Biomechanical Analysis of Spinal Immobilisation
During Prehospital Extrication

Study Interim Report (July 2014)

Mark Dixon
Joseph O’Halloran
Niamh Cummins
Scott Keenan
Ailish Hannigan
Introduction

It is estimated that up to 20,000 cases of spinal cord injuries occur annually in Northern Europe and the United States (Bernhard et al 2005). Severe spinal cord injuries are almost always permanent, with little hope for restoration of neurologic function (Karbi et al 1988). In most countries road traffic collisions (RTC) are the main cause of cervical spine injuries (Dula et al 1979). A potential cause of secondary injury is through inadvertent manipulation of the spinal cord during extrication (Eismont et al 2004). Since the 1960s it has been standard practice to immobilise patients with suspected spinal injuries using a cervical collar and a backboard (White et al 2013). However, cervical spinal injury is actually relatively rare in trauma patients and only occurs in about 2% of admissions (Davis et al 1993). It has also been reported that neurological deterioration in patients with spinal cord injury still occurs in around 5% of cases despite good spinal immobilisation (Marshall et al 1987).

Hauswald et al (1998) conducted a 5-year retrospective chart review of trauma patients in Malaysia and the United States and found that there was less neurologic disability (OR 2.03; 95% CI 1.03-3.99; p = 0.04) in the non-immobilised Malaysian patients (n=120) than the immobilised patients in the United States (n=334). While this study had its limitations it did raise questions about the standard practice of immobilising all trauma patients with suspected spinal injuries. In a Cochrane systematic review of the literature on spinal immobilisation no randomised controlled trials met the inclusion criteria. The authors concluded that the effect of spinal immobilisation on mortality, neurological injury, spinal stability and adverse effects in trauma patients remains uncertain.

Therefore it is apparent that the evidence base is poor for the different spinal immobilisation techniques that are currently used by the EMS during extrication. For example a Pubmed search in 2012 using the term “Kendrick Extrication Device” yielded just six articles, three of which were over 20 years old. In a range of motion study of healthy volunteers (n=10) using computerised digital dual inclinometry it was found that the addition of a rigid collar to head blocks strapped on a spinal board did not result in extra
immobilisation of the cervical spine and opening of the patient’s mouth was significantly reduced with a rigid collar (Holla 2012). In an editorial about the routine application of cervical collars in the journal *Injury* the authors concluded that “The science behind this ritual is limited and the consequences may not always be beneficial” (Deasy & Cameron 2011).

A feasibility study undertaken by this University of Limerick (UL) Research Team in 2012 demonstrated that up to 4 times more cervical spine movement occurs when traditional EMS rescue equipment (rigid collar, long spinal board, Kendrick Extrication Device), is used in comparison to haemodynamically stable patients self-extricating under paramedic instructions. This research won the award for Best Scientific Presentation at the National Association of Emergency Medical Services Physicians (NAEMSP) Annual Conference in January 2013 and was published in the Emergency Medicine Journal later that year (Dixon et al 2013).

**Study Aim**

The primary aim of this study is to build on the findings of the feasibility study by increasing the sample size and including a range of male and female participants with varying ages, heights and weights to represent the general population of potential RTC victims. The specific study objectives are as follows;

- To evaluate controlled self-extrication of the RTC patient by measuring flexion, extension and rotational movements in the cervical spine region using motion analysis.
- To evaluate the long spinal board (LSB) for spinal immobilisation during extrication by measuring flexion, extension and rotational movements in the cervical spine region using motion analysis.
- To evaluate the Kendrick Extrication Device (KED) for spinal immobilisation during extrication by measuring flexion, extension and rotational movements in the cervical spine region using motion analysis.
Methods

Study Design
Ethical approval for this cross-sectional study was obtained from the Scientific Research Ethics Committee at University Hospital Limerick. A sample size calculation was not possible as there are no previous studies with sufficient data to estimate variability between participants. A statistician was consulted and recommended (based on similar studies) that a sample size of 15 subjects would be sufficient to estimate variability (Browne, 1995). The most important consideration is that the subjects selected are representative of the general population in order to ensure that the study findings are potentially transferable to the real world setting.

Setting and Participants
The location of the study was Limerick City Fire and Rescue Station. Volunteers (n=16) were recruited from the UL campus community via email and were divided into three weight categories; <65kg, 65-80kg and >80kg. Exclusion criteria included age <18 years, prior knowledge of extrication procedures and underlying medical conditions which may be affected by the extrication, including but not limited to arthritis, degenerative spinal conditions, previous back or neck injuries and pregnancy. On arrival at the Fire Station the participants received a video induction and were briefed on the study by the Research Team. Participants were then provided with a study information sheet and written informed consent was obtained. Height and weight were measured on calibrated instruments. Reflective markers were placed on the participants in a horizontal plane at the level of the zygoma and in a parallel horizontal plane consistent with the anatomical marking of the clavicles. Reflective markers were also placed in a single vertical alignment along the anterior midline from the frontal bone to the xiphoid process (Figure 1). Two accelerometers were also attached to each participant, the first on the frontal bone and the second in the midline of the chest just below the manubrium.
Extrication Crew and Equipment

