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Review

Should suspected cervical spinal cord injury be immobilised?: A systematic review

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ABSTRACT

Background: Spinal cord injuries occur worldwide; often being life-threatening with devastating long term impacts on functioning, independence, health, and quality of life.
Objectives: Systematic review of the literature to determine the efficacy of cervical spinal immobilisation (vs no immobilisation) in patients with suspected cervical spinal cord injury (CSCI); and to provide recommendations for prehospital spinal immobilisation.
Methods: Searches were conducted of the Cochrane library, CINAHL, EMBASE, Pubmed, Scopus, Web of science, Google scholar, and OvidSP (MEDLINE, PsycINFO, and DARE) databases. Studies were included if they were relevant to the research question, published in English, based in the prehospital setting, and included adult patients with traumatic injury.
Results: The search identified 1471 citations, of which eight observational studies of variable quality were included. Four studies were retrospective cohorts, three were case series and one a case report. Cervical collar application was reported in penetrating trauma to be associated with unadjusted increased risk of mortality in two studies [(OR, 8.82; 95% CI, 1.09–194; $p = 0.038$) & (OR, 2.06; 95% CI, 1.35–3.13)], concealment of neck injuries in one study and increased scene time in another study. While, in blunt trauma, one study indicated that immobilisation might be associated with worsened neurological outcome (OR, 2.03; 95% CI, 1.03–3.99; $p = 0.04$, unadjusted). We did not attempt to combine study results due to significant heterogeneity of study design and outcome measures.
Conclusion: There is a lack of high-level evidence on the effect of prehospital cervical spine immobilisation on patient outcomes. There is a clear need for large prospective studies to determine the clinical benefit of prehospital spinal immobilisation as well as to identify the subgroup of patients most likely to benefit.

Contents

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Introduction

Traumatic spinal cord injury (SCI) is a relatively rare event, however, it may result in critical neurological damage causing permanent disability, reduced participation in work, and decreased quality of life. Global incidence rates are reported to range widely from 8 to 246 cases per million population varying between regions and countries [1]. Differences in incidence rates between countries are likely to relate to a variety of factors, including socio-economic and geographic differences, but may also reflect heterogeneity in reporting and coding practices. Predominantly affecting males [2,3], traumatic SCI is primarily caused by motor vehicle collision [2,4–7] and falls [3,8,9]. With changing demographic trends and injury patterns, the proportion of neck injuries causing a cervical SCI (CSCI) is reported to be growing (around 55–60% of all traumatic SCIs), whilst the incidence of neurologically complete lesions is reducing [10].

Prehospital spinal immobilisation has long been considered as the standard of care for patients with suspected cervical or other SCI [11–13]. This practice is based on the assumption that immobilisation minimises spinal movement [14,15], reduces risk of secondary injuries [15,16], and facilitates extrication and transport [15]. There is emerging evidence, however, that spinal immobilisation may be associated with adverse effects, including increased risk of respiratory compromise [15,17,18], back and neck pain [17–21], pressure sores [22,23], and increased intracranial pressure [24]. Moreover, it may lead to additional cost and scene time [17], as well as the possible risk of dropping the immobilised patient by prehospital providers in difficult extrication situations when traversing narrow and unstable paths [17,22].

As prehospital spinal immobilisation is a widely accepted standard of care for patients with suspected CSCI, the association between immobilisation and patient outcomes should be clearly established on a rigorous evidence base. Following from a Cochrane review in 2001 that demonstrated a lack of evidence to support the value of routine immobilisation a systematic review is required to update the evidence to inform practice guidelines [12].

Objectives

Primary objectives

This systematic review is designed to answer the question: in adult patients attended by emergency medical services (EMS) following suspected cervical spinal cord injury, does the application of a cervical collar improve patient outcome compared to no collar at all [25]?

Secondary objectives

Secondary aims of this systematic review are to identify whether the cervical spine (c-spine) immobilisation is required for all mechanisms of suspected CSCI and to identify any potential sub-groups of patients with cervical SCI who may benefit from spinal immobilisation.

Methods

Information sources, search strategy, and inclusion criteria

The systematic review protocol has been previously described, including a detailed search strategy [25]. Online databases were searched from the first publically accessible date to 7th October 2013. These databases included the Cochrane library, CINAHL, EMBASE, Pubmed, Scopus, Web of science, Google scholar, and OvidSP (MEDLINE, PsycINFO, and DARE). In addition, reference lists of relevant papers were hand-searched to identify further studies that might have been missed by the electronic search. The search included different combinations of Medical Subject Headings (MeSH) terms, prehospital search filter terms [26], as well as keywords that are relevant to immobilisation, traumatic spinal cord injury, and outcomes (see Table 2: summary of search terms).

The studies were eligible for inclusion if they were characterised as primary studies, relevant to the research questions, published in English, based in the prehospital setting, and performed in adult human subjects with traumatic spinal injuries.

Study selection and data extraction

The titles and abstracts were screened for relevancy by two independent reviewers (AOO and PAJ), with disagreements settled by consensus. Potential papers were evaluated for inclusion by two independent reviewers (combination of AOO, PAJ, JS or KS), with disagreement resolved by an adjudicator. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram describes the selection process (Fig. 1).

