Current Problems in Diagnostic Radiology 48 (2019) 45–49

Current Problems in Diagnostic Radiology

journal homepage: www.cpdrjournal.com

Radiographic Cobb Angle: A Feature of Congenital Lumbar Spine Stenosis

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A B S T R A C T

Purpose: A low cost, reproducible radiographic method of diagnosing congenital lumbar spinal stenosis (CLSS) is lacking. We hypothesized that the Cobb angle for lumbar lordosis would be smaller in patients with CLSS, based on observations in our spine clinic patient population. Here, we compared lumbar lordosis Cobb angles with the radiographic ratio method in patients with normal spine imaging, degenerative spinal stenosis, and with CLSS.
Materials and Methods: Orthopedic surgeons categorized patients with low back pain as “Normal,” “Degenerative spinal stenosis,” and “CLSS” based on clinical presentation and findings on lumbar magnetic resonance imaging. We included 30 patients from each cohort who had undergone lateral lumbar spine radiographs and lumbar magnetic resonance imaging. For each lateral radiograph, 2 measurement methods were used (1) 4-line lumbosacral Cobb angle between L2-S1 and (2) the ratio of the anteroposterior vertebral body diameter and spinal canal anteroposterior diameter at the L3 level. We performed logistic regression analyses of CLSS prediction by Cobb angle vs the ratio method in all three cohorts. Covariates included age, gender, and body mass index.
Results: The radiographic Cobb angles were smaller in CLSS patients when compared to the degenerative disease and normal cohorts: a smaller radiographic Cobb angle showed higher odds ratio (OR) of predicting CLSS diagnosis compared to the radiographic ratio when compared with degenerative disease (OR = 0.28; 95% CI: 0.11-0.78, P = 0.01) and when compared with the normal cohort (OR = 0.46; 95% CI: 0.24-0.92, P = 0.03). Radiographic ratio measurements showed no difference between the three cohorts (P = 0.12). CLSS was associated with male gender (P = 0.04), younger age (P = 0.01), and higher body mass index (P = 0.01).
Conclusion: The radiographic Cobb angle method for lumbar lordosis may be useful for raising the possibility of CLSS as the diagnosis.

Introduction

Congenital lumbar spine stenosis (CLSS) is a developmental dysplasia that results in narrowing of the lumbar spinal canal and that can cause back pain.[1] Compared to degenerative lumbar spine stenosis, CLSS occurs in younger patients (40-50 years of age), has a male predilection, and typically shows little to no associated degenerative spine changes on neuroimaging.[2]

In CLSS, the lumbar pedicles are shortened, which decreases both the anterior-posterior (AP) diameter of the spinal canal and the overall cross-sectional area of the spinal canal.[3] CLSS has been evaluated using various measurement techniques on radiography and cross-sectional imaging (mainly magnetic resonance imaging [MRI]), such as pedicle length, pedicle width, spinal canal AP diameter, and spinal canal cross-sectional areas.[3-6] A large case-control population study of lumbar spine MRIs compared various metrics between normal patients and patients with CLSS and determined values for critical lumbar spinal canal diameter values that indicated a higher likelihood for requiring surgery.[4] There has been variable reporting of interobserver reliability for these measurements, especially for ratios.[5]

Despite the availability of these various measurement techniques, a readily reproducible, and cost-effective measurement technique has not been widely adopted. One reason could be that cross-sectional measurements require lumbar computed tomography or MRI, both of which are more costly than lumbar spine radiography.[7]

Anecdotally, we have noticed that patients with clinically diagnosed CLSS have diminished lumbar lordosis on radiographs compared to relatively normal patients or patients with degenerative disease, resulting in a smaller Cobb angle of lumbar lordosis.[8] The purpose of this study was to compare how the radiographic Cobb angle of lumbar lordosis and a radiographic ratio technique (ie, ratio

