion; OR, odds ratio; CSI, cervical spine injury; BMI, body mass index; ASA, American Surgical Association; D & B score, Downs and Black criteria (Downs and Black, 1998).

body tissue pressure (Chan et al., 1996; Hauswald et al., 2000; Main and Lovell, 1996; Sheerin and de Frein, 2007; Walton et al., 1995); however, no study evaluated what constitutes a safe duration of immobilization on a hard board, although tissue interface pressures were elevated even after short periods of rigid immobilization (Main and Lovell, 1996; Sheerin and de Frein, 2007; Walton et al., 1995). None of the studies assessed time on hard board and the clinical outcome of pressure sores. As a result, there is no firm time point cited in the literature after which immobilization should be discontinued.

Main and Lovell (1996) performed an experimental randomized controlled trial in which subjects laid on six different support surfaces and surface pressure readings were obtained both at the sacral region and the thoracic region. Results showed that the traditional spinal board had the highest sacral reading of 233.5 mm Hg and the highest thoracic reading of 82.9 mm Hg, versus other forms of stretchers such as the York Two stretcher, for which readings of 46 mm Hg and 21 mm Hg, respectively, were obtained. The study also found that the traditional board lacked support for the lumbar lordosis. Differences in pressure readings in the various board surfaces and designs may lead to differences in the occurrence of pressure sores in the setting of prolonged transportation times and SCI (Main and Lovell, 1996).

Sheerin and de Frein (2007) conducted an experimental study examining volunteers on different support surfaces and assessed occipital and sacral tissue interface pressures. The highest pressure readings were seen with the traditional unpadded spinal board. They observed that occipital and sacral pressures were lowest with a vacuum mattress device (Sheerin and de Frein, 2007).

Mazolewski and Manix examined different techniques of strapping in spinal immobilization using an experimental study in which subjects were restrained on a spine board. Four different techniques were evaluated and lateral spine motion was measured as the backboard was rolled 90° from side to side. Motion was most reduced by placing two straps that cross over at the chest, with a third strap placed across the umbilicus (Mazolewski and Manix, 1994).

Krell and colleagues compared the scoop stretcher to the long backboard for spinal immobilization in terms of motion and comfort. There were 6–8° more of sagittal motion during the application of the long backboard compared to the scoop board. The scoop board was also perceived to be more comfortable compared to the traditional board (Krell et al., 2006).

There are few published studies evaluating spinal immobilization for children. Only two of the identified publications studied pediatric spinal immobilization (Nypaver and Treloar, 1994; Schafermeyer et al., 1991). There are anatomic differences between adults and children that may prevent valid generalizations of the adult literature to spinal immobilization in a pediatric population. These include increased head:body size ratio, as well as a more posterior occiput relative to the spinal plumb line in children than in adults. With the relative paucity of literature evaluating pediatric immobilization, and the concerns regarding generalizability of adult findings to this population, the group decided to restrict recommendations made in this review to individuals over the age of 12 years.

Question 2. During airway manipulation in the pre-hospital setting, what is the ideal method of spinal immobilization?

Most studies examining airway management were performed in the hospital rather than in the pre-hospital setting (Doran et al., 1995; Maruyama et al., 2008; Scannell et al., 1993; Turkstra et al., 2005). Intubations in the studies were done by senior anesthesia residents or fully-trained anesthesiologists. The studies did not assess intubations done by emergency medical technicians in the field, and there was only one article examining pre-hospital intubation and factors influencing successful intubation in the pre-hospital setting. This prospective study evaluated 4691 transported patients, of which 236 required intubation. The intubation success rate was 88%, and was considered to be technically more challenging, especially in the setting of spinal immobilization (Doran et al., 1995).

The available clinical studies evaluating the impact of airway control using in-line cervical stabilization did not find worsening of neurologic status after airway management (Maruyama et al., 2008; Scannell et al., 1993). Anatomical studies of in-line stabilization with a Miller blade showed less cervical movement compared to use of a cervical collar alone (Gerling et al., 2000).

Several randomized cross-over trials were performed assessing newer forms of indirect intubation in patients undergoing general anesthesia for elective surgeries with live fluoroscopy (Maruyama et al., 2008; Turkstra et al., 2005). Indirect methods of intubation such as the Lightwand with manual in-line immobilization were found to cause less cervical motion than direct laryngoscopy with a Miller blade and in-line immobilization (Maruyama et al., 2008; Turkstra et al., 2005).