Studies were considered relevant if the patients sustained trauma with a potential to cause a spinal cord injury and were managed in the prehospital setting (with or without spinal immobilisation). Any reported outcome measure associated with the application or non-application of c-collars was included [25]. Data were extracted by two independent authors (AOO and PAJ) (see Table 1: Summary of characteristics of included studies).

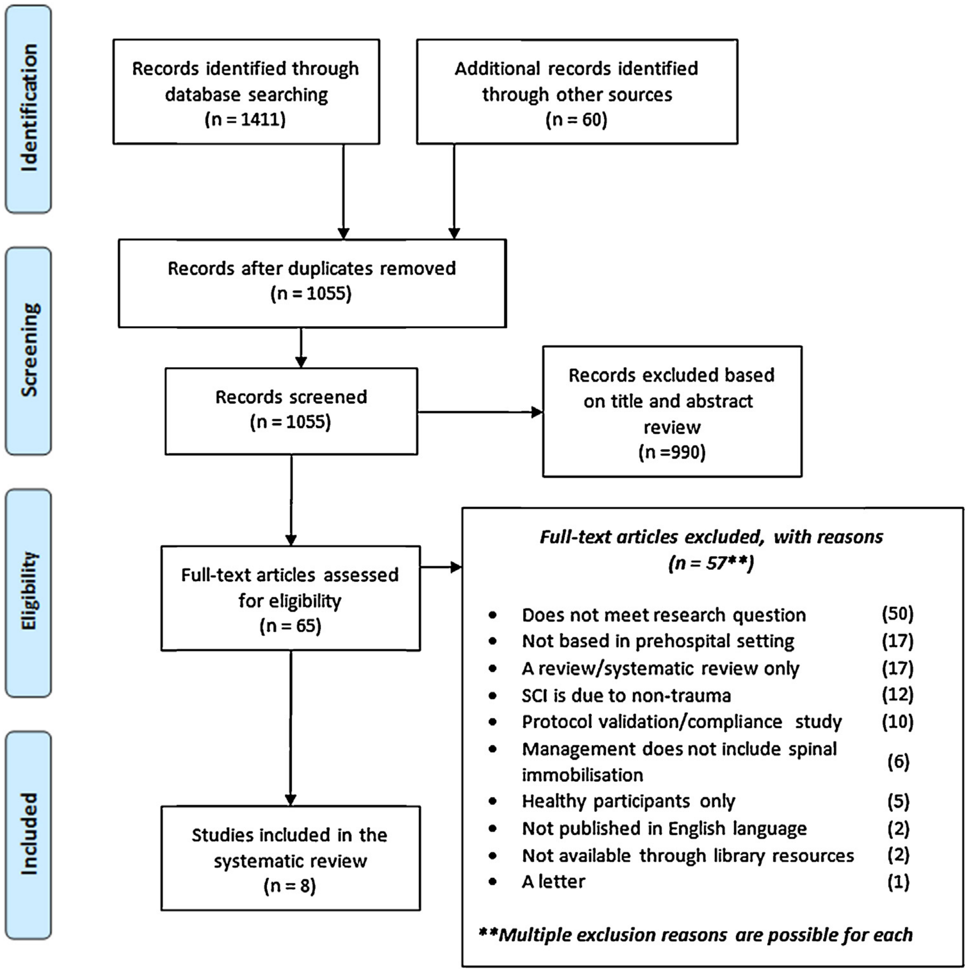

Fig. 1. PRISMA flow diagram: study selection process.

Quality appraisal and risk of bias assessment

Studies were randomly allocated amongst the investigators such that at least two authors critically appraised included studies independently, with disagreement resolved by team consensus. The Newcastle-Ottawa scale (NOS) was used for quality assessment since all of the studies were non-randomised [27]. The NOS scores each study on a nine-star scale consisting of three major evaluation criteria; selection (maximum 4 stars), comparability (maximum 2 stars), and outcome (maximum 3 stars) [28]. Due to the lack of a comparison group, case series studies were scored zero in the comparability criteria, resulting in a maximum possible six stars (for selection and outcome) out of nine stars [29]. The NOS was not considered suitable for application to the Case Report.

The level of evidence (LOE) for each study was assessed using the Australian National Health and Medical Research Committee (NHMRC) Evidence Hierarchy. Specifically, the NHMRC body of evidence matrix was used to assess the strength of the body of evidence for the included studies [30]. Due to the large heterogeneity of the studies with respect to outcome measures, meta-analysis was not attempted.

Two authors (AOO and PAJ) assessed each study for selection bias and confounding, performance, attrition, detection, and reporting biases [31,32]. Each domain was scored as low, moderate, or high risk of bias.

Results

Study selection

Eight observational studies were included, consisting of four retrospective cohort studies, three case series and one case study. The study selection process is illustrated in Fig. 1.

Summary findings

Four observational studies reported on the outcomes associated with c-collar application following penetrating trauma in the prehospital setting. These studies concluded that c-collar application may result in increased mortality rates [33,34], concealment of neck injuries [35], increased scene time [36], and that the use of a c-collar has no or minimum benefits in penetrating trauma [33,34,36]. While in blunt trauma, three retrospective observational studies and one case study (suicide by hanging) reported on outcomes associated with c-collar application following blunt trauma. Single studies reported that c-collar application may result in neurological deterioration [37], increased ICP [38], and that c-collars have no benefits to c-spine injured patients and may be overly conservative [39]. By contrast, an earlier study of a case series proposed that major neurological deterioration would be prevented by early and proper spinal immobilisation [40]. Findings are summarised in a thematic manner in the following sections.