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https://doi.org/10.1067/j.cpradiol.2017.11.001
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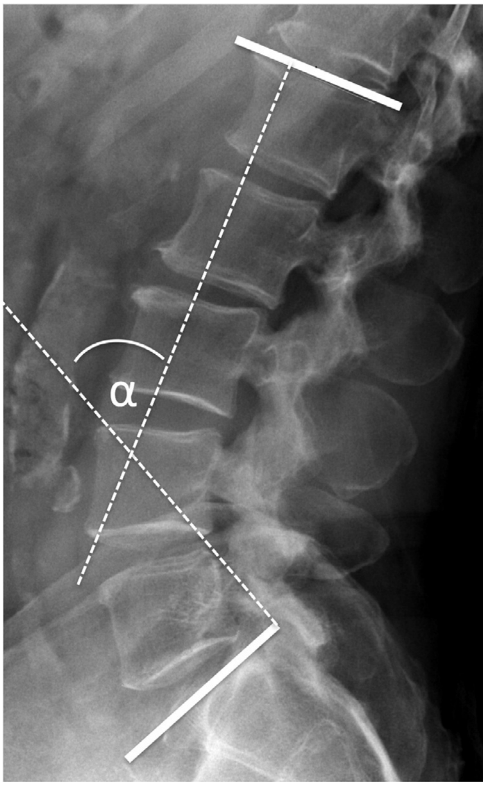

FIG 1. Radiographic measurement of the Cobb angle between the L1 and S1 superior endplates using a 2-line technique on a lateral lumbar radiograph.[8] A line is drawn parallel to the superior endplate of L2 and another line is drawn parallel to the superior endplate of S1. The angle at the intersection of these lines (Cobb angle, asterisk) is then determined using a built-in PACS Cobb angle tool.

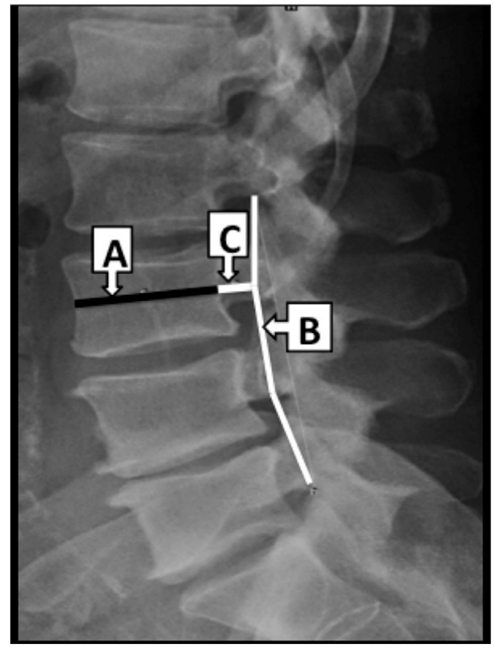

FIG 2. Radiographic measurement technique for the ratio of the AP-VB diameter and the spinal canal AP diameter at the L3 level on a lateral lumbar radiograph. First, a line is drawn through the midsection of the L3 vertebral body, perpendicular to its anterior and posterior borders (A, black line). Next, the spinal-laminar line is delineated using an area drawing tool on the PACS system (B, long white line). Lastly, a line is drawn at the same level as the vertebral body-line and extending from the posterior border of the vertebral body to the spinal-laminar line (C, short white line). The ratio of C over A was calculated.

of VB-AP diameter and spinal canal AP diameter) relate to patients with CLSS, patients with degenerative spine disease, and patients with back pain without significant spine imaging findings.

Methods

Study Design

This retrospective cohort study was approved by the institutional review board and was Health Insurance Portability and Accountability Act compliant. The institutional review board granted a waiver of consent.

Patient Selection

Patients were selected from an orthopedic spine surgery database spanning the years 2013-2015. The database contained patients that presented to the orthopedic spine department with lower back pain and underwent imaging, such as lumbar radiographs, lumbar computed tomography, and lumbar spine MRI. From the orthopedic spine surgery database, starting with most recent patients in 2015, we identified patients who had radiographic and MRI imaging, and who fell in one of the three diagnostic categories (normal, degenerative disease and CLSS). Orthopedic surgeons categorized patients into these 3 cohorts using both clinical *and* certain imaging criteria, *excluding* Cobb angles and Radiographic Ratio. “Normal” cohort: patients without clinical signs of radiculopathy or weakness, responded to physical therapy or medical treatment and with imaging findings of minor degenerative changes without mass effect on neuronal structures; “ Degenerative Disease” cohort: patients with clinical intermittent pain or paresthesia in the legs brought on by walking and standing (relieved with flexion), leg pain, weakness, voiding disturbances, required surgical treatment, and with imaging findings of degenerative changes causing spinal canal stenosis, such as disc disease, osteophytes, facet disease, and ligament hypertrophy or combinations thereof; “CLSS” cohort: patients with clinical intermittent pain or paresthesia in the legs brought on by walking and standing (relieved with flexion), leg pain, weakness, voiding disturbances, required surgical treatment, and imaging findings of minor degenerative changes without mass effect on neuronal structures. We included the first 30 patients who could be categorized into 1 of the 3 cohorts and who had lumbar radiographs and lumbar MRI in this study. The clinical information and imaging studies were reviewed by the study team as part of this study to make the cohort determinations based on the study criteria. For each patient we recorded age, gender, and BMI from medical records as covariates.

