Spinal Immobilisation in Paediatric Trauma Patients.

Abstract:

Introduction: Spinal cord injury (SCI) results in substantial personal, financial and economic costs occurring from the time of injury (1). The global incidence of SCI is greater than 46 million people per year (2). In Australia; the incidence of Paraplegia was 137 new cases and Quadriplegia was 136 in 2008 alone. Paediatric patients suffer devastating loss of quality of life, productivity and disability. Paediatric spinal injury is rare occurring in only 1-2% of trauma cases. 60-80% of paediatric spinal injury occurs in the cervical spine compared with 30-40% in adults (4). Excellence in prehospital care is essential to decrease morbidity and mortality particularly in rural and remote areas hours away from definitive care.

Method: A literature review was conducted using MEDLINE, EMBASE, Cochrane Systematic reviews, One Search and Google Scholar using the following search terms: prehospital care of the paediatric spinal patient, neurological assessment, risk stratification, selective spinal immobilisation, clinical decision making tools, NEXUS and Canadian C-spine rules. Rural clinicians and paramedics were also consulted.

Discussion: A discussion of paediatric spinal injury, immobilisation, neurological assessment, risk stratification, NEXUS, Canadian C-spine rules, selective spinal immobilisation and guidance for clinical making decision tools is provided.

Conclusion: Most health professionals are conditioned to believe that all potential spinal patients must be fully immobilised to prevent further injury. However; there is no substantial evidence for or against spinal immobilisation and yet thousands of patients are collared and tied to hard spinal boards each year resulting in iatrogenic injury and increased length of stay in hospital. Through development and validation of Selective Spinal Immobilisation decision making tools that include assessment of MOI, neurological assessment, risk stratification, NEXUS and Canadian C-Spine Rules may result in prevention of adverse effects and complications with significant cost savings to the health system. Further research is required to develop effective prehospital decision making tools.
Key Words:
SCI, spinal cord injury, paediatric spinal cord injury, spinal immobilisation, cervical collars, adverse effects of spinal immobilisation, risk stratification, NEXUS, Canadian C-spine rules, clinical decision making tools, Neurological Classification of SCI,

Introduction:
Spinal cord injury (SCI) results in substantial personal, financial and economic costs occurring from the time of injury (1). The global incidence of SCI is greater than 46 million people per year (2). In Australia; the incidence of Paraplegia was 137 new cases and Quadriplegia was 136 in 2008 alone. The mortality rates 1 year after injury were: Paraplegia 6.4% and Quadriplegia 13.7%. The chronic prevalence of SCI in Australia is cumulative and is currently being researched. The most common mechanisms of injury for SCI are: Transport accidents, Falls, Strike or collision and Water related accidents (3, Fig.1).

![Figure 2.8: Incident cases of SCI by age, gender and severity, Australia, 2008](image-url)

Fig.1: Incidence of Spinal Cord Injury by Age and Gender (3).
Besides mortality SCI causes extensive morbidity including paralysis of movement, ongoing physical and medical problems, spasticity, pressure ulcers, bowel and bladder dysfunction. SCI impacts on independence of daily living; quality of life; requirement for community services; medical services; financial support; self esteem and psychological welfare across the victim’s lifetime (2).

The costs to the health system include expenditure on acute and long term care; carer costs rehabilitation; equipment and modifications contributing to overall burden of disease. Productivity costs include loss of productivity, unemployment, higher absenteeism, domestic absenteeism and premature death. The total annual cost of SCI was estimated to be $2 billion with a lifetime incident cost per case of SCI estimated to be $5 million per case of paraplegia and $9.5 million per case of quadriplegia (3). This does not include the emotional cost and family dysfunction resulting from neurotrauma (2, Fig.2).