Table 1
Summary of characteristics of included studies.

Authors (year)	Study design	LOE[a]	Quality (NOS)[b]	Country (study period)	N	Mean age (±SD)	Trauma Mechanism	Adjustment for confounding factors
1. Mortality rate								
A. Vanderlan et al. (2009)	Retrospective cohort	III-2	5	USA (9 years & 4.5 months)	188	NR	Penetrating trauma	Unadjusted
B. Haut et al. (2010)	Retrospective cohort	III-2	7	USA (3 years)	45,284	Median: 29	Penetrating trauma	ISS, age, sex, race, insurance status, year of admission, and five prehospital procedures
2. Neurological disability/deterioration								
A. Toscan J. (1988)	Case series	IV	5	Australia (22 months)	123	NR	Blunt trauma	Unadjusted
B. Hauswald et al. (1999)	Retrospective cohort	III-2	5	USA and Malaysia (5 years)	Total 454		Blunt trauma	Age, sex, level of injury, and mechanism of injury
				USA	334	34		
				Malaysia	120	35		
C. Brown et al. (2009)	Case series	IV	4	USA SMH (41 months)	641	28 (±11)	Penetrating Trauma	Unadjusted
				NTDB (60 months)	75,210	30 (±13)	(GSW)	
3. Concealed neck injuries								
A. Barkana et al. (2000)	Case series	IV	5	Israel (4.5 years)	44	NR	Penetrating trauma	Unadjusted
4. Increased scene time								
A. Brown et al. (2009)	Case series	IV	4	USA SMH (41 months)	641	28 (±11)	Penetrating Trauma (GSW)	Unadjusted
				NTDB (60 months)	75,210	30 (±13)		
5. Cervical spine injuries and spinal fracture								
A. Lin et al. (2011)	Retrospective cohort	III-2	6	Taiwan (24 months)	5139	38	Blunt trauma	Unadjusted
6. Increased intracranial pressure								
A. Lemyze et al. (2011)	Case study	NA	NA	NA	1	32	Blunt trauma by hanging	NA

[a] Based on the NHMRC (National Health and Medical Research Council of Australia) levels of evidence.
[b] NOS: Newcastle-Ottawa scale, scores out of a maximum 9 potential stars.
NR: not reported, SD: standard deviation, A/A: as above, GSW: Gun Shot Wounds, SMH: Strong Memorial Hospital, NTDB: National Trauma Data Bank.
I: A systematic review of level II studies II; II: A randomised controlled trial; III-1: A pseudorandomised controlled trial; III-2: A comparative study with concurrent controls; III-3: A comparative study without concurrent controls; IV: Case series.

Mortality rates

Vanderlan et al. conducted a retrospective chart review of admissions following penetrating neck trauma to a level 1 trauma centre in Louisiana, USA from 01/01/1994 to 17/4/2003 to evaluate the effect of spinal immobilisation on mortality. The authors reported a total mortality rate of 23% (35/153), with 94% of injuries due to gunshot wounds (GSW), and a predominantly male population (91%; 32/35) [33].

Among the thirty-five fatalities, twenty-seven were immobilised and eight were not. The authors reported that c-spine immobilisation was associated with an unadjusted higher risk of death compared to non-immobilisation in isolated cervical spine injuries ($n = 107$), (OR, 8.82; 95% CI, 1.09–194; $p = 0.038$). It was also associated with an unadjusted increased risk of mortality among all subjects ($n = 188$) included in the study (OR, 2.77; 95% CI, 1.18–6.49; $p = 0.016$) [33].

In addition, c-spine immobilisation was associated with an unadjusted increased risk of cardiopulmonary resuscitation (CPR) on arrival to emergency department (OR, 3.53; 95% CI, 1.06–12.95; $p = 0.037$) [33]. The authors suggest possible reasons for this association may include masking of important clinical signs, blocked access to injury sites, and impaired intubation [33].

On the other hand, among patients with multiple penetrating trauma, c-spine immobilisation was not significantly associated with an unadjusted death on arrival to emergency departments nor with increased risk of death during their hospital stay [33].

Haut et al. also conducted a retrospective chart review including all penetrating trauma patients available in the American National Trauma Data Bank (NTDB) from 2001 to 2004. The study included 45,284 patients characterised by a median age of 29 years, 87.8% being male, and a total mortality rate of 8.1%. Only 4.3% underwent spinal immobilisation, with immobilised patients more likely to have moderate to severe injuries with an injury severity score (ISS) >15 compared to non-immobilised patients (31.2% vs 20.4%; $p < 0.001$). Furthermore, immobilised patients were more likely to have a complete spinal cord injury (1.4% vs 0.26%, $p < 0.001$), and to have spinal surgery (0.79% vs 0.30%; $p = 0.011$) [34].

The unadjusted mortality rate among the immobilised patients was double the mortality rate among the non-immobilised group (14.7% vs 7.2%; $p < 0.001$). This persisted after adjustment for confounders (AOR, 2.06; 95% CI, 1.35–3.13) such as sex, race, age, ISS, insurance status, year of admission and five prehospital procedures including endotracheal intubation, military anti-shock garment, intravenous fluids, splinting, and chest decompression. Even among patients with lower ISS (ISS < 15), spine immobilisation was independently associated with increased mortality (AOR, 3.40; 95% CI, 1.48–7.81) [34].

