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SYSTEMATIC REVIEW

Spinal immobilisaton in pre-hospital and emergency care: A systematic review of the literature

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Summary
Background: Spinal immobilisation has been a mainstay of trauma care for decades and is based on the premise that immobilisation will prevent further neurological compromise in patients with a spinal column injury. The aim of this systematic review was to examine the evidence related to spinal immobilisation in pre-hospital and emergency care settings.
Methods: In February 2015, we performed a systematic literature review of English language publications from 1966 to January 2015 indexed in MEDLINE and Cochrane library using the following search terms: 'spinal injuries' OR 'spinal cord injuries' AND 'emergency treatment' OR 'emergency care' OR 'first aid' AND immobilisation. EMBASE was searched for keywords 'spinal injury OR 'spinal cord injury' OR 'spine fracture AND 'emergency care' OR 'prehospital care'.
Results: There were 47 studies meeting inclusion criteria for further review. Ten studies were case series (level of evidence IV) and there were 37 studies from which data were extrapolated from healthy volunteers, cadavers or multiple trauma patients. There were 15 studies that were supportive, 13 studies that were neutral, and 19 studies opposing spinal immobilisation.

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Conclusion: There are no published high-level studies that assess the efficacy of spinal immobilisation in pre-hospital and emergency care settings. Almost all of the current evidence is related to spinal immobilisation is extrapolated data, mostly from healthy volunteers.

What is known

- Spinal immobilisation is a mainstay of trauma management in pre-hospital and emergency care environments.
- Spinal immobilisation is frequently used in pre-hospital and emergency care environments.

What this paper adds?

- There is no high level evidence to assess the efficacy of spinal immobilisation in the pre-hospital or emergency settings.
- There is evidence that for some patients spinal immobilisation causes harm.
- Decisions to use spinal immobilisation should be based on careful assessment of risk vs benefit in individual patients.

Introduction

Spinal immobilisation has been a key recommendation in the management of trauma patients for decades.[1,2] Current spinal immobilisation practices are based on the premise that immobilisation will prevent further neurological compromise in patients with a spinal column injury.[1] In Australia, the latest reported statistics on spinal injuries are from 2007 to 2008; during that year there were 362 new cases of spinal cord injury reported by spinal units, 285 of which were related to trauma.[3] The average age of Australians who sustained a traumatic spinal injury was 42 years (SD = 20) and 84% were male.[3] The most common causes of traumatic spinal cord injury were transport incidents (46%), falls (28%), water related injuries (swimming, diving, surfing or falling into water) (9%) and being struck or colliding with an object or person (9%).[3] Cervical spine injuries were the most common injury (53%) followed by thoracic spine injuries (32%). The majority of cervical spine injuries (61%) involved C4—C5 and 11% of cases had neurological impairment at the level of the thoraco-lumbar junction (T12/L1).[3]

The two most dominant decision support rules used in determining the need for cervical spine immobilisation are the NEXUS criteria from the National Emergency X-Radiography Utilisation Study and Canadian C-Spine rules.[4,5] It should be noted however, that both of these decision support tools aim to guide decisions regarding cervical spine imaging, and their results have been extrapolated to guide decisions regarding cervical spine immobilisation. The National Emergency X-Radiography Utilisation Study (NEXUS) found that patients meeting the following five criteria have a low probability of cervical spine injury and therefore do not require routine imaging studies; no midline cervical tenderness, no focal neurological deficit, normal state of alertness, no intoxication and no painful distracting injury.[4] The NEXUS criteria has a sensitivity (true positive rate) of 99% and specificity (true negative rate) of 12.9% for both all patients and patients with clinically significant injuries. The false negative rate (failure to detect a cervical spine injury) was 0.9%.[4] The Canadian C-Spine Rule comprises three main criteria to determine the need for cervical spine radiography.[5] Imaging is recommended in patients[5]:

(i) with high-risk factors that mandate radiography (age ≥65 years, dangerous mechanism of injury or extremity paraesthesia);
(ii) with the absence of low-risk factors that allow safe assessment of range of motion (simple rear-end motor vehicle collision, sitting position in emergency department (ED), ambulation post the injury, delayed onset of neck pain, or the absence of midline cervical spine tenderness); and
(iii) in patients unable able to actively rotate neck 45° to the left and right.[5]

The Canadian C-Spine Rule has 100% sensitivity and 42.5% specificity.[5] There are no validated decision support tools for imaging or spinal immobilisation for patients at risk of thoracic, lumbar or sacral spinal injury.[6] In the main, references to spinal immobilisation for these patients tend to be in the context of general recommendations for the management of trauma patients.[2,6,7]

In recent years, there have been a number of studies that have called the efficacy and effectiveness of spinal immobilisation into question. A Cochrane review in 2001 of 4453 potentially relevant articles found no randomised controlled trials to support the use of spinal immobilisation in either blunt or penetrating trauma.[8] A systematic review of randomised trials, published in 2005, examined the effects of pre-hospital spinal immobilisation on healthy subjects and found that although cervical collars, spine boards, vacuum splints, and abdominal/torso strapping provided significant reduction in spinal movement, spinal immobilisation also resulted in a number of adverse effects such as increased respiratory effort, skin ischaemia, pain and discomfort.[9] Further, it is not known whether spinal immobilisation during pre-hospital and emergency care is effective in preventing secondary spinal cord injuries.[10]

Aim

The aim of this systematic review was to examine the evidence related to spinal immobilisation in pre-hospital and emergency care settings. Specifically, we sought to answer the question: ''*In victims with suspected spinal injury, does the use of spinal immobilisation during pre-hospital or emergency care (in-line manual immobilisation,*

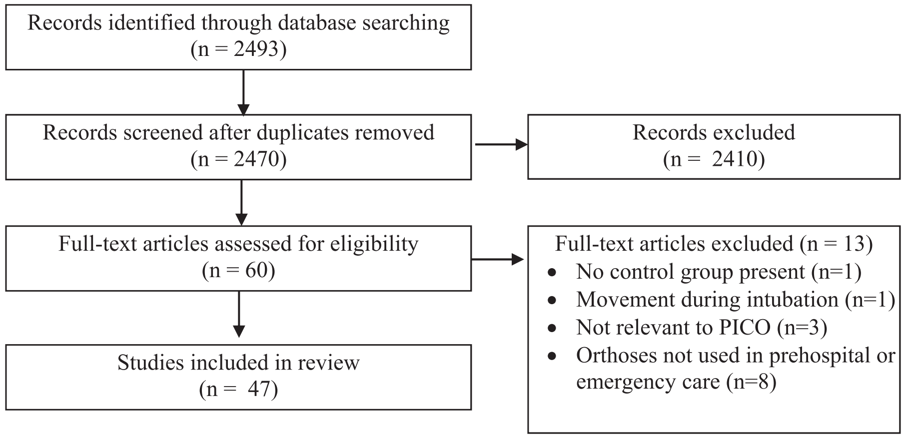

Figure 1 Summary of search results.

head blocks, spinal boards, cervical collars), compared with no immobilisation, effect neurological outcome or other outcomes (prevention of movement, spinal positioning/alignment, comfort or pain, and complications)?''