The crew for each extrication consisted of four members of the Fire Service in addition to two members of the National Ambulance Service totalling a crew of six members. This represents standard deployment levels for RTC attendance in the study region. For health and safety reasons and to avoid repetitive strain injury a pool of six fire personnel and three paramedics were available for the study and rotated between extrications to allow for adequate rest periods. All members of the crew were fully trained in manual handling and lifting techniques with previous experience of extrication and equipment such as the cervical collar (Stifneck®, Laerdal Medical, Stavanger, Norway), Long Spinal Board (LSB) (Hi-Tech 2001, Dixie USA Inc. Texas, USA) and Short Extrication Jacket (SEJ) (Kendrick Extrication Device, Ferno Ltd. West Yorkshire, UK).
Extraction Vehicle

A test vehicle (Ford Focus, Ford Motor Company, Michigan, USA) was prepared prior to initiation of the study with standard rescue cuts through A, B and C posts and subsequent roof and seat-belt pre-tensioner removal. The test vehicle had all glass replaced with Perspex and all sharp edges were ground and body-shop finished to ensure participant safety and the reduction of injury potential. The vehicle was also modified in such a manner that the roof assembly, A, B and C posts can be safely removed and subsequently re-assembled via locating pins attached to the removed sections. Airbag safety was ensured through removal of the vehicle’s electrical system. Scene safety was paramount and all necessary precautions including vehicle stabilisation and standard Fire Service Safety Protocols were in place within the vehicle itself and in the surrounding area during the study.

Biomechanical Analysis

The movements of the participants were captured using 3-dimensional motion analysis cameras (Cortex, Motion Analysis Corporation, CA). Infrared cameras (n=12) sampling at 200Hz were set up and calibrated (to an accuracy of 0.1mm) around the vehicle (Figure 2). The cameras recorded the movement of the markers in 3D space. Following data capture biomechanical analysis of the movement of the markers in all three planes was conducted. The movements in these planes are combined to produce an absolute angle of movement reflecting combined anterior-posterior, medial-lateral and rotational movement of the head relative to the torso throughout the extrication process (Figure 1).

This video analysis technique is considered the gold standard in biomechanics measurement, however to ensure technique accuracy a second set of measuring devices accelerometers (Shimmer S3, Shimmer Sensing, Dublin) were also deployed. The accelerometer sensors again measure all three motions in 3D space and will facilitate the validation of the infrared camera system in a separate analysis to follow.
Protocol for Immobilisation and Extrication Techniques

The order of the controlled immobilisation and extrication techniques were randomised for each participant using a random number generator (www.randomization.com). For clarity the techniques were then numbered in a logical order as presented here and each technique was performed once by the extrication crew for each participant. The starting point for all techniques was with the participant sitting in the driver seat of the test vehicle.
1) The participant exits the vehicle under their own volition while following careful instructions from paramedics regarding their movements (Control – No collar). Self-extrication instructions are outlined in Table 1.

2) The participant is fitted with a cervical collar and exits the vehicle under their own volition with manual c-spine stabilisation while following careful instructions from paramedics regarding their movements (Control + Collar + Manual Support).

3) The participant is fitted with a cervical collar and is removed using the “parcel shelf” technique which consists of an in-line extrication through the rear window using a LSB (LSB In-line)

4) The participant is fitted with a cervical collar and is assisted with a 90° rotation to the door side, a LSB is inserted behind the participant at an angle and the crew slides the participant up the board. The participant is then extricated head first through the passenger door (LSB Passenger).

5) The participant is fitted with a cervical collar and is assisted with a 90° rotation to the passenger side, an LSB is inserted behind the participant at an angle and the crew slides the participant up the board. The participant is then extricated head first through the driver door (LSB Driver).

6) The participant is fitted with a cervical collar and is immobilised using the SEJ and lifted through the driver door without rotation (SEJ Driver).
### Table 1. Paramedic Verbal Instructions for Participant Self-extrication.

<table>
<thead>
<tr>
<th>Instruction Sequence</th>
<th>Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>‘Do you understand what we are asking you to do?’ Try and keep your head as still as possible. Stop at any time if you feel pain or strange sensations in your body.</td>
</tr>
<tr>
<td>Step 2</td>
<td>Slowly move your right foot and place it on the ground outside the car</td>
</tr>
<tr>
<td>Step 3</td>
<td>Using the steering wheel for support pull yourself forward</td>
</tr>
<tr>
<td>Step 4</td>
<td>Keep your left hand on the steering wheel and place your right hand on the edge of the seat behind you</td>
</tr>
<tr>
<td>Step 5</td>
<td>Turn slowly on your seat to face the outside, your left leg should follow when ready but remain seated</td>
</tr>
<tr>
<td>Step 6</td>
<td>With both feet flat on the floor stand straight up using your arms for balance</td>
</tr>
<tr>
<td>Step 7</td>
<td>Take two steps away from the car</td>
</tr>
</tbody>
</table>