In both studies, the authors concluded that the harm associated with prehospital spinal immobilisation outweighs the potential benefits for patients with penetrating trauma [33,34]. Haut et al. have suggested that time spent on spinal immobilisation would be better used towards dealing with significant clinical conditions. They also called for prospective randomised studies to determine the impact of prehospital spinal immobilisation on penetrating trauma patients [34].

Neurological disability/deterioration (penetrating and blunt). A case series by Toscano included 123 patients who had sustained a significant blunt trauma to the spine. Patients were included if the event was in the state of Victoria, Australia, and if the patient was admitted to a large tertiary hospital with a spinal unit between 1/3/1983 and 28/12/1984 [40].

The author reviewed changes in neurological status between the time of injury and time of admission using the Frankel Classification, a 5-point ordinal scale that characterises the extent of neurological impairment (from grade A to E) and upon which the present international standards for neurological classification in SCI have been based [39]. The study also involved interviews with patients, witnesses of the accidents, and the paramedics and hospital staff who were involved in patient care prior to spinal unit admission [40].

Thirty-two (26%) patients had a major neurological deterioration between the time of injury and the time of admission to the Austin spinal injury unit. The author reports that SCI was not suspected in 19/32 (59%) patients, suggesting that neurological deterioration was a result of that patient not being immobilised, inadequately immobilised, or inappropriately handled [40].

Hauswald et al. retrospectively examined the neurological outcome after spinal immobilisation vs non-immobilisation in a 5-year chart review conducted at two university hospitals in the United States and Malaysia [37].

Four hundred and fifty-four patients were included in the study; the Malaysian sample consisted of 120 patients with an average age of 35 years who were predominantly males (88%); while the US sample included 334 patients with an average age of 33 years of whom 77% were male. In both countries, the paramedic crews transferred all patients from the scene to the study hospital directly, excluding interhospital transports. All US patients received spinal immobilisation, whereas none of the Malaysian patients had any type of spinal immobilisation [37].

Adjusting for age, sex, level of injury, and mechanism of injury, the authors reported that the odds of neurological injury in the immobilised group were double the odds of suffering a neurological injury in the non-immobilised group (AOR, 2.03; 95% CI, 1.03–3.99; $p = 0.04$). The authors suggest that spinal immobilisation may increase the risk of neurological injury secondary to tissue hypoxia that may have resulted from delayed resuscitation, or that the benefit of spinal immobilisation is very small [37]. The authors also concluded that spinal immobilisation does not appear to have a significant benefit in preventing neurological deterioration from unstable spinal fractures, as the majority of trauma patients did not have a confirmed SCI [37].

Brown et al. retrospectively reviewed all penetrating trauma to the torso from the Strong Memorial Hospital (SMH) and the NTDB trauma registry in the US. Both datasets included patients with penetrating trauma due to gunshot wound (GSW), although the SMH dataset excluded those patients with isolated GSW to the head or neck [36].

The NTDB population included 75,210 patients from 2001 to 2005, with a mean age of 30 (SD $\pm$ 13) years, 89.7% males, and a mean ISS of 13 (SD $\pm$ 13). Only 26 (0.03%) patients had vertebral fractures without a SCI and required spinal surgery [36].

The SMH data included 357 patients with penetrating GSW to the torso, excluding those with neck injuries, over a 41 month period from 1/1/2003 to 1/6/2007. Cases had a mean age of 28 (SD $\pm$ 11) years, were predominantly males (90.4%), and had a mean ISS score of 15 (SD $\pm$ 13). Among these, 54% underwent spinal immobilisation. None of the 357 patients required surgical spinal stabilisation [36].

The authors argue that little benefit from prehospital spinal immobilisation could have been achieved, as the GSW results in direct injuries to the spinal cord and call for multicentre prospective studies to define the role of prehospital spinal immobilisation for penetrating trauma [36].

C-spine injuries and spinal fractures. Lin et al. evaluated the application of c-collars to patients with cervical spine injury after lightweight motorcycle accidents in Taiwan, defining the c-spine injury as any change in the neurological status resulting from bony lesion of the cervical spine or SCI. Over the period from 1/1/2008 to 12/31/2009, 5139 cases were included in the study with a mean age of 38 years and with 55% being males. Sixty three (1.2%) patients had a cervical spine injury confirmed at hospital, of which fifty nine patients (93%) were isolated injuries, and sixteen patients (25%) received surgical interventions [39].

Spinal immobilisation was applied to 50.7% of the 5139 cases; with 51 of the 63 confirmed SCI cases (80.9%) arriving at hospital with a c-collar in place. Upon comparing the two groups, immobilised vs non-immobilised, no significant correlation with cervical spine injury was observed (X^2, $p = 0.896$). Moreover, the authors have reported that, among patients with c-collars, there was a significant correlation between supraclavicular lesion, neck pain and neurologic deficit (X^2, all $p < 0.001$) [39].