Method

In February 2015, we performed a systematic literature review of English language publications from 1966 to February 2015 indexed in MEDLINE and Cochrane library using the search terms: 'spinal injuries' OR 'spinal cord injuries' AND 'emergency treatment' OR 'emergency care' OR 'first aid' AND immobilisation. EMBASE was searched for keywords 'spinal injury OR 'spinal cord injury' OR 'spine fracture AND 'emergency care' OR 'prehospital care'. Adjacent terms for both searches were

- 'spin$ or cerv$ or lumbar or thora$ or neck or back'
- 'injur$' or 'trauma'
- stabili* or immobili* or collar or back?board or spine?board or strap* or tap* or headblock or sand?bag* or orthosis

Scopus and Google Scholar were also searched using both backward and forward strategies for keywords contained in unpublished documents. We hand searched the reference lists of all relevant articles.

The combined searches outlined above yielded 2470 studies that were assessed for inclusion as evidence. Studies examining the effectiveness of spinal immobilisation in the emergency care of suspected traumatic spinal injuries and studies of the patients with suspected spinal injuries or studies of healthy human volunteers were included in the review. The outcomes of interest were neurological outcome, prevention of movement, spinal positioning/alignment, comfort or pain, and complications. Studies excluded from this review were non-systematic reviews, opinion papers, abstract-only studies, animal studies, studies examining advanced or surgical spinal stabilisation, studies examining helmet removal techniques, use of spinal orthoses not used in emergency care, or movement during intubation and studies reporting on spinal clearance criteria. Both authors examined the electronic search results for reports of possibly relevant trials and these reports were retrieved in full. Both authors applied the selection criteria independently to the trial reports, resolving disagreements by discussion and a consensus process. A summary of the search results is presented in Fig. 1.

Table 1 Australian National Health and Medical Research Council levels of evidence[11].

Level I	Evidence obtained from a systematic review of all relevant randomised controlled trials
Level II	Evidence obtained from at least one properly designed randomised controlled trials
Level III-1	Evidence obtained from well designed pseudo-randomised controlled trials (alternate allocation or other method)
Level III-2	Evidence obtained from comparative studies with concurrent controls and allocation not randomised (cohort studies), case control studies, or interrupted time series with a control group.
Level III-3	Evidence obtained from comparative studies with historical control, two or more single arm studies, or interrupted time series without a parallel control group
Level IV	Evidence obtained from case series, either post-test or pre-test and pos-test

We classified identified studies using the Australian National Health and Medical Research Council levels of evidence (LOE)[11] (Table 1) and the quality of evidence was assessed according to Australian Resuscitation Council (ARC) criteria.[12] Quality of evidence was classified as[12]:

- good (methodological quality of the study is high with the likelihood of any significant bias being minimal),
- fair (methodological quality of the study is high with the potential for significant bias being likely), or
- poor (methodological quality of the study is weak possessing considerable and significant biases).

Results

There were 47 studies meeting inclusion criteria for further review. Ten studies were case series (LOE IV) and there were

Table 2 Methodological quality, levels of evidence and outcomes of studies examining spinal immobilisation for suspected spinal injury.

Good[12]	**Fair**[12]	**Poor**[12]
The methodological quality of the study is high with the likelihood of any significant bias being minimal.	The methodological quality of the study is reasonable with the potential for significant bias being likely.	The methodological quality of the study is weak possessing considerable and significant biases.

1. Studies *supportive* of spinal immobilisation							
Good							
Fair							Cline et al.[24] (B) Graziano et al.[25] (B) Schriger et al.[38] (C) Nypaver et al.[37] (C) DeLorenzo et al.[36] (C) Krell et al.[26] (B)
Poor						Treloar et al.[40] (C)	Podolsky et al.[29] (B) Huerta et al.[23] (B) Burl[32] (B) Rosen et al.[31] (B) Mazolewksi et al.[28] (B) Gunn et al.[39] (C) Boissy et al.[27] (B) Engsberg et al.[35] (B)
NHMRC LOE	I	II	III-1	III-2	III-3	IV	Extrapolated evidence
2. Studies *neutral* for spinal immobilisation							
Good							
Fair						Arishita et al.[16] (A) Hauswald et al.[10] (A) Flabouris et al.[14] (A) Cornwell et al.[15] (A) Brown et al.[13] (A) Lin et al.[18] (A)	Dodd et al.[54] (E) Perry et al.[30] (B) Conrad et al.[21] (B)
Poor						Ramasamy et al.[17] (A)	Hamilton et al.[33] (B) Del Rossi et al.[22] (B) Horodyski et al.[34] (B)
NHMRC LOE	I	II	III-1	III-2	III-3	IV	Extrapolated evidence
3. Studies *opposing* spinal immobilisation							
Good							
Fair						Haut et al.[19] (A)	Schafermeyer et al.[47] (E) Cordell et al.[41] (D) Walton et al.[44] (D) Davies et al.[46] (E) Lerner et al.[43] (D) Totten and Sugarman[48] (E) Hauswald et al.[42] (D) Hunt et al.[58] (E) Ben-Galim et al.[20] (B) Stone et al.[57] (E)
Poor						Kolb et al.[51] (E)	Liew and Hill[49] (E) Raphael et al.[53] (E) Chan et al.[45] (D) Main et al.[55] (E) Houghton and Curley[50] (E) Mobbs et al.[52] (E) Sheerin and deFrein[56] (E)
NHMRC LOE	I	II	III-1	III-2	III-3	IV	Extrapolated evidence

Outcomes: A, improve neurological outcome; B, Prevention of movement; C, optimise spinal positioning/alignment; D, improve comfort/decrease pain; E, cause medical complications.
NHMRC, National Health and Medical Research Council (Australia); LOE, levels of evidence.