Fig.2: Long Term Sequelae of SCI:

<table>
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<tr>
<th>Long term physical disability</th>
<th>Problems in social functioning eg poor access to transport leads to fewer social opportunities;</th>
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<tr>
<td>Complex complications disrupt daily life;</td>
<td>Psychological complications eg depression, life satisfaction;</td>
</tr>
<tr>
<td>Decreased IADLS &amp; QOL</td>
<td>Sleep issues eg high prevalence of obstructive sleep apnoea.</td>
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<tr>
<td>Limitations in mobility</td>
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<td>Approx 60% of SCI patients become wheelchair dependent;</td>
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<tr>
<td>Medical complications eg UTI, bacterial infections, pressure ulcers;</td>
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Health Services Utilisation:

| Acute care | Group home <7 people |
| Rehabilitation care | Centre based respite, respite homes |
| Other types of care | Other respite |
| Case management, local coordination & development | Recreation-holiday programs |
| Therapy support for individuals | Own home respite |
| Learning & life skills development | Host family respite-peer support respite |
| Flexible respite | Attendant care-personal care |
| In home accommodation support | Other accommodation support |
| Behavioural specialist intervention | Hostels- generally not 24 hour care |

Paediatric patients suffer devastating loss of quality of life, productivity and disability. Excellence in prehospital care is essential to decrease morbidity and mortality. Critical Care paramedics may be able to stabilise, resuscitate and prevent further harm to this vulnerable population whilst Community Paramedics may provide clinical care, primary health care, referral, support networks, community education for prevention and early intervention to
increase the paediatric client’s quality of life across the lifespan (3). This literature review will provide an update of the current evidence in relation to prehospital care of the paediatric spinal patient and guidance for development of risk stratification tools to prevent unnecessary spinal immobilisation in rural and remote patients in Australia.

Discussion:

Overview of Paediatric Spinal Injury:
Paediatric spinal injury is rare occurring in only 1-2% of trauma cases. 60-80% of paediatric spinal injury occurs in the cervical spine compared with 30-40% in adults (4).

Paediatric Unique Physiological and Anatomical Characteristics of the Spine:
The immature paediatric spine has shallow facet joints, ligamentous laxity, under developed spinous processes and age related physiologic anatomic variations in structure that may easily be mistaken for spinal injury. The cervical spine is at increased risk of injury due to the hypermobility secondary to ligamentous laxity combined with the large head to body ratio and poorly developed cervical musculature. The intervertebral discs have higher water content relative to adult discs resulting in increased flexibility and compliance to prevent spinal injury (5, Fig.3). In fact; increased ligamentous laxity allows the paediatric spinal column to stretch up to 5 cm without disruption whereas the spinal cord may only stretch 5-6 mm before rupture, transection and disruption of the vascular supply. Therefore; paediatric patients <8 years are predisposed to Spinal Cord Injury With Out Radiological Abnormality (SCIWORA) (4), Multilevel spinal injury (6) and Chance fractures (5).

In many cases the position of the age related fulcrum of the cervical axis predicts the level of injury due to the position of maximal mobility. In children <8 years of age the maximal mobility occurs at C1-C3 resulting in 69-78% of patients <9 years sustaining upper cervical injuries (occiput to C2). At 12 years the fulcrum settles at C5-C6 where it remains throughout adult hood. Patients >10 years old sustain increased lower cervical spine injuries (C3-C7). Therefore; Upper Cervical spine injuries are more common in children <8 years and Lower cervical spine injuries more common in children >8 years. C1-C3 cord transection may result in immediate death due to disruption of innervation of vital centres. C1-C2 cranio-cervical Axis fractures are the most deadly and injury to C3-C4 results in respiratory failure due to
disruption of the phrenic nerve that controls the diaphragm. Neurological deficits occur below the level of the injury with many cervical spine injuries resulting in quadriplegia (5).