The authors also reported a longer ICU stay for patients with Cervical SCI compared to those without a spinal cord injury (7.54 ± 7.93 vs 2.33 ± 1.63 days; $p = 0.002$), whereas no difference was found in the total length of hospital stay (17.43 ± 9.35 vs 12.00 ± 8.89, $p = 0.154$). The authors suggest that c-spine immobilisation is an overprotective practice, and recommend revaluating the spinal immobilisation protocol, as well as conducting large prospective studies to validate the necessity of c-collars for pre-hospital transport [39].

Concealing neck injuries

Barkana et al. retrospectively reviewed battlefield causalities in Israel over a 4.5 year period. The study included 44 casualties of penetrating trauma consisting of 36 medical charts and 8 autopsy reports. The results suggest that signs of life-threatening conditions, including tracheal deviation, subcutaneous emphysema, large expanding haematoma, and diminished or absent carotid pulses, may have been hidden by c-collars [35].

Increased scene time. Brown et al. reported that in the SMH group immobilised patients had a scene time double that of the transport time to the trauma centre as compared to non-immobilised patients (unadjusted analysis). They suggest that prehospital spinal immobilisation is a labour intensive practice that increases scene time [36].

Increased ICP. One case study, of a 43-year-old man who attempted suicide by strangulation, reported that neurological status improved after removing the c-collar. The authors suggested that c-collar may have caused an increase in intracranial pressure (ICP) due to compression of the neck vasculature and recommended that c-collars should be avoided when dealing with such cases [38].

Quality assessment

The quality of studies was generally low and scores according to the NOS ranged from four to seven stars out of a possible nine stars as shown in Fig. 2. It should be noted that the case study was excluded from this evaluation, as the scale was not applicable to this type of study.

Two retrospective cohorts had limited comparisons between the exposure groups and lacked adjustment for confounders [33,37]. In Vanderlan et al's study, the results seem to be based on the unadjusted odds ratio, as the authors have not stated any adjustment for important confounders such as age, sex, or ISS [33]. Moreover, although Hauswald et al. have adjusted the analysis for age and sex, their study lacks adjustment for other key confounders such as ISS scores, which is a significant issue given that the exposed and unexposed groups are derived from different populations [37].

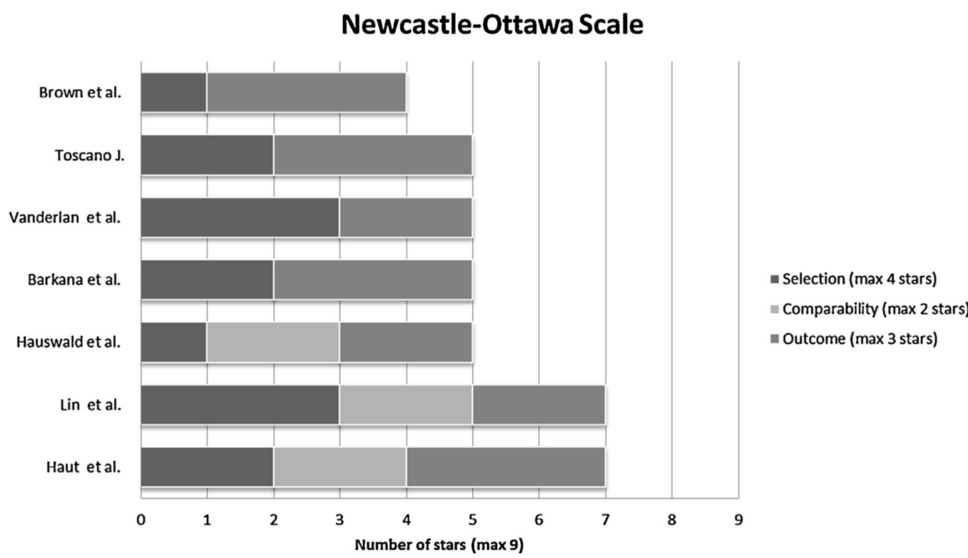

Fig. 2. Quality assessment using the Newcastle-Ottawa scale (NOS).

The absence of critical information made the quality assessment of the studies challenging. Five studies lacked adjustment for key confounders such as ISS, age, sex, and mechanism of injury [33,35,36,39,40], and two studies lacked reporting on patient demographics, limiting the ability to ascertain internal and external validity [35,40].

Vanderlan et al. have based their results on a subset of the patient cohort ($n = 153$) and failed to explain 35 patient charts which were excluded from review [33]. Another two studies lacked reporting on loss to follow up [37,39].

Finally, Lin et al. were inconsistent when reporting the c-collar's association with the ICU length of stay; stating in the abstract that patients with a c-collar had a longer ICU stay compared to patients without one. However, in the results section, this comparison was related to patients with and without spinal injury (7.54 ± 7.93 vs 2.33 ± 1.63 days; $p = 0.002$), again making interpretation of the results difficult [39].

Risk of bias

Fig. 3 provides a summary risk of bias assessment across each domain. All 7 studies had at least moderate risk of bias in one domain, most with moderate to high risk across numerous

Table 2
A summary of search terms.