Table 3 Effect of spinal immobilisation on neurological outcome.

Study	Level of evidence/quality of evidence	Opposing/neutral/supportive of spinal immobilisation	Design	Sample	Major findings
Arishita et al.[16]	IV/Fair	Neutral	Retrospective analysis	Data for casualties with penetrating neck injuries from the Vietnam conflict ($n = 472$)	• Penetrating cervical cord injury was always fatal and usually immediately so • 11/472 patients with spinal column injury survived long enough to receive first aid • None were judged to have clear benefit from immobilisation, 4/11 may have possible benefit from immobilisation and 7/11 would have had no benefit from immobilisation • The risk of performing immobilisation in a hazardous environment is substantial: 11% of casualties were wounded assisting others
Hauswald et al.[10]	IV/Fair	Neutral	Retrospective analysis	Patients with acute blunt traumatic spinal or spinal cord injuries 334 patients with and 120 patients without spinal immobilisation during transport	• There was less neurologic disability in the unimmobilized patients (OR 2.03; 95% CI 1.03—3.99; $p = 0.04$), corresponds to <2% chance that immobilisation has any beneficial effect • Results were similar when the analysis was limited to patients with cervical injuries (OR 1.52; 95% CI 0.64—3.62; $p = 0.34$)
Cornwell et al.[15]	IV/Fair	Neutral	Retrospective analysis	Patients with torso GSW ($n = 1000$)	• 141 patients (14.1%) had vertebral column and/or spinal cord injuries • 73 had complete neurological deficits, 58 had no deficits or incomplete lesion • 2 patients (0.2%) required operative vertebral column stabilisation, 6 patients required other operations for spinal decompression and/or foreign body removal • The presence of vertebral column injury was associated with lower mortality (7.1% vs 14.8%, $p < 0.02$)

Flabouris et al.[14]	IV/Fair	Neutral	Retrospective analysis	Patients with suspected isolated acute spinal injury ($n = 196$) Multiple trauma patients excluded.	• Injuries were 41% cervical, 10% lumbar, 8% thoracic, 2% mixed, 39% no injury • Medical team at scene diagnostic accuracy of spinal injury was 31% • 58% of patients had no abnormal neurology at scene • 80 patients had cervical spine injury: 52% had sensory and motor signs/symptoms, 16% sensory only and 32% no abnormal neurology • Incidence of abnormal neurological signs and/or symptoms was similar amongst patients with (50%) and without (46%) a confirmed spinal injury • Patients with a spinal injury had higher incidence of sensory and motor signs and/or symptoms (42% vs 17%) and less likely to have sensory only signs (8% vs 27%) ($p = 0.035$) • Cervical injuries as part of mixed injuries were the most often missed injuries • Cervical injuries were most likely to be over diagnosed: 18% of referrals were to exclude a suspected spinal injury, of which 34% were normal • No transport related neurological injury or other morbidity documented
Brown et al.[13]	IV/Fair	Neutral	Retrospective analysis	Prehospital spinal immobilisation in patients with torso gunshot wounds (GSW) ($n = 357$) or GSW (75,210) from US trauma registries.	• 9.2% torso GSW patients and 4.3% of GSW patients had spine injury • 51.5% of torso GSW patients and 32.3% of GSW patients had spinal cord injury • No torso GSW patient had an unstable spine fracture requiring surgical stabilisation without complete neurologic injury • No patients with spinal cord injury improved or worsened, and none developed a new deficit • 26 GSW patients (0.03%) had spine fractures requiring stabilisation in the absence of spinal cord injury • Emergent intubation was required in 40.6% of torso GSW patients and 33.8% of GSW patients and emergent surgical intervention was required in 54.5% of torso GSW patients and 43% of GSW patients • Benefit of prehospital spinal immobilisation in patients with torso GSW remains unproven, despite a potential to interfere with emergent care in this patient population

Table 3 (*Continued*)

Study	Level of evidence/quality of evidence	Opposing/neutral/supportive of spinal immobilisation	Design	Sample	Major findings
Ramasamy et al.[17]	IV/Poor	Neutral	Retrospective analysis	British military casualties of combat, from Iraq and Afghanistan presenting with a penetrating neck injury ($n = 90$)	• 73% sustained injuries from explosions and 27% from GSW • 20 casualties sustained cervical spine injuries: 6 survived to reach hospital, 4/6 died within 72 h • 1/56 survivors to reach a surgical facility sustained an unstable cervical spine injury that required surgical stabilisation: this patient later died as result of a co-existing head injury
Haut et al.[19]	IV/Fair	Opposing	Retrospective analysis	Patients from American College of Surgeons National Trauma Data Bank with penetrating trauma from 2001 to 2004 ($n = 45,284$). Excluded patients with blunt trauma or missing pre-hospital procedure data	• 4.3% underwent spinal immobilisation, 0.01% had an incomplete spinal cord injury and underwent operative spinal fixation, overall in-hospital mortality was 8.1% • Unadjusted in-hospital mortality was twice as high in patients who were immobilised (14.7% vs 7.2%, $p < 0.001$) •Odds ratio for death in spine-immobilised patients was 2.06 (95% CI: 1.35—3.13) • The number needed to treat to benefit one patient was 1032 patients and the number needed to harm to potentially contribute to one death was 66 patients
Lin et al.[18]	IV/Fair	Neutral	Retrospective analysis	Motorcycle crash victims ($n = 8633$)	• 63/8633 (0.7%) of patients had cervical spine injury • 47/63 (74.6%) had neurologic deficiency, 21/63 (33.3%) had neck pain and 20/63 (31.7%) had supraclavicular lesion, • Significant correlation between supraclavicular lesion and neck pain ($p < 0.001$) • No significant correlations between — Supraclavicular lesion and neurologic deficiency ($p = 0.653$) and intracranial lesion (=0.745) — Neck pain had no correlation with neurologic deficiency ($p = 0.653$) and intracranial lesion (=0.745) — Neurologic deficiency and intracranial lesion ($p = 0.085$) • Significant correlation in patients with neck collar between supraclavicular lesion, neck pain, and neurologic deficiency ($p < 0.001$) but no difference in patients with intracranial lesion ($p = 0.821$) • No significant correlation of cervical spine injury between the patients who had had the neck collar applied and those who had not ($p = 0.896$)

37 studies from which data were extrapolated from healthy volunteers, cadavers or multiple trauma patients; extrapolated data does not have a level of evidence. There were 15 studies that were supportive of spinal immobilisation, 13 studies neutral for spinal immobilisation and 19 studies opposing spinal immobilisation (Table 2).