Fortunately, paediatric patients with immature spines have enhanced ability for rapid healing of bone, ligaments and central nervous system after acute injury compared to adults. Paraplegia is more common in spinal patients <12 years and older children have increased incidence of incomplete injuries. Incomplete injuries have increased chance of functional neurological recovery in 62% of patients whereas complete transections have a poor prognosis with fewer than 3% of patients having functional improvement if the lesion is diagnosed Complete at 24 hours post injury. Patients with Upper cervical injuries in conjunction with traumatic brain injury result in increased morbidity and mortality (5).

**Fig.3: Spinal Trauma Mechanisms of Injury:** (5).

<table>
<thead>
<tr>
<th>Direct Injury:</th>
<th>Indirect Injury:</th>
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<tbody>
<tr>
<td>Penetrating injuries eg gunshot wound,</td>
<td>Impaction of displaced bone</td>
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<tr>
<td>Blunt force trauma</td>
<td>Associated vascular injury eg arterial disruption, thrombosis</td>
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<tr>
<th>Axial Loading (Vertical compression):</th>
<th>Flexion: (Hyperflexion)</th>
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<tr>
<td>Strain overwhelms absorptive capacity of the vertebral column eg direct blow to top of head (C5-C6 injury). MOI: contact sports, football, diving, trampoline, May also cause Burst fracture (Jefferson burst type fracture) due to excess axial compression; disc is forced into vertebral body in lower thoracic region or in the atlas.</td>
<td>Distraction of the posterior ligamentous structures leading to rupture in a posterior to anterior direction. Hyperflexion: anterior subluxation, wedge compression fractures, facet dislocations. Flexion distraction: fracture goes through neural arches, exits vertebral body anteriorly leading to SCI. Lumbar flexion distraction may occur in seat belt syndrome with resulting Chance fractures.</td>
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<tr>
<th>Hyperextension:</th>
<th>Dislocation:</th>
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<tr>
<td>Whip lash type injuries eg avulsion fractures of the atlas, traumatic spondylolisthesis, laminar and pillar fractures eg MVC, football, other sports.</td>
<td>Rotational forces, damage to muscles, ligaments leads to compromise of vascular structures in spinal cord. Fracture-dislocation injuries usually occur in cervical segments or at thoracolumbar junction resulting in unstable spine requiring operative stabilisation.</td>
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**Evidence Based Spinal Immobilisation:**

In 2001 Cochrane Collaboration published a systematic review on prehospital spinal immobilisation for trauma patients examining the use of devices and strategies to stabilise the spinal column after injury and thus prevent spinal cord damage. However; the researchers
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found no reliable evidence for or against spinal immobilisation resulting in a concerning conclusion. This systematic review was up dated as accurate in 2009 (7, Fig.4).

Fig.4: Kwan, et al, Concerning Conclusion:
‘The effect of spinal immobilisation on mortality, neurological injury, spinal stability and adverse effects in trauma patients remains uncertain. Because airway obstruction is a major cause of preventable death in trauma patients, and spinal immobilisation, particularly of the cervical spine, can contribute to airway compromise, the possibility that immobilisation may increase mortality and morbidity cannot be excluded.’

The Australian Resuscitation Council provides guidance for emergency medical services (ambulance, prehospital care and emergency departments) in Australia. Using dubious evidence; much of which is greater than 5 years old; they have published ‘Guideline 9.1.6: Management of suspected spinal injury’ dated July 2012. The guideline states: ‘The clinical importance of prehospital immobilisation in spinal trauma remains unproven’ due to poor quality research, exaggeration of detrimental neurological effects and lack of randomised control trials (8, pp. 3). ARC & NZRC advise that ‘spinal immobilisation can expose victims to risks associated with specific devices and the time taken in application leads to delays in transport time.’ (8, pp.3; Fig.5). Then states: manual in line stabilisation, cervical collars, log rolling and spine boards MAY be used on trauma patients with suspected spinal injury (8).

Fig.5: Adverse effects of Cervical Collars (8):
- Patient distress, discomfort & pain;
- Restricted mouth opening & difficulty swallowing;
- Airway compromise should the victim vomit;
- Pressure on neck veins raising intra-cranial pressure;
- Hiding potential life-threatening conditions.