Radiographic Evaluation

For each patient, lateral projection standing position lumbar spine radiographs were evaluated using 2 methods: (1) measurement of the Cobb angle for lumbar lordosis[8] between the L1 and S1 superior endplates using an automated function in PACS (Fig 1); (2) the ratio of the AP-VB diameter and the spinal canal AP diameter at the L3 level (radiographic ratio technique) (Fig 2). A single trained reviewer (N.D.) performed all measurements under supervision by an experienced neuroradiologist (N.K.).

Statistical Analysis

To visualize the distribution of data for the three cohorts, we constructed box plots for the radiographic Cobb angle and ratio methods. Demographic and Measurement characteristics were tabulated. For both demographic and radiographic measurements analysis, the

TABLE 1
Patient characteristics. Patients with CLSS were younger and in CLSS males were much more affected than females compared to the other 2 cohorts

Cohort	Male Gender (%)	Mean Age (SD)	Mean BMI (SD)
CLSS	28/30 (93.3)	44.2 (14.5)	32.5 (5.0)
Degenerative disease	20/30 (67.0)	56.5 (12.5)	29.7 (5.6)
Normal	21/30 (70.0)	47.2 (13.6)	31.2 (7.9)
*Fisher exact and ANOVA	$P = 0.023$*	$P = 0.002$	$P = 0.22$

BMI, body mass index; SD, standard deviation.
*Statistically significant when $P < 0.05$.

Fisher exact and ANOVA test were used to compare means between the 3 cohorts for radiographic Cobb angle and the radiographic ratio methods. The Tukey honestly significant difference test was used to determine which cohort's means were different if the ANOVA test did not show all cohort means to be equal.

Next, 2 separate logistic regression analyses were performed examining the factors associated with CLSS compared to (1) the degenerative cohort and (2) the normal cohort. For both analyses the outcome was the odds of predicting CLSS: we used an adjusted multivariate logistic regression model for both analyses, with the covariates as age, gender, BMI, Cobb angle, and the radiographic ratio.

For the regression analysis evaluating the odds of predicting CLSS vs the normal cohort and for evaluating the odds of predicting CLSS vs the degenerative disease cohort, we combined the data from the 2 respective cohorts and constructed a binary outcome with one corresponding to CLSS subjects and zero corresponding to control subjects. Next, a multivariate logistic regression was performed with this binary outcome and the covariates. We computed odds ratios (ORs) for the effect sizes in the logistic regression, and the corresponding confidence intervals for uncertainty quantification. We used Fisher's exact test to test if the ORs were significant. A 95% CI and $P < 0.05$ were considered significant for all analyses.

Results

Demographics

Compared to the normal and degenerative disease cohorts the patients with CLSS were significantly different for gender with a higher percentage of males (93% male, *Fisher exact*, $P = 0.023$) (Table 1). Patients with CLSS were also significantly younger (mean age = 44 years, *ANOVA*, $P = 0.002$). Patients in the degenerative cohort had a higher mean age compared to the other two groups (mean age = 57 years, *ANOVA*, $P = 0.002$). The BMI was similar among 3 cohorts (*ANOVA*, $P = 0.22$). Similarly, when comparing the normal and CLSS cohorts using OR, we found that CLSS was more common in males (OR = 7.16; 95% CI: 1.11-46.24; $P = 0.04$). When comparing the degenerative disease and CLSS cohorts, we found that younger patients were more likely to have CLSS (OR = 7.59; 95% CI: 0.84-68.32; $P = 0.01$).