Effect of spinal immobilisation on neurological outcome

There were eight studies that examined the effect of spinal immobilisation on neurological outcome (Table 3).[10,13–19] All were LOE IV studies of retrospective design, seven of fair quality and one of the poor quality. One study of patients with penetrating trauma opposed spinal immobilisation[19] reporting that the in-hospital mortality of spinal immobilised patients was more than double that of those who were not immobilised (14.7% vs 7.2%, $p < 0.001$). Seven studies reviewed against this outcome were neutral for spinal immobilisation.[10,13–18] Two studies of patients with torso gunshot wounds (GSW)[13,15] showed that few patients have an unstable spinal injury without complete spinal cord injury and thereby argued that spinal immobilisation was not of any actual or potential benefit. Further, Brown et al.[13] argued that 40.6% of patients with torso GSW required emergent endotracheal intubation and 54.5% required emergency surgical intervention so pre-hospital spinal immobilisation in these patients also carried a risk of interfering with emergent care.

There were two studies of patients with penetrating neck injuries[16,17] and both also raised issues of risk benefit ratio. Arishita[16] reported that only 1.4% of patients with penetrating neck injury who survived to require care (4/296) may have had possible benefit from immobilisation. However, 10% of penetrating neck injuries in a combat setting were incurred in personnel who were helping other casualties. Similarly Ramasamy et al.[17] reported that in patients surviving penetrating ballistic trauma to the neck, it is very unlikely that the injury will result in an unstable cervical spine and questioned whether cervical collars may hide potential life-threatening injuries. Both authors concluded that in hazardous environments, the risk benefit ratio of mandatory spinal immobilisation was unfavourable.[16,17] In patients suffering from blunt spinal trauma, Hauswald et al.[10] reported that spinal immobilisation had a less than 2% chance of having a beneficial effect in terms of neurological outcome. In patients who had suffered motorcycle accidents Lin et al. [18] observed that the incidence of cervical spine injury was low (0.7%), that injuries often involve more than two vertebrae and that most cervical spine injuries presented as stable. They concluded that patients who remain conscious without neurologic deficit, neck pain, or supraclavicular lesions may not need a cervical collar or immobilisation at the scene. Further, Flabouris et al.[14] highlighted the diagnostic challenge of identifying which patients require spinal immobilisation in the field, reporting a 31% diagnostic accuracy rate among medical teams in identifying patients with spinal injury.

Effect of spinal immobilisation on preventing movement

Sixteen studies examined the effect of spinal immobilisation on preventing movement (Table 4).[20–35] All were extrapolated data (four cadaver studies,[20–22,34] one manikin study[23] and eleven studies of healthy volunteers[24–33,35]). Ten studies were supportive of spinal immobilisation decreasing movement.[23–29,31,32,35] Four studies were neutral, reporting that immobilisation had no effect on movement when compared to no immobilisation.[21,22,30,34] One study produced conflicting results with increases in some movements and decreases in others[33] and one study opposed spinal immobilisation reporting increased separation between C1 and C2 when spinal immobilisation was in place.[20]

Effect of spinal immobilisation on optimal spinal positioning or alignment

Five studies examined the effect of spinal immobilisation on optimal spinal positioning or alignment (Table 5).[36–40] One study was LOE IV, conducted in injured children requiring cervical spine X-rays[40] and the remainder were extrapolated data from adult volunteers.[36–39] All were of poor methodological quality. All were supportive of the use of spinal immobilisation to optimise spinal alignment (Table 5). Two in adults[36,38] recommended occipital support and one study in children[37] recommended shoulder support to increase cervical spine alignment when immobilised on a back board. One study that focused on patient positioning found that the HAINES (High Arm IN Endangered Spine) modified recovery position resulted in less lateral flexion than the lateral recovery position.[39] The final study examined degree of cervical spine flexion with and without a semi-rigid cervical collar and found that collars decreased but did not eliminate cervical spine flexion.[40]

Effect of spinal immobilisation on decreasing pain or improving comfort

There were five studies that examined the effect of spinal immobilisation on decreasing pain or improving comfort (Table 6).[41–45] All studies presented extrapolated data from adult volunteers.[41–45] Four were of fair[41–44] and one was of poor[45] methodological quality. All opposed the use of spinal immobilisation to decrease pain or improve comfort. Three studies showed that padding a backboard increased patient comfort.[41,42,44] One study investigating the use of occipital padding in conjunction with a back board showed that following removal from the backboard, there was no significant difference in overall pain reports either immediately (76.9% vs 69.2%, $p < 0.45$) or at 24 h (17.9% vs 23.1%, $p < 0.63$). However, the majority of patients in both groups reported pain immediately after backboard removal.[43] In a study comparing backboards with vacuum mattress-splints, there were fewer complaints of occipital and lumbosacral pain in the group immobilised using the vacuum mattress-splint.[45] Two studies also showed that the use of unpadded spinal boards increased board-tissue interface pressure.[41,44]

Table 4 Effect of spinal immobilisation on preventing movement.