Adverse Effects of Spinal Boards (8):
- Patient distress, pain, discomfort, conscious patients continually move to increase comfort potentially exacerbating injury;
- Victims should not be left on rigid spinal boards as they will develop pain in the neck, back of the head, shoulder blades, lower back;
- High risk of pressure necrosis;
- Strapping may compromise breathing.

Advanced Trauma Life Support Paediatric Spinal Immobilisation:
Despite the controversial evidence for spinal immobilisation all Australian ambulance services continue to fully immobilise trauma patients at risk of spinal injury with cervical collar, head immobilisation, spine board, straps, tapes and padding. Kendrick Extrication Devices and various vacuum mattresses are also used by prehospital providers. Cardinal
principles of management of the trauma patient include: careful extrication, ensuring ABCs, securing the airway, ventilation, oxygenation, perfusion, thermoregulation, normoglycaemia and expeditiously transporting the patient to definitive care in a trauma centre capable of managing spinal patients. Paediatric spinal immobilisation requires maintenance of neutral alignment with a torso pad of the appropriate thickness; control of weight centres (head, shoulders, pelvis); securing weight centres and legs; providing padding to maintain neutral position and careful movement toward inline position. This is all very difficult with a distressed, terrified child <12 years often resulting in the necessity of sedation to keep them still (1,5,9).

Clinical Decision Making Tool to Prevent Unnecessary Spinal Immobilisation:

In rural and remote areas of Australia paediatric patients are exposed to extended retrieval times due to the tyranny of distance and time to definitive care. Unnecessary spinal immobilisation may result in iatrogenic extreme pain; pressure ulceration; patient distress; compromised cardio-respiratory status; preventable sedation and intubation to keep them calm and still; preventable admission to hospital; unnecessary retrieval and adverse outcomes for patients (10).

Considering the incidence of paediatric spinal trauma is only 1-2% and there is no reliable evidence for instituting spinal immobilisation developing and validating a Selective Spinal Immobilisation Clinical Decision Rule may result in better outcomes for this population.
Selective Spinal Immobilisation should consist of assessment of MOI, Neurological assessment, Risk stratification and Validated Decision rules for example NEXUS and Canadian C-Spine Rules.

**International Evidence relating to Management of Paediatric Spinal Injury:**

The International Standards for Neurological Classification of Spinal Cord Injury is the gold standard for evaluating and classifying the neurological consequences of SCI in adults and paediatric patients. Intra-rater reliability was maintained across each age group, level of injury and severity of injury (Fig. 4).

**Risk Stratification:**

Selective spinal immobilisation has enabled 59% of all traumatic injuries to be cleared from the unnecessary use of spinal immobilisation devices at the scene resulting in significant cost and time saving; decreased pain and discomfort to patients; preventable admission to hospital; early clearance from the emergency departments; decreased pressure areas caused by spinal immobilisation equipment and better outcomes for pediatric and adult patients (15).
thinking with astute application of decision rules (15,16). Patients should be classified into 3 groups:

1. **Low Risk**: alert, asymptomatic, communicative, with no neck pain or signs of neurological deficits, may be minor isolated head injury eg scalp laceration; (15,16). 
2. **High Risk**: conscious child with high risk criteria; <2 years old, incapable of verbal communication, distressed, neck pain &/or neurological deficits; (15,16). 
3. **Extremely High Risk**: unconscious, obtunded child with high risk criteria (15,16). 

**Canadian C-spine Rules & NEXUS:**

The Canadian C-spine Rule (CCR) and the National Emergency X-Radiography Utilisation Study (NEXUS) are decision rules to guide the use of radiography in patients with trauma. In 2003 the results of a comparison study between CCR and NEXUS in low risk trauma patients (n=8283) were published. Interestingly out of 8283 patients only 169 (2%) had clinically important spinal injuries. The CCR was more sensitive than the NEXUS (99.4 versus 90.7) and more specific (45.1% versus 36.8%) for detecting injury. The conclusion states that with alert patients who have experienced trauma the CCR is more sensitive and specific for detecting cervical spine injury than NEXUS. Using either clinical decision tool will result in significant cost savings to the health system with prevention of unnecessary radiography (17,18).