Question 3. What is the impact of pre-hospital transport time to definitive care on the outcomes of patients with acute SCI?

There is little evidence regarding the impact of pre-hospital transport time to definitive care on the outcomes of patients with acute SCI. However, patients transported within 24 h for treatment fared better than those transported after 24 h. It is unknown if there were confounding factors in those patients transported after 24 h that negatively affected outcomes, such as medical comorbidities or concurrent injuries that hindered earlier transportation, and thus negatively impacted the results of spinal cord injury treatment. Air and ground transport are both safe when spinal precautions are taken for transport (Armitage et al., 1990; Burney et al., 1989; Flabouris, 2001), and these studies did not document the development of any ascending neurological deficits with transport (Armitage et al., 1990; Burney et al., 1989; Flabouris, 2001).

Burney and associates reviewed patients with spinal column fractures with SCI (complete or incomplete) to assess whether these patients could undergo safe early transport to an SCI center using basic equipment for spine stabilization. Transportation was achieved both by ground ambulance (41%) , helicopter (54%), and fixed-wing aircraft (5%), and 84% were transferred within 24 h of injury. No patients suffered ascending injury levels as a result of transfer. There was no significant difference found in the probability of improvement between ground and air transportation (Burney et al., 1989).

Flabouris and colleagues reviewed the pattern of utilization of a medically-staffed transportation service by patients with suspected spinal injuries from a hospital or from a scene of an accident and documented the impact of different modes of transportation. The majority (93%) of transfers were by helicopter, followed by fixed-wing aircraft (3.5%), and lastly road vehicles. Mean duration of inter-hospital transport (42 ± 28 min) was longer than from scene transfers (19 ± 12 min), but this was similar to road vehicle transfers (45 ± 26 min). Rural hospitals were the referral source for 55% of inter-hospital transports. The reason for 18% of all inter-hospital transfers was to exclude a spinal injury that could not otherwise be excluded at the referral hospital. No worse neurological outcomes occurred as a result of transportation (Flabouris, 2001).

Question 4. What is the role for pre-hospital care providers in cervical spine clearance and immobilization?

Clinical evidence reveals that pre-hospital emergency medical technicians can be trained to apply criteria to clear patients of cervical spinal injuries and immobilize patients suspected of having a cervical spinal injury to a level similar to that of emergency physicians (Armstrong et al., 2007; Benner et al., 2006; Brown et al., 1998; Burton et al., 2005, 2006; Campbell, 1987; Domeier et al., 1997, 1999, 2002, 2005; Meldon et al., 1998; Muhr et al., 1999; Sahni et al., 1997; Stroh and Braude, 2001). There was no universal tool or triage index used in the studies.

In some series up to 8% of vertebral column injuries were not immobilized (Armstrong et al., 2007; Brown et al., 1998; Domeier et al., 2002, 2005; Stroh and Braude, 2001). However, there were no clinical consequences of not immobilizing, and none of these column injuries had associated neurological deficits (Armstrong et al., 2007; Brown et al., 1998; Domeier et al., 2002, 2005; Stroh and Braude, 2001).

Armstrong and associates examined whether the incidence of unnecessary cervical spine immobilization by ambulance personnel could be safely reduced through the implementation of an evidence-based algorithm. Following a training program, paramedics collected data on 103 patients with potential cervical spine injuries, of which 69 (67%) had their cervical spines cleared at the accident scene. Of these, 60 (87%) were discharged at the scene with no clinical adverse events reported, and 9 (13%) were taken to the local emergency department with minor injuries, and all were discharged home the same day. However, 34 (33%) patients could not have their cervical spines safely cleared at the scene according to the algorithm. Of these, 4 (12%) patients self-discharged themselves at the scene, and 30 (88%) were conveyed to an emergency department per their procedure protocol (Armstrong et al., 2007).

Brown and co-workers examined whether emergency medical services (EMS) providers can accurately apply clinical criteria for clearing the cervical spine in trauma patients. Both emergency physicians and EMS providers indicated immobilization in 60% of patients, and their assessments differed for 21.3% of patients. Overall agreement indicated a kappa value of 0.48, which reflects moderate agreement. The EMS providers were generally more conservative than the emergency physicians (Brown et al., 1998).