**Data Analysis**

Data was entered into an Excel spreadsheet (Microsoft, San Diego, California, USA) for analysis and descriptive statistics included calculation of means, standard deviations and ranges. Normality testing and repeated measure ANOVA were performed in SPSS (V21 Microsoft, San Diego, California, USA).
Results

Subject Characteristics

- Males: n = 7, Females: n = 9
- Mean Age = 24y (Range: 18-40y)
- Mean Height = 174 (Range: 157-198cm)
- Mean Weight = 76kg (Range: 50-138kg)
  - Weight Categories: <65kg n=5, 65-80kg n=6, >80kg n=5

Biomechanical (Video Analysis) Data

To date the video analysis has been completed and the accelerometer analysis is on-going. Control measurements were taken from the patient during self-extrication under verbal instruction with no collar and the average cervical spine movement for all subjects was 13.333° and ranged from 8.254 to 18.789°. A second set of control measurements were taken from the patient during self-extrication under verbal instruction with a collar fitted and manual support resulting in an average movement of 14.928° with a range of 12.356 to 17.568°. In comparison the smallest average cervical spine movement recorded during equipment-aided extrication (LSB In-line) was movement of 13.564° and ranged from 9.403 to 17.245°. The largest average cervical spine movement recorded during equipment-aided extrication (LSB Driver) was 18.844° with a range of 13.253 to 26.894°. Average movement for all subjects during the SEJ extrication was 17.598° and ranged from 13.245 to 22.597°. Full details for all subjects including variability measures are outlined in Table 2.

In a repeated measure ANOVA there was no significant difference (p>0.05) between the amount of cervical spine movement in the following four techniques;

- Control (No Collar)
- Control (Collar & Support)
- LSB (In-line)
- LSB (Passenger)

These techniques resulted in significantly less movement of the cervical spine on average than the LSB Driver and SEJ Driver techniques (p<0.05).
Table 2. Biomechanical Measurements (°) for Extrication Techniques.

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Control (No Collar)</th>
<th>Control (Collar &amp; Support)</th>
<th>LSB (In-line)</th>
<th>LSB (Passenger)</th>
<th>LSB (Driver)</th>
<th>SEJ (Driver)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.541</td>
<td>14.168</td>
<td>15.737</td>
<td>12.643</td>
<td>18.935</td>
<td>22.597</td>
</tr>
<tr>
<td>14</td>
<td>14.201</td>
<td>16.52</td>
<td>15.234</td>
<td>15.624</td>
<td>18.254</td>
<td>16.542</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>13.333</strong></td>
<td><strong>14.928</strong></td>
<td><strong>13.564</strong></td>
<td><strong>14.380</strong></td>
<td><strong>18.844</strong></td>
<td><strong>17.598</strong></td>
</tr>
<tr>
<td>St Dev</td>
<td>2.67</td>
<td>1.51</td>
<td>2.34</td>
<td>2.64</td>
<td>3.46</td>
<td>3.15</td>
</tr>
<tr>
<td>CoV</td>
<td>20.02</td>
<td>10.11</td>
<td>17.23</td>
<td>18.36</td>
<td>18.35</td>
<td>17.88</td>
</tr>
</tbody>
</table>
Preliminary Conclusions

These results support the findings of the feasibility study (Dixon et al 2013), it appears that self-extrication without the support of a cervical collar results in the least amount of movement of the cervical spine. The evidence presented here suggests that continued use of the LSB with a driver door exit and immobilisation with the SEJ may not be appropriate. This study adds to the growing body of evidence suggesting that current rescue techniques may not be providing optimal care for the post-RTC patient.

An Irish Expert Group was convened on July 4th and the study findings were presented by the Research Team. The Expert Group members included; Advanced Paramedics (3), a Biomechanics Expert, a Research Methodologist, a Fire Officer, Emergency Medicine Consultants (2) and Nurses (2) and the Deputy Medical Director of the National Ambulance Service. Following on from this discussion the results will now be presented to the Medical Advisory Committee of the Irish Statutory Regulator, the Pre-hospital Emergency Care Council, with a view to changing the current clinical practice guidelines pertaining to extrication and spinal immobilisation.

The first manuscript is currently being drafted and will be submitted for publication to The Emergency Medicine Journal over the coming weeks. An abstract is also being prepared for submission to the National Association of Emergency Medical Physicians meeting scheduled for January 2015 (New Orleans USA). When the accelerometer analysis is complete these findings will be compared to those of the video analysis. Pending the expert group validation of both sets of results, definitive evidence can be offered and a national strategy to move forward will be described.

The ramifications for global EMS are considerable; the indoctrinated dogma of mandatory spinal immobilisation must be queried in light of this research. A number of agencies including the NAEMSP in the United States have already released position statements regarding this topic. If the author’s research is validated by the accelerometer evaluation then the evidence strongly points to mandatory changes in EMS protocols.
References

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- Karbi et al 1988 Extrication, immobilization and radiologic investigation of patients with cervical spine injuries. Canadian Medical Association Journal 139 (7) 617-21
- White et al 2013 EMS Spinal Precautions and the use of the long backboard – Resource document to the position statement of the National Association of EMS Physicians and the American College of Surgeons Committee on Trauma. Prehospital Emergency Care. 18 (2) 306-314