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Basic Science

Reference data for interpreting widening between spinous processes in the lumbar spine

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Abstract

BACKGROUND CONTEXT: Traumatic injury to the lumbar spine is evaluated and treated based on the perceived stability of the spine. Recent classification schemes have established the importance of evaluating the posterior ligamentous complex (PLC) to fully comprehend stability. There are a variety of techniques to evaluate the PLC, including assessment of interspinous distance. However reference data to define normal widening are poorly developed.

PURPOSE: Define normal interspinous widening in the lumbar spine.

STUDY DESIGN: Biomechanical and observational. To establish reference data for asymptomatic population and use the reference data to suggest criteria for routine clinical practice to be validated in future studies.

METHODS: Interspinous distances were measured from lateral lumbar X-rays of 157 asymptomatic volunteers. Measurements from the asymptomatic population were used to define normal limits and create a simple screening tool for clinical use. Distances were calculated from the relative position of landmarks at each intervertebral level. The distances were normalized to the anterior-posterior width of the superior end plate of L3. The change in interspinous process distance from flexion to extension was calculated, and the change in interspinous widening between flexion and extension with respect to widening at the adjacent levels was also calculated.

RESULTS: Seven hundred seventy-two thoracolumbar levels were available for analysis. The observed interspinous motion was slightly more than the interlaminar motion. However, the tips of the spinous processes were more difficult to identify in some images, so the interlaminar line distances were considered more reliable. Significant difference in interlaminar distances was not found between levels. The upper limit (UL) of normal spacing measured between the interlaminar lines was approximately 85% of the L3 end plate width at all levels except L5–S1, which was 105%. The UL of normal for interlaminar displacements between flexion and extension was 30% of the L3 end plate width at L1–L2 to L4–L5 and 40% at L5–S1.

CONCLUSIONS: This study provides normative data and methods that can be used in developing guidelines to objectively assess interspinous process widening. Simple rules can be applied to quickly assess interspinous widening. Additional research is required to validate these guidelines. A simple measurement such as spinous process widening is unlikely to be proven as an isolated clinically effective screening test but combining that with other patient evaluation's screening modalities may prove to be a sensitive evaluation protocol for the screening of injuries to the PLC.

Keywords: Spinous process widening; Normal; Lumbar spine; Reference data; Stability assessment criteria

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Introduction

Reliable and validated test methods, and criteria for interpreting the results, are essential for accurate diagnosis of injuries and disease, for use in selecting and evaluating treatment protocols, and may also be of value in the design of new treatment options. For injuries and pathologies of the spine, many diagnostic tests focus on the alignment of and motion between vertebrae. In clinical practice, assessment of alignment and motion is frequently based on subjective assessment of medical images, in part because of a lack of reliable, validated, and accessible quantitative measurement tools. Quantitative measurements also require reference data to determine whether or not a measurement is normal, and these reference data are generally not available.

Traumatic injury to the lumbar spine is therefore evaluated and treated based on the clinical perception of spinal stability. Vaccaro et al. [1] described a comprehensive classification that defines stability as based on three variables, including osseous injury, the integrity of the posterior ligamentous complex (PLC), including the supraspinous ligament, ligamentum flavum, and facet joint capsules, and neurological status. This system has refocused attention on the PLC and soft-tissue component of stability in general. Although traditional evaluation of the injured spine with computed tomography (CT) has been excellent for evaluating fixed deformity, obvious malalignment, or fractures, the ability to determine the presence of soft-tissue injury is less precise [1–9]. Magnetic resonance imaging (MRI) is currently thought to be the gold standard for the assessment of acute soft-tissue injury, but there are limitations to using MRI in the acute setting, such as its availability and feasibility in the trauma setting. Severe trauma patients may not be stable enough for the long duration of an MRI examination or may require MRI-incompatible ventilatory support, monitoring, or interventions with metallic components [10]. In addition, MRI examinations are less reliable with chronic conditions. In the presence of spine alignment abnormalities, CT or radiographs can infer the loss of soft-tissue integrity.

These alignment abnormalities can be seen anteriorly between the vertebral bodies or posteriorly between the lamina and spinous processes. Although spinous process widening is accepted as an indicator of injury to the spine [1], there are no validated methods and criteria to determine if the interspinous process distance is abnormal from lateral radiographs of the spine. Several published studies have focused on sagittal plane intervertebral rotation measured from flexion and extension radiographs [11–13]. Computer-assisted imaging techniques can now be used to reduce errors in the analysis of lumbar spine motion, and reference data for interpreting intervertebral rotations and translations have been published [12,14]. However, flexion-extension studies are frequently not practical or safe in a trauma setting. Interspinous widening is, therefore, frequently assessed from static neutral-lateral X-rays, although only limited criteria are available for using these measurements to diagnose soft-tissue injuries to the lumbar spine [7,15]. In a previous survey study done among the members of the Spine Trauma Study Group, plain radiograph signs were perceived to be more helpful than CT or MRI for identifying PLC injuries [16]. Interspinous spacing 7 mm greater than that of the level above or below, measured from anteroposterior X-rays, was added to the suggested criteria [7]. Upper limits (ULs) of normal that can be used when interpreting lateral radiographs taken at variable magnification and criteria for determining whether abnormal displacement exists when comparing flexion to extension radiographs in the assessment of chronic disorders would also be of value in clinical practice.