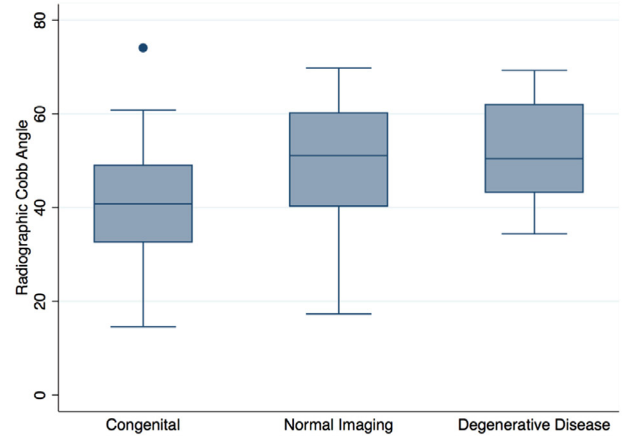

FIG 3. Box plot showing the distribution of Cobb angles when comparing the groups with CLSS, normal imaging, and degenerative disease. Note that the normal imaging and degenerative disease groups had comparable median radiographic ratios, with comparable 25th-75th percentage interquartile range, while those for the CLSS group were lower. (Color version of the figure available online.)

Imaging Metrics

The CLSS group had a significantly smaller median Cobb angle (*ANOVA*, $P = 0.001$) with a lower 25th-75th percent interquartile range compared to the other two groups. Both the CLSS and degenerative disease groups had comparable median Radiographic Ratio (Table 2 and Fig 3), with comparable 25th-75th percentage interquartile ranges (Fig 4), and radiographic ratio did not reach statistical significance across the three cohorts (*ANOVA*, $P = 0.12$).

Logistic Regression

Logistic regression analyses comparing CLSS vs normal imaging cohorts (Table 3) and CLSS vs degenerative disease cohorts (Table 4)

TABLE 2
Measurement characteristics. The Cobb angle was significantly smaller in CLSS when compared to the other 2 cohorts

Cohort	Mean	Median
CLSS		
Cobb angle (SD)	40.1 (13.3)	40.4
Radiographic ratio (SD)	0.342 (0.1)	0.34
Degenerative disease		
Cobb angle (SD)	51.5 (11.1)	50.5
Radiographic ratio (SD)	0.36 (0.07)	0.35
Normal		
Cobb angle (SD)	49.5 (12.6)	51.2
Radiographic ratio (SD)	0.38 (0.06)	0.37
ANOVA		
Cobb angle (SD)	$P = 0.001$	
Radiographic ratio (SD)	$P = 0.12$	

SD, standard deviation.

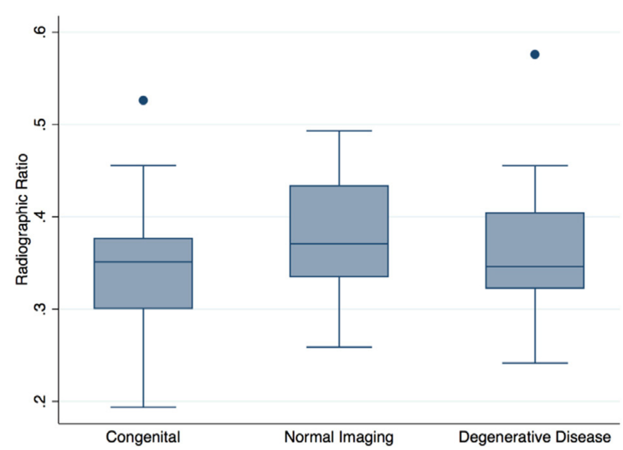

FIG 4. Box plot showing the distribution of radiographic ratio when comparing the groups with CLSS, normal imaging, and degenerative disease. Note all groups had comparable median radiographic ratios, with comparable 25th-75th percentage interquartile range. (Color version of the figure available online.)

TABLE 3
Multivariate logistic regression comparing CLSS with the normal cohort. Results stated as odds ratio of having CLSS. A small cobb angle was more associated with CLSS when compared to the normal cohort

	Odds ratio	95% CI	*P* value
Normal imaging	0.19	0.03-1.09	0.34
Age	0.95	0.51-1.77	0.88
Gender			
Female	Reference for gender		
Male	7.16	1.11-46.24	0.04
BMI	1.08	0.61-1.90	0.80
Cobb angle	0.46	0.24-0.92	0.03
Radiographic ratio	0.67	0.36-1.25	0.21

BMI, body mass index.

was performed. A smaller Cobb angle was more predictive of CLSS compared to normal (OR = 0.46; 95% CI: 0.24-0.92; *P* = 0.03); a smaller Cobb angle was also more predictive of CLSS compared to degenerative disease (OR = 0.28; 95% CI: 0.11-0.71; *P* = 0.01). Although male gender was more predictive of CLSS compared to normal, the CI was very wide (OR = 7.16; 95% CI: 1.11-46.5; *P* = 0.04). A higher patient BMI was more predictive of CLSS compared to degenerative disease (OR = 2.87; 95% CI: 1.26-6.51; *P* = 0.01).

