Three-Dimensional Characterization of Segmental Lumbar Lordosis in Healthy and Low-back Pain Patients

Espinoza Orías, A A; Udayakumar, R K; An, H S; Sugisaki K; Andersson G B J; Inoue, N
Rush University Medical Center, Chicago, IL
Nozomu_Inoue@rush.edu

INTRODUCTION

The three-dimensional (3D) nature of the spinal curvature has posed obvious complications to develop consensus for a 3D clinical characterization convention, with the clinical community opting for practical planar methods to determine its curvature in two dimensions. This has made rather infrequent to describe clinical conditions in three dimensions. Quantification of both total and segmental lumbar lordosis (SLL) and its influence on low back disorders is important due to their implications in clinical, biomechanical and ergonomic areas. True 3D measurements made possible by advanced imaging studies can provide with better diagnoses and treatment options. The objective of this study was to establish relationships between disc degeneration, low back pain and SLL using a novel 3D vertebral-orientation measurement technique.

MATERIALS AND METHODS

This IRB approved study obtained CT and MRI scans from 100 volunteers (60 asymptomatic and 40 symptomatic low back pain patient, mean age 37.3 ± 10.1 y.o., age range 22 to 59 y.o.). The CT data was post-processed to obtain point cloud data based on 3D solid models of lumbar spines (L1-S1). The novel approach in this study is the use of eigenvectors of the posterior wall as an indicator of inclination in space due to its consistent flatness across all lumbar levels and as a reference frame to measure SLL. A custom-written program in visual C++ using Microsoft Foundation Class environment was used to calculate eigenvectors of the posterior wall based on the point cloud data. The angle \( \theta \) between two eigenvectors oriented towards cranial direction (line 1 in Fig. 1) in the adjacent posterior wall was calculated by a vector cross product. It is noteworthy to mention that this angle is a true 3D angle in space and is not a projection onto an orthogonal plane.

RESULTS

SLL increased from L1-L2 to L5-S1 with significant differences seen between L2-L3/L3-L4 (\( p<0.05 \)), L3-L4/L4-L5 (\( p<0.01 \)) and L4-L5/L5-S1 (\( p<0.01 \)) (Fig. 2). There were no significant level differences between normal subjects and subjects with low back pain except in L5-S1 were low back pain subjects showed a significant decrease in lordosis (\( p<0.05 \)). The L1-L2 and L2-L3 groups did not show differences when subjects were grouped by age in decades (20’s, 30’s, 40’s and 50’s). The L3-L4 cohort showed an increase in the 3D lordotic angle with advancing age and significant differences were seen between subjects in 20’s and 50’s (\( p<0.05 \)) and 30’s and 50’s (\( p<0.05 \)). L4-L5 subjects in their 50’s showed increased lordosis when compared with those in their 20’s (\( p<0.05 \)), whereas in L5-S1 there was significant reduction in lordosis among subjects in their 50’s when compared with 20’s (\( p<0.05 \)), 30’s (\( p<0.05 \)) and 40’s (\( p<0.05 \)). SLL and disc height decreased with more severe disc degeneration grades. SLL decreased with increasing MRI grade at all levels, except for L1-L2 (Fig. 3). There was a positive correlation between SLL and mean disc height at L5-S1 (\( r = 0.64 \)) (Fig. 4). No differences were found in total lumbar lordosis (L1-S1) between asymptomatic and LBP subjects or among different age groups.

DISCUSSION

This study describes a straightening effect on the lumbar spine with advancing age. A maximum decrease in curvature was observed at L5-S1, with compensatory increase as an adjacent level effect at L3-L4 and L4-L5. Moreover, SLL showed positive correlation with disc height distribution and negative correlation with MRI grade of disc degeneration. Since the data was recorded in supine position, this could be a possible criticism for this study. It is known that spinal curvature changes with positions and activities, for example when lifting heavy objects, the common concept is that the spine tends to straighten from its original position. However, a supine reference configuration is a benchmark that can be applied to a number of studies.

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Fig. 1: 3D depiction of the posterior walls (white dots) and eigenvectors.

Statistical correlations between angle, disc degeneration grade (graded by a panel of four orthopaedic surgeons using the Pfirrmann scale), presence/absence of low back pain symptoms and disc height were attempted. All the measured parameters were compared among levels with ANOVA and Fisher’s post-hoc tests. Comparison between the symptomatic and asymptomatic groups was done by unpaired t-tests.

Fig. 2: Subjects in their 50’s show decreased SLL at L5-S1 with compensatory increase at L4-L5. Asterisk denotes \( p<0.05 \).

Fig. 3: SLL decreased with increasing MRI grade except at L1-L2. Asterisk denotes \( p<0.05 \).

Fig. 4: Mean Disc Height (in mm) and SLL (in degrees) showed moderately positive correlation at L5-S1.