Study	Level of evidence/quality of evidence	Opposing/neutral/supportive of spinal immobilisation	Design	Sample	Major findings
Cline et al.[24]	Extrapolated data/Fair	Supportive	Randomised trial	Adult volunteers ($n = 97$) randomised to one of the seven methods of cervical spine immobilisation	• Short board was superior to all three collars studied (Philadelphia, Hare extrication, rigid plastic) • Collars provided no further immobilisation over that provided by short board alone
Graziano et al.[25]	Extrapolated data/Fair	Supportive	Prospective, non-randomised, crossover study	Adult volunteers ($n = 45$) immobilised in the short board and one of the test devices studied	• Short board was significantly better ($p < 0.05$) than Stiff-Neck Collar® in extension and lateral bending; Kendrick Extraction Device (KED)® in lateral bending; and XP-One® in extension • KED and XP-One provided the greatest degree of immobilisation
Krell et al.[26]	Extrapolated data/Fair	Supportive	Prospective, non-randomised, crossover study	Adult volunteers in rigid cervical collars ($n = 31$)	• Long back board had 6—8° greater motion in sagittal, lateral, and axial planes during application compared with Ferno Scoop Stretcher® ($p < 0.001$) • No difference in movement during a secured logroll • Ferno Scoop Stretcher® had more sagittal flexion during lifting than the long back board ($p < 0.001$)
Podolsky et al.[29]	Extrapolated data/Poor	Supportive	Prospective, non-randomised, crossover study	Adult volunteers ($n = 25$) lying supine	• No significant differences between control and soft collar measurements except in rotary movement • Philadelphia collar not significantly better than other types of hard collars, except in limiting extension • Sandbags and tape was significantly better than any of the other methods used alone, for all four movements (flexion, extension, rotation, lateral) • Addition of Philadelphia collar to sandbags and tape was significantly more effective in reducing extension only

Huerta et al.[23]	Extrapolated data/Poor	Supportive	Prospective, non-randomised, crossover study	Manikins representing an infant and a 5-year old child	• Rigid plastic collars performed better than foam collars • None of the collars alone provided acceptable immobilisation: best allowed 17° flexion, 19° extension, 4° rotation, and 6° lateral motion • When collars were combined with supplemental devices (KED®, half spine board) immobilisation to <3° in any direction was achieved • Combination methods were more effective than cervical collars alone ($p < 0.001$) or supplemental devices alone ($p < 0.05$). • Modified half-spine board used with a rigid collar and tape was the most effective combination method
Burl[32]	Extrapolated data/Poor	Supportive	Prospective case series	Adult volunteers ($n = 10$)	• Significant decrease in C-spine movement when wearing the collar ($p < 0.0005$) • Flexion/extension was most restricted movement while side flexion was least restricted
Rosen et al.[31]	Extrapolated data/Poor	Supportive	Prospective, non-randomised, crossover study	Adult volunteers ($n = 20$)	• All devices tested (Vacuum Splint cervical collar; Nec-Loc Extrication Collar; Philadelphia Red EM Collar; Philadelphia Collar) decreased all types of cervical spine movement (extension, lateral bending, rotation) when compared to no collar • Vacuum Splint cervical collar allowed significantly less movement in all directions any other collar
Mazolewksi et al.[28]	Extrapolated data/Poor	Supportive	Prospective randomised crossover study	Adult volunteers with no history of head, neck, or back trauma ($n = 19$) restrained on a wooden backboard with a cervical collar in place	• Four techniques tested in random order • Addition of an abdominal strap to control techniques reduced 26% of the lateral motion

Table 4 (*Continued*)

Study	Level of evidence/quality of evidence	Opposing/neutral/supportive of spinal immobilisation	Design	Sample	Major findings
Boissy et al.[27]	Extrapolated data/Poor	Supportive	Prospective, non-randomised, crossover study	Adult volunteers ($n = 2$)	• During placement on a spinal board: — Lift-and-slide technique had less C-spine motion than log roll — In cooperative patients, little difference in C-spine motion between head squeeze and trap squeeze — In confused patients, head squeeze results in more C-spine motion than trap squeeze
Hamilton et al.[33]	Extrapolated data/Poor	Neutral	Prospective, non-randomised, crossover study	Adult volunteers ($n = 26$)	• Following application of a cervical collar, there was a decrease in flexion, right and left lateral rotation) however there was an increase in extension and right and left lateral bending following collar application (no p values reported) • There was no significant difference in flexion or rotation between a full body vacuum splint with cervical collar and backboard with cervical collar • The full body vacuum splint and cervical collar provided significantly better immobilisation to the backboard and cervical collar for extension and lateral movement ($p < 0.05$)
Perry et al.[30]	Extrapolated data/Fair	Neutral	Prospective, non-randomised, crossover study	Adult volunteers ($n = 6$) in simulated ambulance transport	• None of the three techniques eliminated eliminating head motion or neck rotation • Movement of the trunk contributed substantially to the lateral bending across the neck • Placement of wedges underneath the head = small but statistically significant improvements in fixation of the head to the fracture board but no improvement in relative motion across the neck
Del Rossi et al.[22]	Extrapolated data/Poor	Neutral	Repeated measures study	Cadavers with created spine instability at C5-C6	• There was no significant difference in flexion-extension, lateral flexion or axial rotation generated during log roll vs lift-slide transfers when no collar was compared to three different commercially available collars • The log roll created significantly more lateral flexion ($p < 05$) and axial rotation ($p < 0001$) than the lift-slide technique

Conrad et al.[21]	Extrapolated data/Poor	Neutral	Repeated measures	Cadavers with surgically created complete segmental injury (resulting in global instability)	• No significant differences between transfer techniques (manual transfer performed by six people and a transfer by two people using a lateral transfer device) and cervical spine motion: flexion ($p = 0.325$); axial rotation ($p = 0.5900$; lateral bending ($p = 0.112$) • No significant differences between the three collars used and cervical spine motion: flexion ($p = 0.462$); axial rotation ($p = 0.434$); lateral bending ($p = 0.250$) • For all transfers, using no collar resulted in more motion than using a collar but difference was not statistically significant
Ben-Galim et al.[20]	Extrapolated data/Fair	Opposing	Observational study	Cadavers with a created unstable upper cervical spine injury ($n = 9$)	• Collar application resulted in 7.3 mm ± 4.0 mm of separation between C1 and C2
Horodyski et al.[34]	Extrapolated data/Poor	Neutral	Repeated measures	Cadavers with surgically created complete segmental injury (resulting in global instability) ($n = 5$)	• No significant differences in degrees of flexion, extension, right and left bending, right and left rotation when no collar compared with one piece extrication collar or two piece collars (wide 95% confidence intervals)
Engsberg et al.[35]	Extrapolated data/Poor	Supportive	Repeated measures	Adult volunteers ($n = 10$)	• Compared three methods of extrication of the 'driver' from mock motor vehicle onto a long back board: unassisted with no cervical collar, unassisted with cervical collar applied, assisted using backboard and cervical collar, assisted using Kendrick Extrication Device (KED) and cervical collar • Significant decrease in movement for all motions (flexion-extension, lateral flexion, rotation) when driver exited vehicle unassisted with cervical collar in situ when compared to unassisted and no collar applied for all events (pivot in seat, stand, walk to board, recline on board) ($p < 0.10$). • When recline on board event was examined, the unassisted with cervical collar technique resulted in the lowest range of motion compared with other techniques ($p < 0.05$). The combination of KED and cervical collar had greater lateral flexion ($p = 0.010$) and rotation ($p = 0.048$) when compared to unassisted extrication with cervical collar in situ.

