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A call for consistent radiographic definition of lumbar lordosis

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OVER the past several years there has been increased interest in lumbar lordosis (LL) and its relationship to pathology and other spinopelvic parameters, especially pelvic incidence (PI). Lumbar lordosis has been shown to correlate strongly enough with clinical outcome measures in patients with adult spinal deformity (ASD) that some authors suggest its restoration should be a primary objective of deformity surgery.¹⁸ Unfortunately, the measurement of LL with other spinopelvic parameters has become such a norm that some studies¹¹ neglect to even mention it in their *Methods* section. We have identified multiple variations in the definition of LL throughout the literature, and hypothesize that these variations may impact the conclusions and clinical decision making that derives from this measurement. In this paper we attempt to determine how pervasive the variability of the definition of LL is within the current spine literature.

Methods

Search Strategy

A literature search of PubMed was conducted by searching for the term “Lumbar Lordosis” in the Title, Keyword, and/or Abstract fields. The search was restricted to papers published between January 1, 2016, and December 31, 2016. Publications that originally appeared in the query results as “published ahead of print” but that were subsequently updated with later publication dates were not removed. The search was also restricted to the following spine-related journals: *Spine*; *Clinical Spine Surgery*; *The*

Spine Journal; *Journal of Neurosurgery: Spine*; *Neurosurgery*; *Asian Spine Journal*; *International Journal of Spine Surgery*; *Spine Deformity*; *Scoliosis*; *Scoliosis and Spinal Disorders*; and *Global Spine Journal*. Papers were screened by 2 authors and included only if they measured LL in at least 1 patient for the purposes of the study.

Data Extraction

The entirety of each paper was reviewed twice (once each by 2 authors) using a standardized form. The authors recorded whether each study explicitly specified the upper and lower vertebrae from which LL was measured and, if so, whether the study specified if the inferior or superior endplates of each vertebra was used (with the exception of those measurements terminating at S-1, in which case it was only recorded whether the endplate of the rostral vertebra was specified). Discrepancies between reviewers prompted a reevaluation of the article in question by both reviewers.

Results

Of the 118 papers initially identified, 5 (2 editorials, 2 review articles, and 1 research study) were excluded for not measuring LL in at least 1 patient. A total of 113 papers were included and critically reviewed. Thirty-four studies (30%) failed to describe which vertebrae were used to measure LL. One mischaracterized segmental lordosis as LL. One used a nonconstrained measurement. Three measured surface topography. Three studies^{1,6,8} had diagrams illustrating LL but did not explicitly state the vertebrae used for measurement in the text of the manuscript or figure legend. These studies were considered to be lacking a definition, because a nonconstrained measurement could have been used. Of the 79 papers that did specify the rostral and caudal vertebrae from which LL was measured, 21 did not specify which endplate was used for the measurement, leaving only 58 studies (51%) with complete definitions of LL.

In those papers that did define which vertebrae were used to measure LL, 12 different definitions of lumbar lordosis were used (Table 1). This lack of consistency

held true even when comparing papers published within individual journals; only the 4 papers published in *Neurosurgery* had a consistent definition within the same journal (although this could not be assessed for *International Journal of Spine Surgery* or *Global Spine Journal* because these each had only 1 paper that met inclusion criteria).

The included papers used the measure of LL for several different purposes. Thirty-nine (34.5%) of the included papers used LL to assess the impact of an intervention or compare interventions (Supplemental Table 1). Twenty-one (18.6%) used LL to assess the reliability of spinopelvic measures or the relationship between spinopelvic and other physiological or quality of life measures (Supplemental Table 2). Thirty-two (28.3%) used LL measurements to assess whether some values of LL were risk factors for disease, predictors of a complication or outcome, or correlated with disease severity (Supplemental Table 3). Twenty-one (18.6%) used LL measurements to define a disease state or normal parameters in a population (Supplemental Table 4). There was no consistent definition of LL used within any of these groups. These studies also examined several different cohorts: 10 were focused on healthy individuals, 32 on nonoperatively treated or preoperative patients with disease, 70 on postoperative patients, and 1 study was performed on cadavers. Of the 10 studies focused on healthy individuals, 9 of them described how LL was measured, and 5 of these used the same definition (one used the superior endplate of L1–S1; one did not specify which endplates of L1–S1 were used; another used a nonconstrained measurement; and two used surface topography). All of these 10 were used to either assess the reliability of or relationship between spinopelvic measures, or to define normal parameters in a population.