Domeier and colleagues first examined prospectively whether or not retrospectively identified criteria could be used to identify patients without significant spinal fracture outside of the hospital. By utilizing their criteria, 100% of all cervical injuries were identified. They identified 90% of patients with thoracic injuries, and 96% of patients with lumbar injuries. There were three false-negatives, of which two had stable thoracic compression injuries, and one had a lumbar transverse fracture. Only one of these false-negatives was admitted to hospital for pain control, and was discharged within 2 days, and the remaining false-negative injuries were discharged from the emergency department. No significant spinal fractures were missed (Domeier et al., 1997).

In another study, Domeier and associates examined the reliability of a pre-hospital clinical evaluation tool in patients with different severities and mechanisms of injury. In all, 1059 patients were assessed in the high-risk group, of which 9.4% had injuries, and 5423 low-risk group patients were assessed, of which 2% had injuries. The criteria identified 97% of injuries in the high-risk group, and 94% in the low-risk group. The mechanism of injury did not affect the ability of the clinical criteria to predict spinal injury (Domeier et al., 1999).

In 2005, Domeier and colleagues assessed whether the protocols developed allowed EMS providers to appropriately immobilize patients with spinal injuries. The sensitivity of the EMS protocol was 92% (95% CI 89.4, 94.6), and 8% of patients with spinal injuries did not have immobilization; however, none of the non-immobilized patients sustained cord injuries. EMS providers also immobilized 12% of patients not required by the protocol. The use of the selective immobilization protocol resulted in spine immobilization for most patients with spinal injury, without causing harm in cases in whom immobilization was withheld (Domeier et al., 2005).

Muhr and associates also examined training paramedics to use a clearance algorithm. If patients met all the criteria, paramedics could transport them without spine immobilization. They found that there was a 33% reduction in the utilization of spinal immobilization compared to pre-study data (Muhr et al., 1999).

Further research is needed to determine a universal triage system that can be implemented to train emergency medical technicians in the pre-hospital setting. However, the results of the systematic review for this question must be balanced with the realities of geographic variations in law and health policy, and the varying risk tolerance of EMS systems in different regions.

Recommendations

All recommendations were derived from the systematic reviews, statements from the authors, and the Delphi process. The latter was reported using the level of agreement and the comments and suggestions of experts.

Question 1. What is the optimal type and duration of pre-hospital spinal immobilization in patients with acute SCI?

- Immobilization of patients with SCI during the pre-hospital setting should include a cervical collar, head immobilization, and a spinal board.
- Patients should be transferred off the hardboard on admission to a facility as soon as is feasible to minimize time on the hardboard. If patients are awaiting transfer to another institution, they should be taken off the hardboard while awaiting transfer.

- Padded boards or inflatable bean bag boards should be utilized to reduce pressure on the occiput and sacrum.
- These recommendations are intended for adults and children over the age of 12 years.

Question 2. During airway manipulation in the pre-hospital setting, what is the ideal method of spinal immobilization?

- Airway management of acute SCI patients requiring intubation in the pre-hospital setting should include the use of manual in-line cervical spine traction.
- Intubation of patients with acute SCI in the pre-hospital setting should not rely solely on cervical collar neck immobilization.
- Indirect methods of intubation may cause less cervical movement than with direct laryngoscopy with a Miller blade.

Question 3. What is the impact of pre-hospital transport time to definitive care on the outcomes of patients with acute SCI?

- Transport of patients with acute traumatic SCI to the definitive hospital center for care should occur within 24 h of injury.

Question 4. What is the role for pre-hospital care providers in cervical spine clearance and immobilization?

- Emergency medical personnel in the pre-hospital setting can be trained to apply criteria to clear patients of cervical spinal injuries and immobilize patients suspected of having a cervical spinal injury.
- The implementation of this recommendation will likely be impacted by regional variations in law and health policy.

There is insufficient evidence to make recommendations for children, and the authors have concerns regarding the applicability of adult recommendations to pediatric patients.