Table 5 Effect of spinal immobilisation on optimising spinal positioning/alignment.

Study	Level of evidence/quality of evidence	Opposing/neutral/supportive of spinal immobilisation	Design	Sample	Major findings
Treloar and Nypaver[40]	IV/Poor	Supportive	Prospective clinical study	Children < 8 years of age with head or neck injury undergoing cervical spine X-rays ($n = 18$)	• Mean flexion with collar was $3.4 \pm 9.9^\circ$ and $5.6 \pm 6.8^\circ$ without a collar ($p > 0.05$) • Most children < 8 years on back boards have flexed cervical spines • Semi-rigid cervical collars do not eliminate flexion
Schriger et al.[38]	Extrapolated data/Poor	Supportive	Prospective observational study	Adult volunteers with no history of back disease ($n = 100$)	• Amount of occipital offset required to achieve neutral position varied from 0 to 3.75 in. (mean = 1.5 in.) • Mean occipital offset for men (1.67 in.) was significantly greater than that for women (1.31 in.) • Immobilisation on flat backboard places 98% of subjects in relative cervical extension • Occipital padding would place a greater percentage of patients in neutral position and increase patient comfort during transport.
Nypaver et al.[37]	Extrapolated data/Poor	Supportive	Prospective observational study	Children aged < 8 years in the emergency department or outpatient clinics with non-head-injury related complaints ($n = 40$)	• All children required elevation of the back for correct neutral position of the cervical spine (mean height, 25.4 ± 6.7 mm; range, 5—41 mm) • Children less than 4 years old required more elevation than those aged ≥ 4 years (27 ± 7.2 vs 22 ± 4.2 mm, $p < 0.05$)
Gunn et al.[39]	Extrapolated data/Poor	Supportive	Prospective observational study	Adult volunteers ($n = 2$)	• Total degree of lateral flexion of the cervical spine in the HAINES (High Arm IN Endangered Spine) modified recovery position was less than half of that measured during use of the lateral recovery position (while an open airway was maintained in each).
DeLorenzo et al.[36]	Extrapolated data/Poor	Supportive	Prospective observational study	Adult volunteers ($n = 19$)	• At C5 and C6, the maximal ratio of spinal canal and spinal cord cross-sectional areas was most consistently obtained with slight flexion (cervical-thoracic angle of 14°) ($p < 0.05$) • Flexion equivalent to 2 cm of occiput elevation produces a favourable increase in spinal canal/spinal cord ratio at C5 and C6 for a patient lying flat on a backboard

Table 6 Effect of spinal immobilisation on improving comfort or decreasing pain.

Study	Level of evidence/quality of evidence	Opposing/neutral/supportive of spinal immobilisation	Design	Sample	Major findings
Cordell et al.[41]	Extrapolated data/Fair	Opposing	Prospective crossover study	Adult volunteers ($n = 20$)	• Mean pain scores on VAS = 9.7 mm (spine board with air mattress) 37.5 mm (spine board, no-mattress) ($p = 0.0001$). • Interface pressure levels were significantly less when air mattress was used period for the occiput ($p = 0.0001$), sacrum ($p = 0.0001$), and heel ($p = 0.0001$).
Walton et al.[44]	Extrapolated data/Fair	Opposing	Prospective randomised, controlled crossover study	Adult volunteers ($n = 30$)	• Padding the spinal board significantly reduced subject discomfort ($p = 0.024$) • Significant difference in flexion ($p = 0.410$), extension ($p = 0.231$), rotation ($p = 0.891$), or lateral bending ($p = 0.230$) with padded vs unpadded spinal boards • No significant difference in drop in sacral transcutaneous O_2 tension from time zero to 30 min for the padded and the unpadded groups (mean drop = 14.8% ± 17.5% vs 12.2% ± 16.8%, respectively; $p = 0.906$).
Lerner et al.[43]	Extrapolated data/Fair	Opposing	Prospective, randomised, crossover laboratory study	Adult volunteers ($n = 39$)	• Following removal from the backboard, pain was reported by 76.9% of subjects without occipital padding and 69.2% of subjects with occipital padding ($p < 0.45$) – Neck pain was reported in 23.1% of subjects without padding and 38.5% of subjects with padding ($p < 0.07$) – Occipital pain was reported in 35.9% of subjects without padding and 25.6% of subjects with padding ($p < 0.29$) • 24 h later, pain was reported by 17.9% of the subjects without padding and 23.1% of subjects with padding ($p < 0.63$) – Neck pain at 24 h was reported by 7.7% of subjects without padding and 12.8% of subjects with padding ($p < 0.5$) – Occipital pain at 24 h was reported by 7.7% of the subjects without padding and 2.6% with padding ($p < 0.63$)
Hauswald et al.[42]	Extrapolated data/Fair	Opposing	Prospective, non-blinded comparative trial	Adult volunteers (emergency medical technician students) ($n = 22$)	• Comfort scores were significantly different for all methods ($F = 101$, $p < 0.001$): score of 0 = least comfort, score of 10 = most comfort • Backboard padding resulted in the following comfort scores: gurney mattress and egg-crate foam = 9.6 cm (95% CI, 8.9—9.8 cm); gurney mattress = 7.0 cm, 95%/CI, 6.4—7.4 cm); folded blanket = 3.3 cm (95% CI, 2.6—4.9 cm); backboard alone = 0.8 cm (95% CI, 0.7—2.1 cm)
Chan et al.[45]	Extrapolated data/Poor	Opposing	Prospective, crossover study	Adult volunteers ($n = 37$)	• Subjects were 3.08 times more likely to have symptoms when immobilised on a backboard than when immobilised on a vacuum mattress-splint • Subjects were 7.88 times more likely to complain of occipital pain and 4.27 times more likely to complain of lumbosacral pain when backboard was used • Severity of occipital and lumbosacral pain was also significantly greater during backboard immobilisation

Table 7 Effect of spinal immobilisation on causing complications.

