HIGH SPEED VIDEO ANALYSIS OF THORACOLUMBAR BURST FRACTURES

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Introduction
Following a burst fracture, decompressive surgery is often recommended on the basis of imaging alone. There is, however, little evidence that the removal of intra-canal bone fragments is of neurological benefit to the patient (1). Further, there is doubt as to whether the fragment position seen on post-injury CT scans represents the true extent of the occlusion produced during the fracture process (2). The aim of this study was to develop an experimental method for examining the events that are likely to cause neurological injury at the time of fracture. A new technique, using high-speed video to film inside the spinal canal during the fracture event, is described.

Methods
A rig was built to create reproducible burst fractures by dropping a mass of up to 7kg from a maximum height of 2m onto three-vertebra spinal segments. The thoracolumbar spines were harvested from calves aged 21 days. During preparation, the spinal cord was removed and the ends of the specimens were fixed in polymethylmethacrylate holders that allowed unimpeded access to the spinal canal.

In order to film the fracture process, a high-speed video (Kodak HS4540, Roper Scientific MASD, CA, USA) was used. The system was capable of recording 3072 frames of 256 x 256 pixels at a speed of 4500 frames/second. The spinal canal was illuminated via a mirror above the specimen using a 50W light source. The camera was positioned in line with a second mirror below the specimen so that the cross-section of the canal could be seen (Figure 1). A second camera was used to film the outside of the specimen to determine if buckling occurred during the impact process. After capture, the frames were downloaded to a PC and analysed using a custom written algorithm in an image analysis package (Image-Pro Plus 3.0, Media Cybernetics, MD, USA) to determine the canal cross-sectional area as a function of time during the fracture event. To validate the results, CT scans were taken of nine of the specimens and compared with the final video images taken during the test.

Results
A total of 25 tests were carried out at nine different impact conditions. The images taken from the high-speed video clearly showed the vertebral bone fragment being projected into the spinal canal and then recoiling to the final resting position. For each test, the relative canal cross-sectional area was plotted during the impact event (Figure 2). In every case, the final level of canal occlusion was less than the maximum that occurred during the impact. There was also an increase in maximum occlusion with an increase in impact momentum and impact energy. Repeated tests at the same impact conditions gave similar levels of maximum occlusion, but there was much greater variability in the final fragment position. Results from the second camera showed no buckling of the specimen during impact.

Discussion
A new method has been developed to demonstrate the geometrical changes that occur during the burst fracture process. The high level of agreement between the post-impact CT scans and the video images taken at maximum occlusion and at the final resting position were assessed using statistical methods proposed by Lin (3) and Bland and Altman (4). The concordance coefficients are shown in Table 1. The coefficients show a statistically significant difference between the CT-measured occlusion and maximum video-measured occlusion.

<table>
<thead>
<tr>
<th>Agreement between:</th>
<th>Concordance coefficient</th>
<th>Confidence levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final occlusion measured from video and occlusion measured from post-impact CT</td>
<td>0.938</td>
<td>0.793 – 0.982</td>
</tr>
<tr>
<td>Maximum occlusion measured from video and occlusion measured from post-impact CT</td>
<td>0.483</td>
<td>0.164 – 0.802</td>
</tr>
</tbody>
</table>

Figure 2: Four typical plots of canal area against time with different impact conditions

The levels of agreement between the post-fracture CT scans and the video images taken at maximum occlusion and at the final resting position were assessed using statistical methods proposed by Lin (3) and Bland and Altman (4). The concordance coefficients are shown in Table 1. The coefficients show a statistically significant difference between the CT-measured occlusion and maximum video-measured occlusion.

Figure 3: Levels of agreement between canal occlusion measurements

Acknowledgements

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Figure 1: Experimental set-up

Figure 2: Four typical plots of canal area against time with different impact conditions

Figure 3: Levels of agreement between canal occlusion measurements