INTRODUCTION:
Lumbar spine vertebrae are complicated in structure. Knowledge of motion patterns of lumbar vertebrae is important for treatment of intervertebral disc diseases using dynamic fusion or total disc replacement (TDR). Vertebral rotational center data is especially important since reproduction of physiological vertebral segment rotation is one of the major goals [1].

Previous in-vivo studies have mostly used X-ray images to measure the vertebral rotational centers in sagittal plane. Recently, advanced medical image techniques such as CT, MRI and dual plane fluoroscopic have enabled investigation of 3D motions of the vertebral body in space. We have applied the combined dual fluoroscopic imaging system (DFIS) and MR imaging technique to investigate the 6DOF motion of human lumbar spine [2-4]. Combined with 3D vertebral geometry, we investigated motion characters at different portions of the vertebrae and the rotational centers of the vertebrae in the sagittal and transverse planes.

METHODS:
Ten healthy subjects of 40-60 years old were recruited under IRB approval and informed consent. 3D lumbar spine models of L2, L3 and L4 were reconstructed from MR scans. Spine motions were then reproduced using combined DFIS and MR imaging technique [3] during flexion-extension and left-right twisting of the body. Based on the geometrical features of the vertebrae, ranges of motion (ROM) of 3 representative locations were measured from anterior to posterior: the vertebral body center (B), the spinal cord canal center (C) and the spinous process tip (P) (Fig 1). ANOVA was used to compare the ROMs between L23 and L34 at the 3 locations. Rotational centers of the vertebral segments were then located by calculating the point of zero ROM (Fig 2).

RESULTS:
Motion patterns: The ROMs of L2 with respect to L3 (L23) and L34 increased proportionally from anterior to posterior locations Table 1. During flexion-extension motion, the vertebral body center moved within a range of 0.6 mm, while the spinous process tip moved within 7.5 mm in the sagittal plane. During left-right twisting, the vertebral body center moved within 1.0 mm, while the tip moved within 1.6 mm in the transverse plane. No statistical differences were found in the ROMs between L23 and L34.

Table 1: ROMs of lumbar vertebral segments at different anatomical locations. PD: proximal-distal, ML: medial-lateral

<table>
<thead>
<tr>
<th>Vertebral body</th>
<th>Canal</th>
<th>Process</th>
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<tbody>
<tr>
<td>L23</td>
<td>-0.3 ± 0.3</td>
<td>2.5 ± 1.7</td>
</tr>
<tr>
<td>L34</td>
<td>-0.6 ± 0.3</td>
<td>2.3 ± 1.1</td>
</tr>
</tbody>
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Twist – ML translation (mm)

| L23 | 0.7 ± 0.4 | 1.1 ± 1.0 | 2.3 ± 1.6 |
| L34 | 1.0 ± 0.9 | 1.4 ± 1.3 | 1.6 ± 0.9 |

DISCUSSION:
Motion of lumbar vertebrae is difficult to characterize because of the complicated geometric structures involved. This study, combining the 3D vertebral geometry and 6DOF vertebral kinematics, investigated the range of motion of different portions of the vertebrae and motion center of vertebral segments in sagittal plane during flexion-extension and in transverse plane during left-right twisting of the body. Relatively few studies have reported on the rotational centers of the lumbar vertebra in the transverse plane due to the limitation of technique.

The anterior portion of the vertebra was found to have smaller ROM than the posterior portion. The vertebra rotates with the center of rotation located at approximately the posterior one-third of the vertebral body in sagittal plane. However, the vertebra rotates in transverse plane with respect to a point about 30 mm in front of the vertebra. The data indicated that the different portions of the vertebra have distinct motion characters during different motions. These data may be quite valuable for considerations of dynamic fixation and both TDR design and surgical implantation of the prosthesis.

Reference: