In Vivo Three-Dimensional Kinematics of the Degenerative Cervical Spine

INTRODUCTION:
In vivo three-dimensional (3D) kinematic changes associated with degeneration of the cervical spine have not previously been well described since they are too complicated to elucidate using conventional radiography or computed tomography techniques. We have developed a 3D imaging system to evaluate the relative motion of individual cervical vertebra in vivo and reported the kinematics of the normal cervical spine using this original method. The purpose of this study is to investigate in vivo 3D kinematics of the degenerative cervical spine in head rotation and to compare them with those of non-degenerative cervical spine.

METHODS:
10 healthy volunteers (control group) and 15 patients who have the degenerative cervical spine (degenerative group) underwent 3D-MRI of the cervical spine with the head rotated at following angles, 11 positions (neutral, 15° increments to the maximal head rotation at both sides) in the control group and 5 positions (neutral, ±45° and ±maximal head rotation) in the degenerative group. Relative motions of the cervical spine were calculated by automatically superimposing a segmented 3D-MRI of the vertebra in the neutral position over images of each position using volume registration. 3D motions of adjacent vertebra were represented with 6 degree of freedom (DOF) by Euler angles and translations on the coordinate system defined by Panjabi et al, then visualized in animation using surface bone models.

RESULTS:
Mean (±SD) maximal head rotation was 72.0±5.3° in the control group and 63.4±8.9° in the degenerative group. Because of the significant difference between the two groups in maximal head rotation, 3D kinematics in both groups was compared in 45° head rotation. Mean axial rotation in 45° head rotation was 0.4° at Oc-C1, 29.4° at C1-C2, 0.5° at C2-C3, 2.1° at C3-C4, 2.4° at C4-C5, 2.6° at C5-C6, 1.6° at C6-C7 and 0.8° at C7-T1 in the control group and 0.2° at Oc-C1, 28.8° at C1-C2, 0.9° at C2-C3, 2.0° at C3-C4, 2.0° at C4-C5, 1.1° at C5-C6, 0.6° at C6-C7 and 0.7° at C7-T1 in the degenerative group (fig.1).

Significant decrease of mean axial rotation and mean coupled lateral bending were observed at C5-C6 and C6-C7 in the degenerative group (p<0.01, student-t test), although both of the two groups showed the same pattern of the coupled motions. The screw axis of each intervertebral motion with head rotation and angles of rotation about the screw axis were calculated from its kinematic matrix (fig.2). Angles of rotation about the screw axis were decreased at C5-6 and C6-7 in the degenerative group as well as mean axial rotation and mean coupled lateral bending (p<0.01, student-t test).

CONCLUSION:
We demonstrated in vivo 3D kinematics of the degenerative cervical spine during head rotation for the first time. Axial rotation, coupled lateral bending and angles of rotation about the screw axis were significantly decreased at C5-C6 and C6-C7 in the degenerative cervical spine, although both of the non-degenerative and the degenerative cervical spine showed the same pattern of the coupled motions.

Fig.1: Axial rotation at 45° head rotation

Fig.2: The screw axis of intervertebral motion and angles of rotation about the screw axis at each level