Thus, the goals of this study were to establish a database of normal interspinous process widening in an asymptomatic population and then to suggest a practical measurement that could be later validated in the trauma patient setting and be used as a screening tool to identify clinically abnormal interspinous process widening.

Materials and methods

To establish a database of normative values, static and dynamic relationships of the posterior elements were analyzed from an asymptomatic population of 157 skeletally mature subjects. The data were retrieved from an original database collected to evaluate sagittal plane lumbar intervertebral motion [12]. There were 80 females and 77 males. The average age was 42±15 years. Seventy-five subjects were under the age of 40 years, 60 in the 41- to 60-year age group, and 22 older than 61 years. Potential volunteers were excluded if they reported ever having back pain necessitating a visit to a physician.

All these studies had been previously tracked and analyzed anteriorly with a previously validated computer-assisted method (QMA; Medical Metrics, Inc., Houston, TX, USA) [14]. For this study, they were reanalyzed for the specific purpose of evaluating interspinous widening. The distances between the spinous processes in flexion and extension were determined by placing landmarks on the most cephalad and caudal aspects of the spinolaminar line and also to the most cephalad and caudal aspects of the tips of the spinous process (Figure). Distances between landmarks on adjacent vertebrae were calculated using the QMA software, both in the flexion and extension images. To make the measurements applicable when the magnification in a radiograph is not known, the distances were normalized to the anterior-posterior width of the superior end plate of L3. The change in distance between flexion and extension was calculated as the spinous process displacement. The displacements were also used to calculate a ratio of the percent of widening at each level with respect to widening at the adjacent levels.

Results

Thirteen sets of images from the 157 flexion-extension studies of asymptomatic subjects could not be analyzed because of poor quality radiographs, where the spinous process landmarks could not be reliably identified. The remaining analyzable subjects provided 772 thoracolumbar levels for analysis.

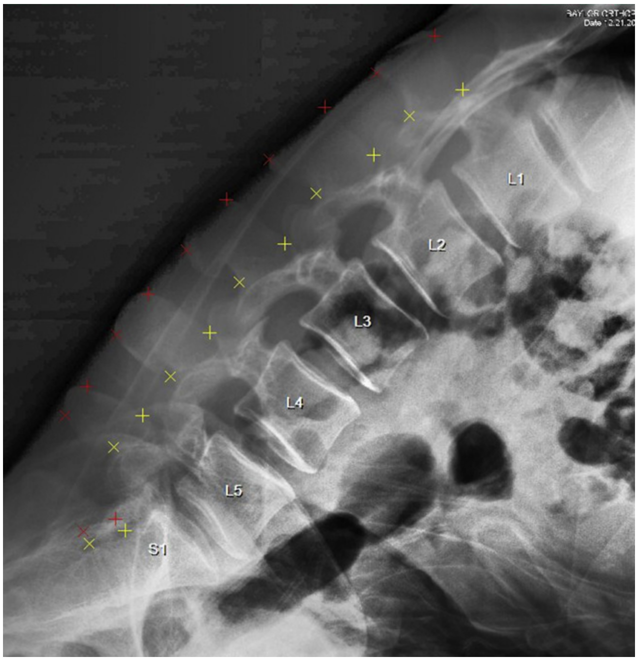

Figure. An example of landmark placement on the tips of the spinous processes and on the interlaminar lines.

The distances between spinous processes, measured in the flexion image and then normalized to width of the anterior-posterior width of the superior end plate of L3, are provided in Tables 1 and 2. The observed interspinous motion was slightly more than the interlaminar motion. However, the tips of the spinous processes were more difficult to identify in some images, so the interlaminar line distances were considered more reliable. Based on one-way analysis of variance, a significant difference in interlaminar distances was not found between levels (p value), except the L5–S1 level, where there is more subjectivity in selecting landmarks analogous to the interlaminar line at the other levels. The UL of normal spacing measured between the interlaminar lines was approximately 85% at all levels except L5–S1, which was 105%.