Summary

Pre-hospital care of patients with potential spinal cord injury requires great care to minimize secondary SCI and potential morbidity related to spinal immobilization. This systematic review provides an evidentiary table and a summary of the review, in addition to recommended guidelines based on use of the Delphi method by a group of experts.

References

Armitage, J.M., Pyne, A., Williams, S.J., and Frankel, H. (1990). Respiratory problems of air travel in patients with spinal cord injuries. BMJ (Clinical research ed.) 300, 1498–1499.

Armstrong, B.P., Simpson, H.K., Crouch, R., and Deakin, C.D. (2007). Prehospital clearance of the cervical spine: does it need to be a pain in the neck? Emerg. Med. J. 24, 501–503.

Benner, J.P., Brauning, G., Green, M., Caldwell, W., Borloz, M.P., and Brady, W.J. (2006). Disagreement between transport team and ED staff regarding the prehospital assessment of air medically evacuated scene patients. Air Med. J. 25, 165–169.

Brown, L.H., Gough, J.E., and Simonds, W.B. (1998). Can EMS providers adequately assess trauma patients for cervical spinal injury? Prehosp. Emerg. Care. 2, 33–36.

Burney, R.E., Waggoner, R., and Maynard, F.M. (1989). Stabilization of spinal injury for early transfer. J. Trauma 29, 1497–1499.

Burton, J.H., Dunn, M.G., Harmon, N.R., Hermanson, T.A., and Bradshaw, J.R. (2006). A statewide, prehospital emergency medical service selective patient spine immobilization protocol. J. Trauma 61, 161–167.

Burton, J.H., Harmon, N.R., Dunn, M.G., and Bradshaw, J.R. (2005). EMS provider findings and interventions with a statewide EMS spine-assessment protocol. Prehosp. Emerg. Care 9, 303–309.

Campbell, P. (1987). Comparison of flight nurses' prehospital assessments and emergency physicians' ED assessments of trauma patients. J. Emerg. Nurs. 13, 219–222.

Chan, D., Goldberg, R.M., Mason, J., and Chan, L. (1996). Backboard versus mattress splint immobilization: a comparison of symptoms generated. J. Emerg. Med. 14, 293–298.

Chandler, D.R., Nemejc, C., Adkins, R.H., and Waters, R.L. (1992). Emergency cervical-spine immobilization. Ann. Emerg. Med. 21, 1185–1188.

Cordell, W.H., Hollingsworth, J.C., Olinger, M.L., Stroman, S.J., and Nelson, D.R. (1995). Pain and tissue-interface pressures during spine-board immobilization. Ann. Emerg. Med. 26, 31–36.

Cornwell, E.E., 3rd, Chang, D.C., Bonar, J.P., Campbell, K.A., Phillips, J., Lipsett, P., Scalea, T., and Bass, R. (2001). Thoracolumbar immobilization for trauma patients with torso gunshot wounds: is it necessary? Arch. Surg. 136, 324–327.

Crosby, E.T. (2006). Airway management in adults after cervical spine trauma. Anesthesiology 104, 1293–1318.

Crosby, E.T. (1992). Tracheal intubation in the cervical spine-injured patient. Canadian J. Anaesthesia (J. canadien d'anesthesie.) 39, 105–109.

Davies, G., Deakin, C., and Wilson, A. (1996). The effect of a rigid collar on intracranial pressure. Injury 27, 647–649.

De Lorenzo, R.A., Olson, J.E., Boska, M., Johnston, R., Hamilton, G.C., Augustine, J., and Barton, R. (1996). Optimal positioning for cervical immobilization. Ann. Emerg. Med. 28, 301–308.

Domeier, R.M., Evans, R.W., Swor, R.A., Hancock, J.B., Fales, W., Krohmer, J., Frederiksen, S.M., and Shork, M.A. (1999). The reliability of prehospital clinical evaluation for potential spinal injury is not affected by the mechanism of injury. Prehosp. Emerg. Care 3, 332–337.

Domeier, R.M., Evans, R.W., Swor, R.A., Rivera-Rivera, E.J., and Frederiksen, S.M. (1997). Prospective validation of out-of-hospital spinal clearance criteria: a preliminary report. Acad. Emerg. Med. 4, 643–646.