Prehospital	Immobilisation	Spinal cord injury	Outcome
Emergency medical services	Immobili* or mobility	Spinal cord injury	Outcome
Emergency medical technicians	Immobilization	Spinal cord injuries	Recovery
Emergency treatment	Immobilisation	Spinal Injuries	Follow up or follow-up
Emergency medicine	Collar*	Neck injuries	After discharge
Air ambulances	Headblock*	Whiplash	Mortality
First aid	Sandbag*	"Spinal trauma"	Morbidity
Military medicine	Kendrick	"c-Spine injury*"	Sequelae or sequel
Ambulances	Spine board*	Spine	Consequences
Prehospital	Splint	Spinal	Aftereffect
Pre-hospital	Backboard*	Cervical	Quality of Life
Paramedic*	Vacuum splint*	Concussion	Health Related Quality of Live (HRQOL)
Ambulance*	Vacuum mattress		Functional
Out-of-hospital	Strap*		Activities of Daily Living (ADL's)
Out of hospital	Scoop stretcher		Complications
EMS	Log roll		
EMT	Orthosis		
Emergency services	Tapes or taping		
Emergency medical service*	Neutral position		
Emergency technician	Orthotic		
Emergency practitioner*	Orthotic devices		
Emergency dispatch*			
Emergency despatch*			
First responder*			
Public access defibrillation			
Emergency rescue			
Emergency resus*			
Emergency triage			
Advanced life support			
Community support co-ordinator			
Community support coordinator			
Emergency care practitioner			
Extended care practitioner			

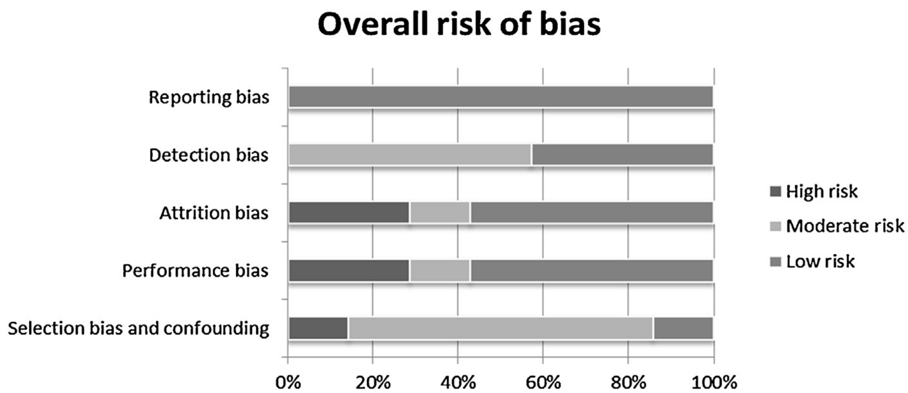

Fig. 3. Overall risk of bias.

domains. It should be noted that the case study was excluded from this assessment.

Strength of evidence

Based on the NHMRC matrix, the strength of evidence is identified to be poor, with poor consistency, poor clinical impact, poor generalizability, and poor applicability to the Australian health care system [30].

Discussion

The practice of prehospital spinal immobilisation in patients with blunt trauma to the cervical spine may be an overly conservative practice, which has no or little benefit and possible adverse effects on neurological outcomes. Only one older case series study in Australia conducted in 1988 suggested that spinal immobilisation improved neurological outcomes. However, it should be noted that this was a small study that lacked adjustment for confounders and adequate description of the study sample [40].

There is agreement in the literature that the use of c-collars is harmful to penetrating trauma patients as it leads to increased mortality rates, concealed significant injuries, increased transport time, and may have a little benefit for patients. The studies in this review support two recently published position statements in that prehospital cervical and spinal immobilisation should be more selective and avoid spinal immobilisation for all penetrating trauma. These included the recommendations by the Prehospital Trauma Life Support Executive Committee [41], and the Position statement entitled "EMS spinal precautions and the use of the long backboard" [42]. Furthermore, this review supports a recent critical review in that the use of c-collars outweighs its benefits, and that its use should be minimised through the use of cervical clearance protocols. This systematic review, however, only includes primary studies that are based in the prehospital setting and were performed in adult human subjects with traumatic spinal injuries, excluding literature and systematic reviews, protocol validation studies, and studies that included healthy volunteers.

Vanderlan et al. and Haut et al. reported that prehospital spinal immobilisation is associated with increased mortality rate in patients with penetrating trauma [33,34]. Vanderlan et al. however reported that among patients with multiple penetrating trauma, c-spine immobilisation was not significantly associated with death on arrival or increased risk of death during their hospital stay [33]. We speculate that this may be due to death being related to other critical injuries however the numbers included in this study (n = 188) are quite small, results were unadjusted and it is not clear whether the study was adequately powered to detect a difference between those who were immobilised and those who were not for this sub-group. Moreover, Haut et al. reported that other prehospital procedures may be associated with increased mortality, but this was not adjusted for as a confounding factor [34].

In a very small study, Barkana et al. concluded that there was no benefit from spinal immobilisation to the studied population consisting of 44 casualties of penetrating trauma, and recommended a re-evaluation of routine spine immobilisation, where avoiding collars in such circumstances should be the primary rule [35].

Brown et al. reported that the number of National Trauma Data Bank patients who might have benefited from spinal immobilisation was negligible and the benefit from its use remains to be determined. However, this study provided limited details regarding prehospital spinal immobilisation procedures and relied on International Classification of Disease (ICD-9) coding to identify the 26 patients. In addition, although the authors reported that a longer scene time was associated with spinal immobilisation, this was limited to the Strong Memorial Hospital group only and it also lacked adjustment for confounding factors such as ISS and age [36].