While the NEXUS criteria was developed to be used on the adult population in an analysis of over 3000 patients the criteria was found to have a negative predictive value of 100% with 100% sensitivity in excluding spinal cord injury in children >9 years (19). In a prospective multicentre study NEXUS Low Risk Criteria assessment was applied to 3065 children resulting in prediction rules with 100% sensitivity to identify cervical spinal injury. Limitations included the small number of patients who actually had SCI. Preverbal children are unable to answer all the NEXUS criteria so it is not recommended for children <3 years. However; in a study of 575 patients <3 years NEXUS was able to exclude 80% based on paediatric GCS verbal assessment. Prediction rules for children at low risk of cervical spinal injury may be feasible (16,20).

Prehospital providers may be able to develop a 2 step clinical decision rule that first assesses the NEXUS and then assesses CCR ensuring great care in assessment and detection of any neurological deficit (Fig.5). Although only 1-2% of paediatric patients suffer traumatic spinal injury; the increased incidence of c-spine injury, SCIWORA and spinal concussion results in more obvious neurological deficits immediately post accident. Paramedics must be trained to
accurately assess neurological status, mechanism of injury and the possibility of spinal injury with a high index of suspicion. This may be difficult when the patient is fully charged with adrenalin, in shock or preverbal. However; low risk patients are usually very obvious and missed diagnosis may not result in significant consequences as there is no evidence for or against spinal immobilisation (16,20). Careful management of every patient is required at all times.

Fig.5: Example of Modified Low Risk Criteria Assessment for the Prehospital arena:

<table>
<thead>
<tr>
<th>Modified NEXUS Criteria Low Risk Criteria</th>
<th>Modified Canadian C-spine Rule:</th>
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<tbody>
<tr>
<td>Spinal immobilisation is indicated for patients with trauma unless they meet all of the following criteria:</td>
<td>1. Any high risk factor that mandates spinal immobilisation?</td>
</tr>
<tr>
<td>o No posterior midline C-spine tenderness,</td>
<td>o Age &gt;65 years</td>
</tr>
<tr>
<td>o No evidence of intoxication,</td>
<td>o Dangerous MOI</td>
</tr>
<tr>
<td>o A normal level of alertness,</td>
<td>o Paresthesias in extremities?</td>
</tr>
<tr>
<td>o No focal neurological deficits,</td>
<td>2. Any low risk factors that allows safe assessment of range of motion?</td>
</tr>
<tr>
<td>o No painful distracting injuries.</td>
<td>o Simple rear end MVA?</td>
</tr>
<tr>
<td>3. Able to rotate neck actively?</td>
<td>o Sitting position or ambulating?</td>
</tr>
<tr>
<td>o 45 degrees left &amp; right?</td>
<td>o Delayed onset of neck pain?</td>
</tr>
<tr>
<td></td>
<td>o Absence of mid line C-spine tenderness?</td>
</tr>
</tbody>
</table>

Conclusion:

Most health professionals are conditioned to believe that all potential spinal patients must be fully immobilised to prevent further injury. However; there is no substantial evidence for or against spinal immobilisation and yet thousands of patients are collared and tied to hard spinal boards each year resulting in iatrogenic injury and increased length of stay in hospital. The time has come to empower prehospital providers with evidence based clinical decision making tools to prevent unnecessary spinal immobilisation.

Through development and validation of Selective Spinal Immobilisation decision making tools that include assessment of MOI, neurological assessment, risk stratification, NEXUS and Canadian C-Spine Rules may result in prevention of adverse effects and complications with significant cost savings to the health system. Further research is required to develop effective prehospital decision making tools.
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