Twenty-one papers focused primarily on some form of scoliosis, with 7 focusing on either adolescent idiopathic or congenital scoliosis. There was no consistency in the measure of LL used within any of these groups.

Discussion

Impact of Different Definitions

The lack of a consistent definition of LL was first brought to light by Polly et al. more than 20 years ago when they identified 4 different definitions of LL in the popular literature and examined the interobserver reliability of each.¹⁵ We found 12 different definitions of LL used among the studies we analyzed. The most obvious implication of these differences is that uncertainty is introduced when making comparisons between studies. For illustration, the T-12 and L-1 vertebral bodies have each been shown to contribute an average of approximately 4° of kyphosis due to anterior wedging.⁷ This has been corroborated by other studies, with at least one population demonstrating statistically significant differences in vertebral body angulation between sexes.^{2,14} Similarly, the L5–S1 disc space has been shown to contribute an average of 11.7° of lordosis in at least one population,³ and the segmental angle between the superior endplate of L-5 and the superior endplate of S-1 (i.e., both the L-5 vertebral body and L5–S1 disc space combined) has been shown to contribute an average of approximately 25° of lordosis,¹² suggesting an approximately 13° contribution from the L-5 vertebral body. As a result, the difference between measuring from the superior endplate of T-12 to S-1 versus the superior endplate of L-1 to the inferior endplate of L-5 (as was done in 9 and 5 of the studies reviewed, respectively) can easily exceed the 11° PI-LL mismatch commonly accepted to be clinically significant for LL_{sL1–S1}.¹⁹ In fact, one group found an 18.3° difference between the means of 90 measurements each of LL_{T12–S1} and LL_{sL1–iL5} on 30 radiographs.¹⁰

TABLE 1. The number of papers in the 2016 literature using each definition of LL

Definition of LL	No. of Papers
Superior L1–superior L5	1
Superior L1–inferior L5	5
Endplates unknown, L1–L5	2
Superior L1–superior S1	33
Inferior L1–superior S1	1
Endplates unknown, L1–S1	12
Inferior T12–superior S1	9
Superior T12–superior S1	9
Endplates unknown, T12–S1	7
Nonconstrained Cobb angle	1
Surface topography	3
Segmental lordosis	1
Not stated	29

These discrepancies in the definition of LL create an inconsistent platform for the use of PI-LL as a clinical tool. This was demonstrated by one study in which logistic regression was used to determine a cutoff for a PI-LL value that had adequate sensitivity and reliability for predicting the risk of developing adjacent-segment disease in patients with prior lumbar fusions. Calculations were performed for both LL_{sL1–S1} and LL_{T12–L5}, and the authors found a 55% higher cutoff value for the latter (9.8° and 15.2°, respectively), further illustrating the impact of different LL definitions on PI-LL and the clinical decisions made from this calculation.¹⁶

Unfortunately, the lack of a consistent definition of LL is pervasive throughout the literature. In some cases, the same primary author or large spine study group have used different definitions in different publications.^{20,21} As a result of both how common the use of different LL definitions is and the potential impact of different definitions on a study's findings, questions are raised by those studies that fail to specify the definition of LL used. Take for example a large multicenter trial in which it was concluded that there was no correlation between LL and patient satisfaction scores in postoperative patients with ASD. The authors did not specify the definition of LL they used for measurement, raising the question of whether uniform measurements were used between study sites.⁹

A Call for Consensus

We have found that the literature is rife with studies whose methodology or conclusion has been negatively

