

THREE-DIMENSIONAL IN VIVO ROTATION OF FUSED AND ADJACENT LUMBAR VERTEBRAE

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INTRODUCTION

Over 300,000 spinal fusion operations were performed in the United States in 2001 and the frequency is increasing [1]. Vertebral motion is three-dimensional (3D) and dependent upon bone, ligament and disc constraints in addition to active musculature. To understand normal vertebral motion and the effects of surgical procedures on spine function, in vivo 3D studies must be performed during muscle driven activities.

Previous in vivo 3D lumbar vertebrae motion studies have included only static measurements [2-4], while dynamic motion has been studied only in 2D [5]. The present pilot study investigated the in vivo 3D motion of lumbar vertebrae during movement. The purpose was to measure the relative rotation between fused and unfused vertebral segments.

METHODS

Five lumbar fusion surgery patients served as subjects (44 ± 12 yrs). Informed consent was received prior to surgery. Three to five tantalum beads were implanted into each of the fused vertebrae and the vertebrae adjacent to them. Subjects were tested 2, 3 and 6 months after surgery. Implanted beads were tracked (accuracy ± 0.10 mm [6]) in biplane x-ray images (50 fps, 100 kV, 100 mA) to determine 3D vertebral kinematics. Subjects performed six motions: forward and backward bending, lateral bending to both sides and axial twisting in both directions. Data collection began with the subject seated upright and continued for 1.0 s per movement. Subjects moved until they reached the end of their range of motion. Reflective markers placed on the shoulders, C7, suprasternal notch, ASIS and PSIS tracked trunk rotation.

Vertebrae were CT scanned and reconstructed into 3D surface models [7]. Relative rotations between adjacent vertebrae (e.g. L3/L4 means "L3 relative to L4") were calculated by body-fixed, ordered rotations about vertebral body anatomical axes (defined by CT reconstructions) in the order flexion/extension, axial (twist), and lateral bending.

RESULTS AND DISCUSSION

Data collected 2 and 3-months post surgery showed less than 2° of relative motion between vertebrae for all subjects, likely because their range of motion was still limited. Patient mobility increased six months post surgery. Between subject variation (fusion site, number of vertebrae fused, type of fusion) was wide ranging and grouping results was inappropriate. Thus, results from one patient 6 months post surgery are presented here. This subject had an L4-L5 fusion. Rotation of L5/Pelvis (inferior to fusion), L4/L5 (fused site) and L3/L4 (superior to fusion) were calculated.

In the left lateral bend (Figure 1), there was less than 0.3° of rotation between fused vertebrae. The vertebra inferior to the fusion had a relative rotation opposite the trunk rotation and the vertebra superior to the fusion had a relative rotation in the direction of trunk rotation. The relative rotation between vertebrae did not necessarily change linearly with trunk

rotation, as there was little movement in L3/L4 until after the trunk rotated 10° (Figure 1). Conversely, L5/Pelvis varied more linearly with trunk rotation.

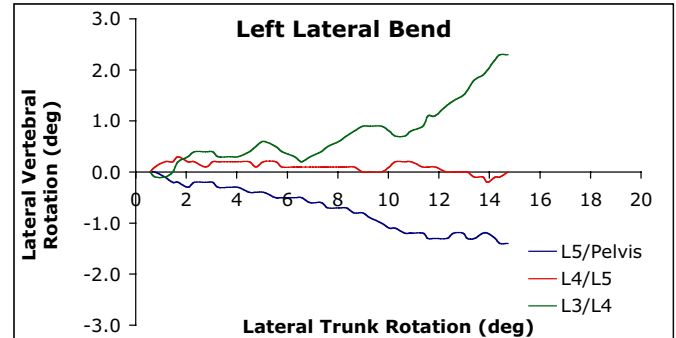


Figure 1: Relative vertebrae rotation during a left lateral bend. Positive values are in the direction of trunk rotation.

Forward bending induced relative motion between the fused vertebrae (Figure 2). Also, relative motion between vertebrae occurred near the initiation of trunk rotation. After 7° of trunk rotation, there was little change in relative rotation between adjacent vertebrae in spite of continued trunk flexion.

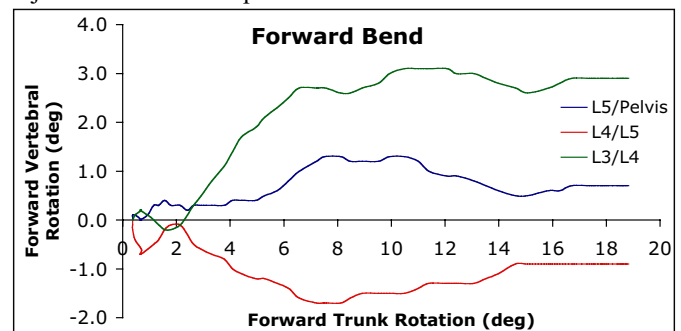


Figure 2: Relative vertebrae rotation during a forward bend. Note relative motion of fused vertebrae (L4/L5). Note also the non-linear relationship between trunk rotation and relative rotation between vertebrae.

CONCLUSIONS

The primary findings were: 1) relative rotation between adjacent vertebrae was not always linearly related to trunk motion; 2) motion in different planes should be studied to investigate relative motion between fused vertebrae, and 3) relative rotation of the vertebra superior to the fused site tended to be in the same direction as the trunk, however relative rotation of the vertebra inferior to the fused site was often in the direction opposite of trunk rotation.

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