Domeier, R.M., Frederiksen, S.M., and Welch, K. (2005). Prospective performance assessment of an out-of-hospital protocol for selective spine immobilization using clinical spine clearance criteria. Ann. Emerg. Med. 46, 123–131.

Domeier, R.M., Swor, R.A., Evans, R.W., Hancock, J.B., Fales, W., Krohmer, J., Frederiksen, S.M., Rivera-Rivera, E.J., and Schork, M.A. (2002). Multicenter prospective validation of prehospital clinical spinal clearance criteria. J. Trauma 53, 744–750.

Doran, J.V., Tortella, B.J., Drivet, W.J., and Lavery, R.F. (1995). Factors influencing successful intubation in the prehospital setting. Prehosp. Disaster Med. 10, 259–264.

Downs, S.H., and Black, N. (1998). The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. J. Epidemiol. Community Health 52, 377–384.

Eismont, F.J., Currier, B.L., and McGuire, R.A., Jr. (2004). Cervical spine and spinal cord injuries: recognition and treatment. Instructional Course Lectures 53, 341–358.

Fehlings, M.G., and Louw, D. (1996). Initial stabilization and medical management of acute spinal cord injury. Am. Fam. Physician 54, 155–162.

Fenstermaker, R.A. (1993). Acute neurologic management of the patient with spinal cord injury. Urologic Clin. North Am. 20, 413–421.

Flabouris, A. (2001). Clinical features, patterns of referral and out of hospital transport events for patients with suspected isolated spinal injury. Injury 32, 569–575.

Gerling, M.C., Davis, D.P., Hamilton, R.S., Morris, G.F., Vilke, G.M., Garfin, S.R., and Hayden, S.R. (2000). Effects of cervical spine immobilization technique and laryngoscope blade selection on an unstable cervical spine in a cadaver model of intubation. Ann. Emerg. Med. 36, 293–300.

Graziano, A.F., Scheidel, E.A., Cline, J.R., and Baer, L.J. (1987). A radiographic comparison of prehospital cervical immobilization methods. Ann. Emerg. Med. 16, 1127–1131.

Hamilton, R.S., and Pons, P.T. (1996). The efficacy and comfort of full-body vacuum splints for cervical-spine immobilization. J. Emerg. Med. 14, 553–559.

Hasson, F., Keeney, S., and McKenna, H. (2000). Research guidelines for the Delphi survey technique. J. Adv. Nurs. 32, 1008–1015.

Hauswald, M., Hsu, M., and Stockoff, C. (2000). Maximizing comfort and minimizing ischemia: a comparison of four methods of spinal immobilization. Prehosp. Emerg. Care 4, 250–252.

Hauswald, M., Ong, G., Tandberg, D., and Omar, Z. (1998). Out-of-hospital spinal immobilization: its effect on neurologic injury. Acad. Emerg. Med. 5, 214–219.

Huerta, C., Griffith, R., and Joyce, S.M. (1987). Cervical spine stabilization in pediatric patients: evaluation of current techniques. Ann. Emerg. Med. 16, 1121–1126.

Johnson, D.R., Hauswald, M., and Stockhoff, C. (1996). Comparison of a vacuum splint device to a rigid backboard for spinal immobilization. Am. J. Emerg. Med. 14, 369–372.

Keeney, S., Hasson, F., and McKenna, H.P. (2001). A critical review of the Delphi technique as a research methodology for nursing. Int. J. Nursing Studies 38, 195–200.

Kennedy, H.P. (2004). Enhancing Delphi research: methods and results. J. Adv. Nurs. 45, 504–511.

Krell, J.M., McCoy, M.S., Sparto, P.J., Fisher, G.L., Stoy, W.A., and Hostler, D.P. (2006). Comparison of the Ferno Scoop Stretcher with the long backboard for spinal immobilization. Prehosp. Emerg. Care 10, 46–51.

Luscombe, M.D., and Williams, J.L. (2003). Comparison of a long spinal board and vacuum mattress for spinal immobilisation. Emerg. Med. J. 20, 476–478.

Main, P.W., and Lovell, M.E. (1996). A review of seven support surfaces with emphasis on their protection of the spinally injured. J. Accident Emerg. Med. 13, 34–37.