Discussion

Our analysis shows some evidence that the radiographic Cobb angle of lumbar lordosis could be more valuable for identifying patients with CLSS compared to the radiographic ratio technique. The Cobb angle was significantly lower in patients with CLSS when compared to normal and degenerative disease cohorts. Making a diagnosis of CLSS can have prognostic value for patients with neurologic symptoms who choose to undergo surgical decompression. A recent study showed that after lumbar surgical decompression patients with CLSS are less likely to require surgical fusion than patients with degenerative spinal stenosis.[9]

We found an average Cobb angles for lumbar lordosis of 40° in patients with CLSS. The Cobb angle measurements can vary depending on factors such as age, gender, body mass index, ethnicity, and athletic activities, making it difficult to generate normal reference angles.[10] The average Cobb lordosis angle for the unstressed lumbar spine was reported to be 40° when measured on cadavers.[11] Several studies report the average lumbar lordosis Cobb angle to be on average between 54.2° and 62.1°, with reported ranges from 31-89.[12] These values are slightly higher than the ones we found in our cohorts, which could be due to the fact that the reported reference values were obtained from clinically normal and asymptomatic subjects. Given our average lumbar lordosis Cobb angle for patients with CLSS was 40° and the reported normal averages are 54°-62°, comparison of an individual measurement with reported averages in normal populations can still be helpful in raising the possibility of CLSS as the diagnosis.

TABLE 4
Multivariate logistic regression comparing CLSS and the degenerative disease cohort. Results stated as odds ratio of having CLSS. A small cobb angle and higher BMI was more associated with CLSS when compared to the degenerative disease cohort

	Odds ratio	95% CI	*P* value
Degenerative disease	0.22	0.03-1.59	0.79
Age	0.29	0.12-0.69	0.01
Gender			
Female	Reference for gender		
Male	7.59	0.84-68.32	0.07
BMI	2.87	1.26-6.51	0.01
Cobb angle	0.28	0.11-0.71	0.01
Radiographic ratio	0.99	0.38−2.56	0.98

BMI, body mass index.

Recently, several subtypes of CLSS were described based on spinal canal morphology, including a type with a flattened canal, a type with predominantly reduced interlaminar angle, and a type with global reduction of all canal parameters.[6] A potential benefit of the radiographic Cobb method is that canal morphology does not influence this measurement, while it may influence the radiographic ratio because it includes a measurement of the canal depth.

Our results confirm previously published characteristics of patients with CLSS, namely an association with male gender and younger age.[3] Interestingly, in our cohort, a higher BMI was more common in the CLSS cohort compared to the degenerative cohort, although this did not reach statistical significance overall. An interesting consideration for future study is that an already congenitally small lumbar canal diameter may become symptomatic with additional epidural fat deposition in patients with higher BMI.[13]

The retrospective study design is a limitation of this study as we cannot account for selection bias and unidentified confounders as can be done with a prospective randomized study design. Although our orthopedic surgeons used imaging criteria that did not include the Cobb angle or the radiographic ratio, since they were the ones observing a correlation with CLSS and small Cobb angles, they may have performed such measurements in the past. In addition, our "Normal" cohort was not truly normal because patients in this cohort may have had mild degenerative changes, but these were considered insufficient to explain their symptoms. Only patients with "severe" degenerative stenosis changes on imaging were included in the "Degenerative Disease" cohort, but we did not implement standardized imaging criteria (ie, canal AP measurements in mm, relative, definite, and absolute stenosis) to select these patients. In addition, it is possible that patients with CLSS were part of the degenerative disease cohort because there is evidence that degenerative changes can also occur in patients with CLSS.[1] However, patients with CLSS tend to have multilevel symptoms clinically while patients with only degenerative disease tend to have fewer segments involved, which may have helped in an accurate assignment of patients to the cohorts.[4,6]

In summary, the Cobb angle is a method to quickly raise the possibility of a diagnosis of CLSS from lateral lumbar radiographs. Future prospective studies may be helpful to determine the diagnostic value of this imaging sign.

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