In Vivo Three-Dimensional Motion Analysis of the Lumbar Spine —Coupling Motion of the Lumbar Spine during Rotation—

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INTRODUCTION

In *vivo* 3D kinematics of the lumbar spine during rotation has not been well evaluated by the conventional methods because of inaccuracy. Only *in vitro* studies reported quantitative data in 3D intervertebral motions. However, the lack of physiologic muscle activity makes the results of *in vitro* study impractical [1]. Peacy et al [2] attempted to document *in vivo* coupled motion with axial rotation using biplanar radiography but failed to accurately demonstrate complex coupled motion, because their methods depended greatly on subjective assessments by examiner in tracking bony landmarks on plain radiographs. Considering those facts, in order to evaluate accurately, we developed a 3D imaging system for the relative motion of individual vertebra *in vivo* and reported the kinematics of the cervical spine using this original method [3,4]. The purpose of this study was to evaluate *in vivo* 3D intervertebral motions of the lumbar spine during rotation.

METHODS

Ten healthy volunteers underwent 3D-MRI of the lumbar spine in 9 positions with 15° increments during trunk rotation using a 1.0-T imager. Relative motions of the lumbar spine were calculated by automatically superimposing a segmented 3D-MRI of the vertebra in the neutral position over images of each position using voxel-based registration. 3D motions of adjacent vertebrae were represented with six degrees of freedom by Euler angles and translations on the coordinate system defined by Panjabi, and visualized in animations using surface bone models.

RESULTS AND DISCUSSION

The mean axial rotation of T12/L1, L1/2, L2/3, L3/4, L4/5 and L5/S1 in maximum trunk rotation (56.1°) to each side was 1.3°, 1.6°, 1.5°, 2.0°, 2.1° and 1.7°, respectively. Coupled lateral bending of L1/2, L2/3, L3/4, and L4/5 according to axial rotation was 2.0°, 3.6°, 3.8°, and 1.9°, respectively in the opposite direction and that of T12/L1 and L5/S1 was 0.9° and 0.8° in the same direction (Figure 1). Coupled flexion with axial rotation was observed (L1/2;1.0°, L2/3;1.5°, L3/4;1.5°, L4/5;1.2°, L5/S1;2.5°), while in thoracolumbar junction, extension was coupled with axial rotation (T12/L1;0.1°). These results are consistent with a previous *in vivo* study by Peacy et al (Table 1).

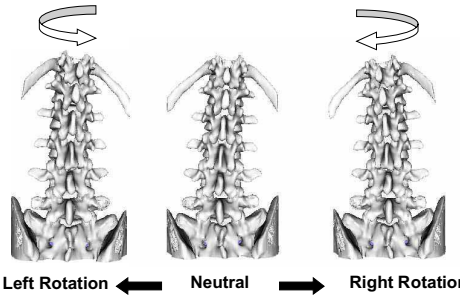

Figure 1: Coupled lateral bending with axial rotation was observed in the opposite direction as axial rotation from L1/2 to L4/5 level, in the same direction T12/L1 and L5/S1 level.

CONCLUSIONS

We investigated the 3D intervertebral motions of the lumbar spine during trunk rotation using a novel *in vivo* 3D motion analysis system, and this is a first report for the *in vivo* coupled motions with accuracy. This result will be helpful for the analysis of other lumber kinematic abnormalities.

REFERENCES

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Table 1: Comparison of the Mean Range (°±SD) of Coupled Rotational Motion on one side

		T12-L1			L1-L2			L2-L3		
***In vivo* study**	**modality**	**Main AR**	**Coupled LB**	**Coupled F-E**	**Main AR**	**Coupled LB**	**Coupled F-E**	**Main AR**	**Coupled LB**	**Coupled F-E**
Peacy et al (1984)	**Bi-plane X-ray**	-	-	-	1	3	0	1	4	0
Present study	**3D-MRI**	1.3(0.5)	`-0.9(0.6)	`-0.1(0.4)	1.6(0.8)	2.0(0.8)	1.0(1.1)	1.5(0.6)	3.6(1.0)	1.5(0.9)
		L3-L4			**L4-L5**			**L5-S1**		
***In vivo* study**	**modality**	**Main AR**	**Coupled LB**	**Coupled F-E**	**Main AR**	**Coupled LB**	**Coupled F-E**	**Main AR**	**Coupled LB**	**Coupled F-E**
Peacy et al (1984)	**Bi-plane X-ray**	2	3	0	2	2	0	1	-2	0
Present study	**3D-MRI**	2.0(0.6)	3.8(1.1)	1.5(0.7)	2.1(0.7)	1.9(0.8)	1.2(0.7)	1.7(0.6)	`-0.8(0.7)	2.5(1.9)

Coupled lateral bending (+) represent the opposite direction of axial rotation Coupled flexion-extension (+) represent flexion.
AR = axial rotation; LB = lateral bending; F-E = flexion-extension