Study	Level of evidence/quality of evidence	Opposing/neutral/supportive of spinal immobilisation	Design	Sample	Major findings
Dodd et al.[54]	Extrapolated data/Fair	Neutral	Prospective case series	Patients undergoing anaesthesia via facemask with spontaneous ventilation ($n = 38$)	• Cervical collar made no statistically significant difference to tidal volume in any one of the three different airway positions – Neutral position: 263 ml without collar vs 278 ml with collar – Jaw thrust: 371 ml without collar vs 335 with collar – Chin lift: 328 ml without collar vs 314 ml with collar
Schafermeyer et al.[47]	Extrapolated data/Fair	Opposing	Prospective study with each subject serving as his own control	Healthy children aged 6–15 years ($n = 51$)	• Supine forced vital capacity (FVC) was less than upright FVC ($p < 0.001$) • When immobilised, FVC ranged from 41% to 96% of supine FVC (80 ± 9%) • No difference in FVCs between strapping techniques (=0.83)
Davies et al.[46]	Extrapolated data/Fair	Opposing	Prospective case series	Injured patients with cervical collars in situ ($n = 19$) and who required ICP monitoring	• Following collar application there was a significant rise in ICP ($M = 4.5$, SD 4.1 mmHg) ($p < 0.001$) • Insignificant changes in mean arterial pressure suggested that this effect is a response to distortion of venous drainage rather than cutaneous stimulation alone • Patients with abnormal cervical spine X-rays, unstable or elevated ICP or who underwent changes in ventilation during the study period were excluded
Main et al.[55]	Extrapolated data/Poor	Opposing	Prospective, crossover study	Adult volunteers ($n = 4$)	• Mean sacral pressure readings were spinal board 233.5 mm Hg, old vacuum stretcher 139 mm Hg, new design 94.8 mm Hg, prototype board 119.5 mm Hg, York Two stretcher 46 mm Hg, Army stretcher 61 mm Hg, and the PVC and aluminium stretcher 66 mm Hg ($p < 0.001$). • Thoracic pressure readings were: spinal board 82.9 mm Hg, old design vacuum stretcher 58 mm Hg, new design 37.8 mm Hg, prototype board 53.7 mm Hg, York two 21 mm Hg, army stretcher 35.4 mm Hg, and PVC stretcher 38.5 mm Hg ($p < 0.001$).

Totten and Sugarman[48]	Extrapolated data/Fair	Opposing	Randomised, crossover laboratory study	Adult volunteers ($n = 39$)	• Both wooden backboards and vacuum mattresses restricted respiration an average of 17% • Mean forced expiratory volume in l s (FEV_1) was lower on the vacuum mattress than a wooden backboard ($M = 1.83$ vs 1.94. $p = 0.022$)) • Respiratory restriction was more pronounced at extremes of age
Liew and Hill[49]	Extrapolated data/Poor	Opposing	Case series	Multiple trauma patients ($n = 2$)	• Two patient case reports of significant pressure ulceration requiring additional surgical intervention in the operating theatre caused by cervical immobilisation (both patients managed with a hard cervical collar, plus cervical traction in one case).
Raphael et al.[53]	Extrapolated data/Poor	Opposing	Randomised, single-blind, crossover study	Patients scheduled for elective spinal anaesthesia ($n = 9$)	• Significant elevation of cerebrospinal fluid pressure in 7/9 patients studied when a cervical collar was applied ($p < 0.01$)
Houghton and Curley[50]	Extrapolated data/Poor	Opposing	Case study	Case study ($n = 1$)	• Single patient case study of dysphagia caused by hard cervical collar in patient with cervical myelopathy secondary to rheumatoid arthritis
Kolb et al.1999 [51]	Extrapolated data/Poor	Opposing	Prospective study	Adult patients undergoing lumbar puncture ($n = 20$)	• Average cerebrospinal fluid pressure (CSFP) increased from 176.8 mmH_2O before collar application to 201.5 mmH_2O after placement of a rigid Philadelphia collar (range 0—120) ($p = .001$)
Mobbs et al.[52]	Extrapolated data/Poor	Opposing	Prospective case series	Adult head-injured patients with a GCS ≤ 9	• ICP increased significantly post collar application (mean difference 4.4 mmHg, $p < 0.05$)
Sheerin and deFrein[56]	Extrapolated data/Poor	Opposing	Non-randomised control trial	Adult volunteers ($n = 2$)	• Occipital pressures were highest for the unpadded spinal board (79.5—95 mmHg) followed by spinal board with flotation device (56.7—66.7 mmHg) then vacuum mattress (54—65) • Sacral pressures were highest for the unpadded spinal board (118.3—154.3 mmHg) then were variable when spinal board with flotation device (43—76 mmHg) and vacuum mattress (60.3—70.7 mmHg) were used

Table 7 *(Continued)*

Study	Level of evidence/quality of evidence	Opposing/neutral/supportive of spinal immobilisation	Design	Sample	Major findings
Stone et al.[57]	Extrapolated data/Poor	Opposing	Case series	Adult volunteers ($n = 42$)	• Application of cervical collar, increased cross sectional area of the internal jugular vein (0.70 vs 0.89 mm, $p < 0.0001$) • Mean % increase in cross sectional area of the internal jugular vein was 37%
Hunt et al.[58]	Extrapolated data/Poor	Opposing	Prospective case series	Adult patients with severe traumatic brain injury in the neurosurgical ICU ($n = 30$)	• Mean ICP increased significantly post collar application (difference +4.6 mmHg, $p < 0.0001$) • ICP decreased to baseline values immediately after collar removal • Mean increase in ICP following collar application was greater in patients with an ICU > 15 mmHg (5.9 mmHg vs 3.6 mmHg, $p < 0.05$)