The decision to apply the cervical collar might be a surrogate for the EMS responder's clinical concerns that the patient has a true cervical spine injury. It would be anticipated that all patients with altered mental status or abnormal neurological exams were more likely to have a cervical collar applied, compared to those patients who were alert, oriented, and able to move their extremities. There is likely a selection bias whereby the more critically ill are at increased risk of death from their injuries and are being placed more frequently in cervical collars.

Strength and limitations

Although this systematic review has a comprehensive search strategy, some studies might have been missed. However, reference lists of eligible studies were manually searched, where an additional 60 potential studies were identified, but none met the inclusion criteria. Moreover, a meta-analysis was not possible due to the substantial heterogeneity in study design and outcome measures. Therefore, the primary findings are discussed using a thematic approach, summarising the study characteristics where possible.

Finally, the recommended Newcastle-Ottawa Scale used to assess the quality for cohort and case series studies [23]. The cohort studies and case series quality assessment tools have a tendency to score the studies higher than the quality assessors considered warranted. This was due to the scoring criteria lacking sufficient options resulting in higher scores.

Conclusion and recommendations

There is evidence in the literature that cervical spine and spinal immobilisation should be avoided when dealing with penetrating neck trauma. The practice of spinal immobilisation remains controversial in regards to its possible benefits, or harms, in blunt trauma patients.

This systematic review demonstrates a lack of high-level evidence about the impact of prehospital spinal immobilisation on patient outcomes. While it supports recommendations from previous studies stressing the importance of conducting well-designed, prospective studies, including randomised controlled trials to investigate this association, ethical, consent and potential medico-legal issues are barriers to conducting such studies in the prehospital setting. In addition, there is concern about the consequence of not immobilising patients with suspected spinal cord injuries and the ability of paramedics to adequately screen patients for eligibility in such trials.

Large cohort studies may identify the key predictors associated with subsequent confirmed spinal cord injuries. Such studies could provide a better understanding of the harm and benefits associated with prehospital spinal immobilisation, optimise the cervical clearance criteria to be generalisable to different prehospital settings, and potentially improve the paramedics' accuracy of diagnosing patients with spinal cord injuries.

Comparative studies are also required to inform the safety of restricting the use of cervical and spinal immobilisation. This could be achieved by conducting further outcome studies that compare different jurisdictions with similar EMS systems, yet recommend different spinal immobilisation practices. An alternate research design may be a before and after study, comparing outcomes before and after refinement of prehospital spinal immobilisation guidelines.

Conflict of interest statement

The authors declare that they have no conflict of interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.injury.2014.12.032.

