EFFECT OF CERVICAL LESIONS ON NEURAL SPACE INTEGRITY

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Introduction
Instability is the basis for treatment of the majority of spinal conditions including: trauma, malformations, vertebral infections, rheumatoid arthritis, primary tumors, metastases, and chronic degenerative diseases. Assessment of spinal instability, although rooted in the functional-structural as well as neuro-protective capacities of the spine, does not currently include neurologically defensive management criteria.[1] Since neurologic deficit typically dictates functional outcome, this assessment should include a measure of the neural protective capability of the spine. Thus, we have defined and quantified this role of the spine — preventing compressive injury to the spinal cord and nerve roots— as neural space integrity. This study directly examines the relationship between structural loss in the spinal column and compression of spaces occupied by the neural elements. We created controlled lesions in the anterior cervical spine and measured the resulting changes in the space occupied by the nerve roots and spinal cord. Our motivating hypothesis was: Anterior cervical spine lesions result in increased stenosis of the spinal canal and intervertebral foramen indicating diminished neural space integrity with successively destructive lesions.

Methods
Eight unembalmed human cervical spine specimens were used in a repeated measures study design to compare the effects of sequentially induced, simulated lesions on neural space integrity under physiologic loading conditions. Neural space monitoring was accomplished using unique neural-space occlusion transducers[2] which, when inserted into the intervertebral foramen and spinal canal, measured their cross-sectional area. The mean age of the five females and three males was 75-years (range: 49–92-years).

Specimen Preparation. Each osteoligamentous specimen was potted inferiorly at C7 and superiorly at C3. Pins were inserted into the vertebral bodies of C6 and C4 for the attachment of 3-D motion tracking sensors (3 Space Fastrak System, Polhemus Inc., Colchester, VT). These sensors recorded the relative translational and angular orientation of vertebrae across the lesion site. After removal of the neural tissues, the intervertebral foramen occlusion transducers were inserted into the bilateral foramen of C3-4, C4-5, and C5-6, and a spinal canal occlusion transducer was inserted into the canal.

Experimental Procedure. The cervical spine was placed in a custom loading frame which loaded the specimen in bending by 1.0-Nm increments up to 4-Nm, applied in eight directions: flexion, extension, right and left lateral bending, and four off-axis bending motions. In addition to bending, axial torque was applied up to 3-Nm in 1.0-Nm increments. This full range of motion was executed for the intact case and after each sequential lesion. The lesions, created using a high-speed drill (Midas Rex, Fort Worth, TX), included the sequential transection of the following: ALL (across C4-5 disc), C4-5 disc (discectomy), C5 body (corpectomy), left anterior C5 body (hemivertebrectomy), and right anterior C5 body (full vertebrectomy). In addition to the eight study specimens, a control specimen was tested through six full loading cycles without lesions to determine the effects of repeated loading alone.

Data Analysis. An analysis of variance was used to evaluate differences in neural space integrity for successive lesions using blocks to evaluate the effects of motion, foraminal level and side and canal level (SPSS, SPSS Inc.). This enabled the examination of the effect of lesions on the individual neural spaces as well as the relative neural space integrity for a specific lesion.

Results
Range of Motion. Evaluation of the loading and subsequent range of motion of the intact cervical spine between the C4 and C6 vertebral bodies were not statistically different from normal cervical ranges of motion reported in the literature. The classical examination of instability (using displacements) revealed that with sequential lesions, the range of motion across the lesion site (C4-6) increased in extension. In this study, extension motion across the defect increased from 12° (intact) to 21° with a discectomy lesion and up to 32° with a full anterior resection of one vertebra.

The control specimen demonstrated no statistically significant motions across C5 from the first to the sixth trial indicating that our experimental measures can be attributed to the lesions and are not a result of the repeated loading.

Spinal Canal Integrity. Changes in the spinal canal integrity were not statistically different for any lesion or motion, and in fact revealed the robustness of the spinal canal space during quasi-static loading of specimens with anterior spinal lesions.

Intervertebral Foramen Integrity. Statistically significant changes in intervertebral foramen integrity were measured for successive anterior lesions at various spinal positions. The results presented here are for the final (max.) loading case (4-Nm bending, 3-Nm rotation) for each lesion at each cervical position. Assessed against intact normal range-of-motion neural space integrity values, flexion, extension, ipsilateral bending, ipsilateral bending with flexion, and ipsilateral bending with extension resulted in significant increases in neural space stenosis (p < 0.01). Intervertebral foramen integrity was compromised to the greatest degree in extension (72.7%), ipsilateral bending (74.9%), and ipsilateral bending with extension (70.5%) for each lesion following the corpectomy and were significant (p < 0.0001) compared with intact measurements. Maximum intervertebral foramen integrity deficit resulted from the vertebrectomy lesion in each position, and the greatest potential for neurologic injury with this lesion occurred with the spine loaded in extension with ipsilateral bending (58.9%).

Discussion
The current findings demonstrate significant and unique maps of neural space integrity. The effects of both anterior lesions and cervical position on the ability of the spine to protect its neural tissue were elucidated. Statistically significant intervertebral foramen integrity changes were found for various lesions and positions, while spinal canal integrity was maintained throughout these experiments. Assessment of neural space integrity that would be injurious to a patient’s neural tissues remains a clinical judgment; however these data may help to enhance the accuracy and precision of this evaluation. Further delineation of the neural protective ability of the spinal column to lesions and trauma remains our focus as we attempt to define fully neural space integrity for enhanced clinical assessment of all spinal conditions.

References

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Figure 1: Effect of Extension with Anterior Lesions on the Integrity (cross-sectional area) of Spinal Neural Spaces. Percent changes in neural space cross-sectional area from neutral position are illustrated for 4-Nm of extension loading. While the spinal canal is little affected by these data may help to enhance the accuracy and precision of this evaluation. Further delineation of the neural protective ability of the spinal column to lesions and trauma remains our focus as we attempt to define fully neural space integrity for enhanced clinical assessment of all spinal conditions.

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References

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