Complications caused by spinal immobilisation

There were thirteen studies that examined complications caused by spinal immobilisation (Table 7).[46–58] All studies used extrapolated data; seven studies were conducted in adult volunteers,[46,48–50,55,56] one study in healthy children,[47] two studies focused on head injured patients,[52,58] two studies involved adults undergoing lumbar punctures ± spinal anaesthesia[51,53] and one study was of patients undergoing general anaesthesia but with spontaneous ventilation.[54] Four studies were of fair[46,54] and nine studies were of poor methodological quality.[49–53,55,56,58] Twelve studies opposed the use of spinal immobilisation because it caused complications. Five studies found that cervical collars caused a significant increase in intracranial pressure.[46,51–53,58] Further, Stone et al.[57] found that the cross sectional area of the internal jugular vein increased following application of a cervical collar and hypothesised that this was a possible explanation for the increase in intracranial pressure seen with rigid cervical collar use. Two studies reported respiratory complications.[47,48] One study[47] reported that spinal immobilisation using a backboard decreased forced vital capacity (FVC) in children. The other study of adult volunteers showed that both wooden backboards and vacuum mattresses restricted respiration an average of 17% and that the mean forced expiratory volume in l s (FEV1) was significantly lower for patients immobilised using a vacuum mattress when compared to a wooden backboard ($M = 1.83$ vs 1.94, $p = 0.022$).[48] There were two studies that showed increased tissue-device interface pressures with spinal immobilisation[55,56] and one case study publication also showing significant pressure ulceration from spinal immobilisation in two patients.[49] One case study also reported dysphagia caused by hard cervical collar in a patient with cervical myelopathy secondary to rheumatoid arthritis.[50] There was one study that was neutral for the effect of cervical spine immobilisation on tidal volume.[54] Dodd et al.[54] concluded that cervical collars made no statistically significant difference to tidal volume and that a correctly fitting cervical collar had no significant effect on airway patency.

Discussion

The results of this systematic review yielded 47 studies examining the outcomes of spinal immobilisation in pre-hospital or emergency care settings. Overall, there were 15 studies supportive of spinal immobilisation, 13 studies neutral for spinal immobilisation and 19 studies opposing spinal immobilisation. There were no published high-level studies that assessed the efficacy of spinal immobilisation in the pre-hospital or emergency care setting and no randomised controlled trials were found. There were few studies included in the review that were conducted in injured patients and almost all of the current evidence related to spinal immobilisation is extrapolated data, mostly from healthy volunteers. Spinal immobilisation may cause complications such as respiratory compromise, raised intracranial pressure, and pressure injuries, so protocols that recommend application of spinal immobilisation should also consider the risk vs benefits for specific patients.

For neurological outcome, all eight studies reviewed were conducted in trauma patients, however they were all retrospective in nature (LOE IV and fair methodological quality) raising issues of bias. The studies reviewed for the outcome of preventing movement were conducted in manikins ($n = 1$), healthy volunteers ($n = 11$) or cadavers ($n = 4$). The generalizability of the findings of these studies to injured humans who may have a spinal injury is questionable. All of the cadaver studies had surgically created injuries so the similarities in movement compared to a living patient with a traumatic spinal injury are unknown. It is unlikely that healthy volunteers subjected to spinal immobilisation will experience the pain, cervical and paraspinal muscle spasm[34,59] and voluntary guarding[34,60] of an injury to a similar extent of an injured trauma patient. Further, one study clearly acknowledged that it is unlikely that an alert patient with cervical spine instability or unconscious patients would be subject to the same forces of range of motion as those that occurred in cadavers.[34]

There were only five studies identified that tested the effect of spinal immobilisation on optimising spinal positioning/alignment and all examined cervical spine alignment leaving a major research gap in the effectiveness of spinal immobilisation in optimising alignment of thoracic, lumbar and sacral spine. Two studies were in children aged less than eight; this age is of interest because of their large head-to-torso ratio.[40,61] One study included eighteen children aged less than eight years with head or neck injury and who required cervical spine X-rays.[40] Children with unstable vital signs, actual or potential cervical spine injury on history and, or physical examination were excluded.[40] The other study was also in children aged <8 years, recruited from the emergency department or outpatient clinics with non-head-injury related complaints and excluded children ''too ill to cooperate''.[37] The mean ages ranged from 33 months[37] to 46 months.[40] No further details were given about the clinical status of the children included in either study. The remaining three studies that examined optimal spinal positioning were in adult volunteers with sample sizes ranging from 2 to 100 participants and were of poor methodological quality.

All seven studies reviewed for the effect of spinal immobilisation on patient comfort had negative outcomes. All studies reported pain or discomfort in uninjured adult volunteers; it may be proposed that pain and discomfort would be increased in patients with actual injuries. Pain or discomfort from spinal immobilisation may also cause the patient to move as they try to decrease these symptoms, negating the effects of immobilisation. Further, injured patients who have paralysis will have no or decreased sensation placing them at considerable risk of pressure injuries. Based on the evidence to date, consideration should be given to padding spine boards and there is some low level evidence to support padding under the head in adults and under the shoulders in children to optimise spinal alignment. There was clear evidence of complications from spinal immobilisation including increased intracranial pressure, respiratory issues and pressure injuries.

Toscano[62] highlights the importance of an index of suspicion for potential spinal injury. In this study of 123 trauma patients, 28 of the 32 patients who sustained a major deterioration in neurological function were not suspected of potentially having a spinal injury. The results of this study suggest that in the absence of suspicion of a spinal injury, patient handling techniques may have been sub-optimal and may not have placed importance on spinal alignment and minimisation of neck movements, especially in patients who required general anaesthesia. Further, the majority of studies to date relate to the use of various devices for spinal immobilisation; the effectiveness of manual in-line immobilisation on the outcomes examined in this review is poorly understood.

Conclusion

There are no published high-level studies that assess the efficacy of spinal immobilisation in the pre-hospital and emergency care settings. Almost all of the current evidence related to spinal immobilisation is extrapolated data, mostly from healthy volunteers. There were no studies that showed spinal immobilisation improved neurological outcomes as all studies using neurological outcome as an endpoint were neutral due to high mortality rates from other causes (mostly gunshot wounds). Based on the current evidence it appears immobilisation does prevent movement but the clinical significance of movement prevention is unknown. Spinal immobilisation has a high risk of complications and cervical collars may mask other injuries and delay diagnosis and definitive care. Protocols that recommend application of spinal immobilisation should consider the risk vs benefits. Prospective studies of patients at risk of, or with actual spinal injuries, are needed using real pre-hospital or clinical environments.

Provenance and conflict of interest

Professor Julie Considine is a Deputy Editor of the Australasian Emergency Nursing Journal but had no role to play in the peer review or editorial decision-making process whatsoever, and was blinded to this process. There were no other conflicts of interest declared with this manuscript. This paper was not commissioned.

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