References

[1] Furlan JC, Sakakibara BM, Miller WC, Krassioukov AV. Global incidence and prevalence of traumatic spinal cord injury. Can J Neurol Sci 2013;40:456–64.
[2] Pickett GE, Campos-Benitez M, Keller JL, Duggal N. Epidemiology of traumatic spinal cord injury in Canada. Spine 2006;31:799–805.
[3] Kattail D, Furlan JC, Fehlings MG. Epidemiology and clinical outcomes of acute spine trauma and spinal cord injury: experience from a specialized spine trauma center in Canada in comparison with a large national registry. J Trauma-Inj Infect Crit Care 2009;67:936–43.
[4] Sekhon LH, Fehlings MG. Epidemiology, demographics, and pathophysiology of acute spinal cord injury. Spine 2001;26:S2–12.
[5] O'Connor P. Incidence and patterns of spinal cord injury in Australia. Accid Anal Prev 2002;34:405–15.
[6] Akmal M, Trivedi R, Sutcliffe J. Functional outcome in trauma patients with spinal injury. Spine 2003;28:180–5.
[7] Burton JH, Harmon NR, Dunn MG, Bradshaw JR. EMS provider findings and interventions with a statewide EMS spine-assessment protocol. Prehosp Emerg Care 2005;9:303–9.
[8] Celani MG, Spizzichino L, Ricci S, Zampolini M, Franceschini M, Retrospective Study Group on SCI. Spinal cord injury in Italy: a multicenter retrospective study. Arch Phys Med Rehabil 2001;82:589–96.
[9] Pickett W, Simpson K, Walker J, Brison RJ. Traumatic spinal cord injury in Ontario, Canada. J Trauma-Inj Infect Crit Care 2003;55:1070–6.
[10] Devivo M. Epidemiology of traumatic spinal cord injury: trends and future implications. Spinal Cord 2012;50:365–72.
[11] Bulger EM, Maier RV. Prehospital care of the injured: what's new. Surg Clin North Am 2007;87:37–53. vi.
[12] Kwan I, Bunn F, Roberts I. Spinal immobilisation for trauma patients. Cochrane Database Syst Rev 2001;CD002803.
[13] Del Rossi G, Heffernan TP, Horodyski M, Rechtine GR. The effectiveness of extrication collars tested during the execution of spine-board transfer techniques. Spine J 2004;4:619–23.
[14] Miglietta MA, Levins T, Robb TV. Evaluation of spine injury in blunt trauma. J Am Osteopath Assoc 2002;102:87–91.
[15] Vickery D. The use of the spinal board after the pre-hospital phase of trauma management. Emerg Med J 2001;18:51–4.
[16] Geisler FH, Coleman WP, Grieco G, Poonian D, Sygen Study Group. Recruitment and early treatment in a multicenter study of acute spinal cord injury. Spine 2001;26:S58–67.
[17] Stroh G, Braude D. Can an out-of-hospital cervical spine clearance protocol identify all patients with injuries? An argument for selective immobilization. Ann Emerg Med 2001;37:609–15.
[18] Hankins DG, Rivera-Rivera EJ, Ornato JP, Swor RA, Blackwell T, Domeier RM, et al. Spinal immobilization in the field: clinical clearance criteria and implementation. Prehosp Emerg Care 2001;5:88–93.
[19] Belanger E, Levi AD. The acute and chronic management of spinal cord injury. J Am Coll Surg 2000;190:603–18.
[20] Domeier RM, Frederiksen SM, Welch K. Prospective performance assessment of an out-of-hospital protocol for selective spine immobilization using clinical spine clearance criteria. Ann Emerg Med 2005;46:123–31.
[21] Kang DG, Lehman Jr RA. Spine immobilization: prehospitalization to final destination. J Surg Orthop Adv 2011;20:2–7.
[22] Oteir A, Smith K, Jennings P, Stoelwinder J. The prehospital management of suspected spinal cord injury: an update. Prehosp Disaster Med 2014;29:399–402.
[23] Benger J, Blackham J. Why do we put cervical collars on conscious trauma patients? Scand J Trauma Resusc Emerg Med 2009.
[24] Davies G, Deakin C, Wilson A. The effect of a rigid collar on intracranial pressure. Injury 1996;27:647–9.
[25] Oteir AO, Jennings PA, Smith K, Stoelwinder J. Should suspected cervical spinal cord injuries be immobilised? A systematic review protocol. Inj Prev 2014;20:e5.
[26] Smith E, Archer F, Jennings P, Wasiak J, McDonald S, MacPherson C. The development of a prehospital search filter for the Cochrane Library. Aust J Paramed 2012;2:13.
[27] Hootman JM, Driban JB, Sitler MR, Harris KP, Cattano NM. Reliability and validity of three quality rating instruments for systematic reviews of observational studies. Res Synth Methods 2011;2:110–8.
[28] Wells G, Shea B, O'connell D, Peterson J, Welch V, Losos M, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses; 2000, http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp [accessed 12.03.14].
[29] Duggal A, Perez P, Golan E, Tremblay L, Sinuff T. Safety and efficacy of noninvasive ventilation in patients with blunt chest trauma: a systematic review. Crit Care 2013;17:R142.
[30] Coleman K, Norris S, Weston A, Grimmer K, Hillier S, Merlin T, et al. NHMRC additional levels of evidence and grades for recommendations for developers of guidelines. Canberra: NHMRC; 2005.
[31] Higgins JP, Green S. Cochrane handbook for systematic reviews of interventions. Wiley Online Library; 2008.
[32] Viswanathan M, Ansari MT, Berkman ND, Chang S, Hartling L, McPheeters M, et al. Assessing the risk of bias of individual studies in systematic reviews of health care interventions; 2012, http://www.effectivehealthcare.ahrq.gov/ehc/products/322/998/MethodsGuideforCERs_Viswanathan_IndividualStudies.pdf [accessed 11.05.14].
[33] Vanderlan WB, Tew BE, McSwain NE. Increased risk of death with cervical spine immobilisation in penetrating cervical trauma. Injury 2009;40:880–3.
[34] Haut ER, Kalish BT, Efron DT, Haider AH, Stevens KA, Kieninger AN, et al. Spine immobilization in penetrating trauma: more harm than good? J Trauma 2010;68:115–20. discussion 20–21.
[35] Barkana Y, Stein M, Scope A, Maor R, Abramovich Y, Friedman Z, et al. Prehospital stabilization of the cervical spine for penetrating injuries of the neck – is it necessary? Injury 2000;31:305–9.
[36] Brown JB, Bankey PE, Sangosanya AT, Cheng JD, Stassen NA, Gestring ML. Prehospital spinal immobilization does not appear to be beneficial and may complicate care following gunshot injury to the torso. J Trauma 2009;67:774–8.
[37] Hauswald M, Ong G, Tandberg D, Omar Z. Out-of-hospital spinal immobilization: its effect on neurologic injury. Acad Emerg Med 1998;5:214–9.
[38] Lemyze M, Palud A, Favory R, Mathieu D. Unintentional strangulation by a cervical collar after attempted suicide by hanging. Emerg Med J 2011;28:532.
[39] Lin H-L, Lee W-C, Chen C-W, Lin T-Y, Cheng Y-C, Yeh Y-S, et al. Neck collar used in treatment of victims of urban motorcycle accidents: over- or underprotection? Am J Emerg Med 2011;29:1028–33.
[40] Toscano J. Prevention of neurological deterioration before admission to a spinal cord injury unit. Paraplegia 1988;26:143–50.
[41] Stuke LE, Pons PT, Guy JS, Chapleau WP, Butler FK, McSwain NE. Prehospital spine immobilization for penetrating trauma – review and recommendations from the Prehospital Trauma Life Support Executive Committee. J Trauma-Inj Infect Crit Care 2011;71:763–9. discussion 9–70.
[42] National Association of EMS Physicians and the American College of Surgeons Committee on Trauma. EMS spinal precautions and the use of the long backboard. Prehosp Emerg Care 2013;17:392–3.