INTERNAL PRESSURE IN HUMAN LUMBAR VERTEBRA

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INTRODUCTION
In Roaf’s theory of burst fracture formation, he described an axial compressive load on a vertebra, which induced endplate failure from the nucleus pulposus being pushed into the vertebral body. This resulted in an increase in vertebral internal pressure that would cause the body to explode with retropulsion of bony fragments into the canal space (Roaf 1960). This aspect of Roaf’s burst fracture theory (internal vertebral pressurization) has not been previously tested under destructive impact conditions.

The current research measures changes in internal pressure of lumbar spinal segments under high- and slow-speed axial-compressive loads to determine whether an internal pressure rise is associated with burst fracture formation.

PROCEDURES
Specimen Preparation: Twenty-one human cadaveric thoracolumbar 3-body spinal segments were used (sections T12-L2, T11-L1, and L1-L2). They were randomly divided into two groups: high- and slow-speed with mean ages of 73.7 ± 8.8 and 67.4 ± 12.0 years, respectively. These specimens were determined to be free of pre-existing pathologies and fractures using visual and radiographic inspections. Bone mineral density (BMD) was determined for each specimen using dual x-ray absorptiometry (DXA) (Hologic Inc., Waltham, MA).

Internal Pressure System: The internal pressure (IP) measurement system consisted of a pressure transducer (Model 4503, Eaton Lebow, Troy, MI), a 90° brass elbow, and a 3/16-inch brass tube.

Mechanical Testing: The internal pressure system was degassed with a vacuum pump while submerged in distilled water bath. It was not removed from the bath for the remainder of the test.

The upper and lower vertebrae were potted in dental cement (Labstone Buff, Miles Dental Products), so only the middle vertebra and its adjacent discs would be exposed to axial compressive loading. While the specimen was submerged, a hole in the pedicle of the middle vertebra was made to a depth of 1/2 inch. The 3/16-inch brass tube was removed from the rest of the IP system, but it was kept submerged. The 3/16-inch brass tube fitted with a 1/8-inch brass rod insert was pressed into the undersized pedicle hole. The brass rod was used to keep the tube clear of bone debris. This rod was removed and the rest of the internal pressure system (elbow and pressure transducer) was reattached to the secured metal tube. The potted specimen was secured to the water tank with a metal bracket. The tank was bolted to a load cell (MTS, Minneapolis, MN) (Figure 1). The water was then heated to 37°C and the specimen remained at that temperature for at least 1/2 hour.
The specimens were then subjected to axial compressive loading at 10mm/sec and 2500mm/sec, slow- and high-speed, respectively under displacement controlled testing. The maximum displacement for each specimen was limited to 1/4 the middle vertebral height plus 1/2 the heights of both discs, as measured from lateral radiographs.

Analysis: An ANOVA was used to determine the differences in measured internal pressure, failure load and energy absorption, based on a significance level of 0.05. Clinical fracture type was determined from post-injury lateral radiographs by an orthopaedic surgeon.

RESULTS AND DISCUSSION

The measured initial peak internal pressure was 6.23 ± 3.97 kPa and 2.38 ± 1.56 kPa for slow- and high-speed, respectively. Internal pressure decreased significantly from the slow to high speed tests (p < 0.01), while neither failure load or energy absorption were significantly different (Figure 2).

All of the slow-speed specimens resulted in compression fractures. The high-speed specimens had 3 burst, 3 compression with burst elements, 3 compression with disc herniation, and 2 compression fractures.

Roaf’s theory of burst fracture formation described an internal pressure rise, which resulted in vertebral explosion and bony retropulsion into the canal space. The current research does not support this theory in that there was no measured increase in internal pressure at high speed and burst fractures were still produced. In conclusion, a possible modification to Roaf’s theory could be that entry of the nucleus into the vertebral body does not cause an internal pressure rise, but instead acts as a wedge, which splits the vertebral body apart and then pushes bony fragments into the canal space.

REFERENCES


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