FIG. 1. Illustration showing our proposed standardized definition of LL as measured from the superior endplate of L-1 to the superior endplate of S-1. Copyright Mark Frenkel. Published with permission. Figure is available in color online only.

impacted by lack of a strict universal definition of LL. We propose that the angle formed by the intersection of a line tangent to the superior endplate of L-1 with a second line tangent to the superior endplate of S-1 be used as the common measure of LL (Fig. 1). The S-1 level was chosen rather than L-5 because of the large degree of lordosis provided by the L5–S1 disc. The L-1 level was chosen rather than T-12 because the transitional vertebrae between thoracic kyphosis and LL are at or below L-1 in the majority of patients.²² In addition, this was the most commonly used definition in the literature we examined from 2016.

Although the issues arising from the use of different definitions of LL can be avoided in the future by using the single standardized definition proposed above, this may be unrealistic because it would require extensive collaboration. In addition, a new dimension of difficulty is introduced when referencing papers that have already been published. This difficulty can be seen in a 2013 paper,¹⁸ which provides a table with the “LL (L1–S1)” from 6 prior papers. However, of these papers, one⁴ measured a nonconstrained LL to iL5, two^{5,22} measured a nonconstrained LL to S-1, another¹³ measured LL_{T12–?L5}, and the final one measured “S1 lordosis,” which they failed to describe.¹⁷

We propose that the best method for avoiding uncer-

TABLE 2. Proposed shortened nomenclature for definitions of LL

Short Nomenclature	Long Nomenclature
LL _{sL1-S1}	Superior endplate of L-1 to S-1
LL _{iT12-S1}	Inferior endplate of T-12 to S-1
LL _{sT12-S1}	Superior endplate of T-12 to S-1
LL _{sL1-iL5}	Superior endplate of L-1 to inferior endplate of L-5

FIG. 2. Illustration showing the 4 most common definitions of LL that appeared in the 2016 literature, along with our new descriptive nomenclature. Copyright Mark Frenkel. Published with permission. Figure is available in color online only.

tainty in the future is with the introduction of a new nomenclature for LL (Table 2). Ideally, this should replace every instance where the term “LL” appears in a manuscript. It is as follows.

- 1) LL should be followed by a subscript indicating the levels from which it was measured.
- 2) The most rostral vertebra measured should be named first, followed by a dash, and then the most caudal vertebra.
- 3) Levels in the thoracic spine, such as T-12, should include the “T” prefix. The same applies to “S” for levels in the sacrum and “L” for lumbar levels.
- 4) The endplate used for measurement should be identified with either a lowercase “i” for the inferior endplate or a lowercase “s” for the superior endplate preceding the level. A “?” should be used if the endplate used is unknown.
- 5) The endplate identifier is not necessary for S-1 because it is assumed that the superior endplate is used.
- 6) Nonstandard or calculated values of LL may be de-

noted with an “x” in subscript to refer the user to the *Methods* section of the manuscript.

For example, LL measured from the superior endplate of L-1 to the inferior endplate of L-5 would be described as $LL_{sL1-iL5}$ (Fig. 2). Likewise, a measurement from the superior endplate of T-12 to S-1 would be $LL_{sT12-S1}$. The use of a subscript allows this nomenclature to be used in situations such as the PI-LL equation without having a significant impact on formatting.

Conclusions

Our analysis of the 2016 spine literature has revealed a high degree of variability in the definitions of LL used in different manuscripts. This lack of consensus introduces a degree of uncertainty in comparing the findings of different studies, and may have a significant impact on the clinical relevance of PI-LL differences. We propose that a standardized definition of LL, from the superior endplate of L-1 to the superior endplate of S-1, be adopted and that authors and editors alike remain vigilant in its use. Furthermore, we have introduced a proposed nomenclature for when this definition cannot be used or when referencing prior studies.

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Disclosures

Dr. Branch is a consultant for and a patent holder with Medtronic.

Supplemental Information

Online-Only Content

Supplemental material is available with the online version of the article.

Supplemental Tables. <https://thejns.org/doi/suppl/10.3171/2017.11.SPINE17976>.