IN VIVO THREE-DIMENSIONAL MORPHOMETRIC ANALYSIS OF THE LUMBAR SPINAL BONY CANAL IN HEALTHY AND LOW BACK PAIN PATIENTS

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OBJECTIVE

To accurately quantify the anatomic parameters of the lumbar spinal bony canal using a novel three-dimensional imaging technique based on in vivo CT three-dimensional models.

INTRODUCTION

Accurate morphometric characterization of the lumbar spinal canal is important in understanding several low back disorders such as lumbar spinal stenosis, which is defined as the narrowing of any spinal neural axial canal from various anatomical factors that can stem from various etiologies (1). The anterior-posterior (AP) diameter of the lumbar spinal bony canal measured in the axial plane as demonstrated by Abbas et al. (2) is a commonly measured parameter for defining the bony canal. Current conventional methods for measuring the AP diameter use practical plane and clinically available methods where patient CT scans are analyzed in two dimensions. This method, however, does not take into account the obliquity of the spine since CT scans are taken perpendicular to the plane of the ground, potentially omitting the fact that the largest diameter might not lie in an arbitrarily predefined anatomical plane (e.g. sagittal or coronal), thus leading to less accurate measurements. To the best of our knowledge, there have been no previous studies using in vivo three-dimensional CT models to measure the lumbar spinal bony canal. The aim of this study was to utilize a novel three-dimensional CT-based measurement approach in order to account for the obliquity of the spine and obtain a more accurate measurement of the lumbar spinal bony canal.

MATERIALS AND METHODS

This IRB-approved study obtained CT scans from 10 volunteers. (5 males and 5 females, age range: 20-59 years, 5 symptomatic for low back pain and 5 asymptomatic for low back pain). The subjects' CT image data were used to create three-dimensional vertebral surface models of the lumbar spine (L1-S1) (Volume Zoom, Siemens, Malvern, PA). To create the models, the CT images (1.0-mm thick axial slices) were imported into a three-dimensional reconstruction software package (Mimics, Materialise, Inc., Leuven, Belgium) where a thresholding technique was used in order to segment each vertebral body of the lumbar spine (L1-S1) (3).

Point-cloud data of each segmented vertebral body was obtained using the same software package. This study presents a novel method using the eigenvectors of the posterior walls of each vertebral body calculated from point-cloud data. These eigenvectors were utilized as a reference frame to measure the anterior-posterior (AP) diameter of the bony canal at each level and allows the natural inclination and obliquity of the spine to be taken into account. A custom-written program in Visual C++ using the Microsoft Foundation Class environment was created in order to compute posterior wall eigenvectors.

Two points were set along the approximate inferior and superior ends of the posterior wall (height of the posterior wall) in 3D space. This axis line was shifted 7 mm posteriorly for visibility purposes. Along this axis line, bony canal cross sections were determined at approximately 0.3 mm to 0.4 mm intervals depending on the height of the posterior wall (normalized to 1/100 increments). At each intersection point (point O) of the posterior wall axis line and each cross-section, a spherical coordinate system was established to act as a centered pivoting point for a virtual cone with a vertex angle of 10° (Figure 1).

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This method allows the obliquity of the spine to be taken to account and provides a much more accurate measurement compared to two-dimensional CT scans (Fig. 2, Right). For each subject, the minimum AP diameter (Fig. 3) of the bony canal, the maximum AP diameter of the bony canal and average AP diameter of the bony canal were calculated at levels L1 through L5.

RESULTS

Significant differences in the canal dimensions were found between asymptomatic patients and symptomatic patients. Symptomatic patients had significantly smaller minimum AP diameters (p<0.05) and average AP diameters (p<0.05) than asymptomatic patients. Across each level there was no significant difference of the minimum, average, and maximum AP diameters except that L3 had significantly smaller minimum AP diameters than L1 (figure 4).

When comparing minimum and average AP-diameters by gender, statistically significant differences were also found. Males had significantly larger minimum (p<0.001) and average (p<0.005) AP-diameters than females. A comparison among age groups showed that 20- and 30-year-olds had larger minimum and average AP diameters than the 40- and 50-year-old groups. For maximum AP diameters, only the 50-year-old group had smaller diameters.

DISCUSSION

This study describes a novel three-dimensional imaging technique used to accurately describe the morphometry of the lumbar spinal bony canal compared to conventional two-dimensional techniques. The results indicate a significant difference in AP diameter between low back pain and healthy patients with symptomatic patients having a significantly smaller minimum AP diameter. There was also found to be no difference in minimum AP diameter among levels but a significant gender difference. The use of posterior wall eigenvectors calculated from subject point-cloud data enabled a more accurate measurement of the minimum AP diameter of the bony canal, which is a common parameter used for characterizing the bony canal. Use of this method also enables collection of other important data such as where along the posterior wall axis the minimum and maximum AP diameter of the bony canal occurs (on a normalized scale of 1 to 100) along with other parameters such as curvature of the spinal canal. Future studies should utilize this method for more accurate measurements and greater understanding of the anatomy of the lumbar spine.

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