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The reproducibility comparison of two intervertebral translation measurements in cervical flexion-extension

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Abstract

BACKGROUND CONTEXT: The abnormal translations between vertebrae in the sagittal plane are important clues to spinal dysfunction or instability. Several studies have reported significant variability in their translation measurements with no analysis of data reproducibility.

PURPOSE: We sought to determine the intra- and interobserver reproducibility of the computer-assisted geometric midplanes and rotation matrix methods in the measurements of intervertebral translations at different motion ranges of cervical flexion-extension in asymptomatic subjects and disc-herniated patients.

STUDY DESIGN: A blind, repeated-measure design was applied to determine the reproducibility for intervertebral translation measurements.

METHODS: A total of 608 videofluoroscopic image sequences from the different motion ranges of cervical flexion and extension in 38 asymptomatic subjects and 38 disc-herniated patients were digitized for further analysis.

RESULTS: The intra- and interobserver reproducibility on measuring the sequential translations were in the acceptable range for geometric midplanes method (average intraclass correlation coefficients [ICCs], 0.860 and 0.806; mean absolute difference [MAD] 0.19 and 0.33 mm) and rotation matrix method (average ICCs, 0.807 and 0.735; MAD, 0.35 and 0.42 mm). There was significantly better reproducibility on the measurements of intervertebral translation for the geometric midplanes method than those of rotation matrix method ($p=.001-.040$). The absolute mean differences of the translation measurements between two image protocols averaged 11.2% and 10.8% for the asymptomatic subjects and disc-herniated patients, respectively.

CONCLUSIONS: Based on these results, both methods demonstrated acceptable reproducibility on the intervertebral translation measurements. The geometric midplanes method involving an averaging effect on the placements of vertebral landmarks and closer to center of rotation might reduce the errors in translation estimations. The rotation matrix protocol simultaneously illustrated horizontal and vertical translation motion despite greater digitizing and/or measurement errors.

Keywords: Cervical spine; Intervertebral translation; Geometric midplanes; Rotation matrix

Introduction

The cervical spine is a structure that delicately houses the spinal cord and flexibly allows movement of the head in different directions. Alterations in spinal mechanics as a result of injury or disease have been thought to increases the subsequent risk of developing neck symptoms [1–5]. Abnormal translations between vertebrae in the sagittal plane are important clues to dysfunction or pathology [2,3,5,6]. The

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recognition of cervical malalignment and signs of dysfunction are essential to accurate radiologic diagnosis; however, some are qualitatively illustrated by the simple connection the portions of vertebral bodies [7–9]. The vertebral translation was proposed as a measure from the transverse distance between the lines drawn along posterior vertebral bodies at the level of inferior endplate of the upper vertebra [10]. Nevertheless, the judgment on smoothness of this George's line measured from the posterior vertebral alignment throughout motion was reported to be imprecise for clinical interpretation of vertebral instability [11].

Previous research has relied on different experimental approaches for quantifying cervical spine position or motion. The relatively easy identifications of vertebral landmarks on inferior endplates or posterior body corners have been commonly used in clinical practice, whereas the irregularity of vertebral bodies could produce considerable discrepancies while locating the best-fit line between spinal segments within and between observers [12,13]. Several spinal studies reported significant variability in translation measurements with no analysis of data reproducibility or precision. These variances may be attributed to liberty in selection of anatomic landmarks for reference points by investigators [7–10,13]. Frobin et al. [14] proposed a computer-assisted geometric midplanes protocol to precisely measure the sagittal plane intervertebral motion of cervical spines by radiographs. The similar analysis was further applied to detect the abnormal, increased, segmental motion in patients with chronic whiplash-associated disorders [15]. Some investigators also successfully constructed the well-defined, three-dimensional (3-D) vertebral coordinates by the rotation matrix methods to describe the spinal kinematics [16–18]. Taylor et al. [9] suggested that commonly used methods to assess flexion-extension X-rays of the cervical spine may not provide reliable clinical information about intervertebral motion abnormalities, and that validated, computer-assisted methods can improve agreement among clinicians. The conventional X-ray has contributed to the understanding of segmental spinal motion, but these studies have been restricted to intervertebral measurements at static neck positions. Spinal motion was routinely assessed by end ranges radiographic images to depict the whole sequences of movement change. Consequently, these conventional approaches analyzing cervical spine motion at end ranges of neck motion may not actually reflect the true range of motion of cervical spine [19]. On the other hand, videofluoroscopy is regarded as an accurate assessment of dynamic skeletal motion with the advantages of real-time visualization and reduced radiation exposure [2,20]. A normal disc functions as a shock absorber, but an injured or degenerative disc loses its function and a painful or unstable spine frequently results [21]. Spinal patients with disc herniation may have a certain degree of spinal mobility change; however, the application of the computer-assisted image methods has not been fully investigated. Therefore, this study aimed to determine the intra- and interobserver reproducibility of the computer-assisted geometric midplanes and rotation matrix methods in the measurements of intervertebral translations at different motion ranges of cervical flexion-extension in asymptomatic subjects and disc-herniated patients and to offer further exploration of cervical biomechanics.

Methods

We enrolled 38 asymptomatic subjects and 38 disc-herniated patients. Asymptomatic subjects were excluded if they had history of cervical trauma or surgery, bone pathology, arthritic or inflammatory disorders, pregnancy, or restrictive muscle spasm. Another 38 age-matched patients diagnosed C4–C5 and/or C5–C6 disc-herniation without a history of cervical surgery, significant potential for spinal cord injury, advanced cervical spondylosis, severe spinal stenosis, inflammatory arthritic disorders, or pregnancy were enrolled. This study was approved by the Human Research Ethics Committee and experimental procedures and risks of radiation exposure were fully explained in signed informed consent forms. Subjects practiced the flexion-extension of cervical spine several times to the end range of motion with correction to reduce trunk and out-of-plane motions. The cervical neutral position to the end ranges of cervical flexion and extension were performed in 5 seconds. The cervical motion was evaluated by the videofluoroscopy system (Diagnost 97, Philips Corporation, Andover, MA, USA) [22]. The recorded video images of the spinal motion were captured at 30 frames/second using the Avid Mojo system (Avid Inc., Burlington, MA, USA). The digital images were then transformed into the sequences of bitmap pictures with the aids of the Avid Xpress Pro computer software (Avid Inc.). Four image pictures in evenly divided intervals from the neutral position to end-range flexion were selected to represent the initial third, middle third, and final third ranges of flexion, respectively. Accordingly, another four pictures in evenly divided intervals from the neutral position to end-range extension were selected to represent the initial third, middle third, and final third ranges of extension, respectively. There were eight sequential images from each subject selected to represent the different ranges of flexion and extension for digitizing. In all, two sets of 608 image sequences were digitized by two experienced research members of spine laboratory and the activities for identifying vertebral landmarks were blinded. These vertebral landmarks were digitized three times by each observer, and the mean values were used for subsequent analysis.

Geometric midplanes method

During image analysis, the positions of 22 bony landmarks were digitized utilizing SigmaScan 5.0 (SPSS Inc., Chicago, IL, USA) on a high-resolution monitor. The anatomic identifications of bony landmarks were based on the well-accepted radiographic method [11,14,15]. They were