Maruyama, K., Yamada, T., Kawakami, R., and Hara, K. (2008). Randomized cross-over comparison of cervical-spine motion with the AirWay Scope or Macintosh laryngoscope with in-line stabilization: a video-fluoroscopic study. Br. J. Anaesthesia 101, 563–567.

Mazolewski, P., and Manix, T.H. (1994). The effectiveness of strapping techniques in spinal immobilization. Ann. Emerg. Med. 23, 1290–1295.

McGuire, R.A., Neville, S., Green, B.A., and Watts, C. (1987). Spinal instability and the log-rolling maneuver. J. Trauma 27, 525–531.

Meldon, S.W., Brant, T.A., Cydulka, R.K., Collins, T.E., and Shade, B.R. (1998). Out-of-hospital cervical spine clearance: agreement between emergency medical technicians and emergency physicians. J. Trauma 45, 1058–1061.

Muhr, M.D., Seabrook, D.L., and Wittwer, L.K. (1999). Paramedic use of a spinal injury clearance algorithm reduces spinal immobilization in the out-of-hospital setting. Prehosp. Emerg. Care 3, 1–6.

Nypaver, M., and Treloar, D. (1994). Neutral cervical spine positioning in children. Ann. Emerg. Med. 23, 208–211.

Peery, C.A., Brice, J., and White, W.D. (2007). Prehospital spinal immobilization and the backboard quality assessment study. Prehosp. Emerg. Care. 11, 293–297.

Perry, S.D., McLellan, B., McIlroy, W.E., Maki, B.E., Schwartz, M., and Fernie, G.R. (1999). The efficacy of head immobilization techniques during simulated vehicle motion. Spine 24, 1839–1844.

Sackett, D.L., Strauss, S.E., Richardson, W.S., Rosenberg, W., and Haynes, R.B. (2000). Evidence-based medicine: How to practice and teach EBM. Toranto, Ontario: Churchill Livingstone.

Sahni, R., Menegazzi, J.J., and Mosesso, V.N., Jr. (1997). Paramedic evaluation of clinical indicators of cervical spinal injury. Prehosp. Emerg. Care 1, 16–18.

Scannell, G., Waxman, K., Tominaga, G., Barker, S., and Annas, C. (1993). Orotracheal intubation in trauma patients with cervical fractures. Arch. Surg. 128, 903–905; discussion 905–906.

Schafermeyer, R.W., Ribbeck, B.M., Gaskins, J., Thomason, S., Harlan, M., and Attkisson, A. (1991). Respiratory effects of spinal immobilization in children. Ann. Emerg. Med. 20, 1017–1019.

Schriger, D.L., Larmon, B., LeGassick, T., and Blinman, T. (1991). Spinal immobilization on a flat backboard: does it result in neutral position of the cervical spine? Ann. Emerg. Med. 20, 878–881.

Sheerin, F., and de Frein, R. (2007). The occipital and sacral pressures experienced by healthy volunteers under spinal immobilization: a trial of three surfaces. J. Emerg. Nurs. 33, 447–450.

Stroh, G., and Braude, D. (2001). Can an out-of-hospital cervical spine clearance protocol identify all patients with injuries? An argument for selective immobilization. Ann. Emerg. Med. 37, 609–615.

Turkstra, T.P., Craen, R.A., Pelz, D.M., and Gelb, A.W. (2005). Cervical spine motion: a fluoroscopic comparison during intubation with lighted stylet, GlideScope, and Macintosh laryngoscope. Anesthes. Analg. 101, 910–915, table of contents.

Walton, R., DeSalvo, J.F., Ernst, A.A., and Shahane, A. (1995). Padded vs. unpadded spine board for cervical spine immobilization. Acad. Emerg. Med. 2, 725–728.

Waninger, K.N., Richards, J.G., Pan, W.T., Shay, A.R., and Shindle, M.K. (2001). An evaluation of head movement in backboard-immobilized helmeted football, lacrosse, and ice hockey players. Clin. J. Sport Med. 11, 82–86.

Address correspondence to:
Albert Yee, M.D., M.Sc., F.R.C.S.C.
Department of Surgery
University of Toronto
2075 Bayview Avenue
Room MG-371
Toronto, Ontario M4N3M5, Canada

E-mail: Albert.yee@sunnybrook.ca