Between flexion and extension, the relative displacements of the spinous processes, measured between the interlaminar lines and normalized to the width of the superior L3 end plate, are provided in Table 3. The mean widening at the interlaminar lines ranged from 13% at L5–S1 to approximately 25% at the levels above. There were significant differences between L5 and S1 and the other levels ($p<.0001$), with no differences between any levels from L4–L5 to L1–L2.

Table 1
Mean distances between the tips of the spinous processes in the lumbar spine of an asymptomatic population, measured from radiographs with the spine in flexion, and normalized to the width of the superior end plate of the third lumbar vertebra

Level	Mean	SD	LL	UL
L1–L2	61.6	17.1	27.9	95.2
L2–L3	62.7	12.6	37.9	87.4
L3–L4	62.1	14.5	33.7	90.5
L4–L5	62.4	13.4	36.0	88.7
L5–S1	79.3	19.4	41.2	117.5
Average	65.6	17.0		

SD, standard deviation; LL, lower limit for the 95% confidence interval; UL, upper limit for the 95% confidence interval.

Table 2
Distances between the interlaminar lines of the spinous processes in the lumbar spines of an asymptomatic population, measured from radiographs with the spine in flexion, and normalized to the width of the superior end plate of the third lumbar vertebra

Level	Mean	SD	LL	UL
L1–L2	60.9	12.2	36.9	84.9
L2–L3	61.9	11.4	39.6	84.3
L3–L4	61.6	11.4	39.1	84.1
L4–L5	58.4	12.6	33.6	83.3
L5–S1	73.5	15.2	43.5	103.4
Average	63.2	13.7		

SD, standard deviation; LL, lower limit for the 95% confidence interval; UL, upper limit for the 95% confidence interval.

Discussion

Many published studies, and others cited in these publications, focused on sagittal plane intervertebral rotation measured from flexion and extension radiographs [1–3,7,9,17,18]. Computer-assisted imaging techniques can now be used to reduce errors in the analysis of lumbar spine motion, and reference data for interpreting intervertebral rotations and translations have been published [12]. Interspinous widening is also commonly used as a marker of disease or injury to the spine, particularly for injuries or degeneration of posterior structures and evaluation of pseudoarthrosis, again with no validated criteria for these measurements. This lack of standardization limits the ability to interpret and compare data in the clinical settings and across studies.

First and foremost, this study provides a normative database of interspinous distances to assist the clinician in interpretation of dynamic lateral X-ray studies of the lumbar spine, which are not commonly used in trauma assessments but used in assessment of suspected chronic instability. Although these guidelines were developed based on flexion-extension studies, they may also provide UL

Table 3
Change in distance between the interlaminar lines of the spinous processes from extension to flexion, normalized to the anterior-posterior width of the superior end plate of the third lumbar vertebra

Level	Mean	SD	LL	UL
L1–L2	21.4	6.8	8.0	34.8
L2–L3	24.8	6.6	11.8	37.9
L3–L4	25.2	6.9	11.5	38.9
L4–L5	25.2	9.1	7.3	43.1
L5–S1	13.2	7.1	−0.6	27.2
Average	22.0	8.6		

SD, standard deviation; LL, lower limit for the 95% confidence interval; UL, upper limit for the 95% confidence interval.

guidelines useful for interpreting neutral lateral X-rays. A possible scenario would include a patient with an equivocal CT or MRI, where an upright X-ray, and preferably a flexion X-ray, can be obtained. Another scenario would be the patient suspected of chronic instability where a flexion X-ray can be obtained. In either of these scenarios, the reference guidelines for assessing widening might be helpful in diagnosing PLC injuries. Clearly, additional validation would be required of this hypothesis and the central hypothesis that the guidelines could be sensitive to soft-tissue injuries in patients with acute and chronic spinal disorders.

Criteria were derived that could eventually be used as a "rule of thumb" screening method for injury or deficiency of the posterior-ligamentous complex. This criterion is based on the measurement of the distance between interlaminar lines in flexion and the comparison of this measurement to the diameter of the L3 vertebra; measurements above 85% could be considered abnormal (105% for L5–S1). Additional research would be needed to determine the criteria that would be applicable to the thoracic spine, which is a common location of fractures.

Comparing vertebral motion to the adjacent levels has the theoretical advantage of accounting for individuals with general hypermobility. However, false positives may occur because of a hypomobile segment causing the appearance of a relative greater motion at the adjacent level. Thus, with this approach, care must be taken to critically look for the existence of hypomobility. In addition, the data suggest greater variability and, therefore, higher thresholds for the L5–S1 measurements because of difficulties in visualizing the required anatomic details.

Prior radiographic criteria for abnormal interspinous widening have been published using both a frontal plane and lateral plane projection [3,7]. Pearcy and Tibrewal [3] stated that the ULs of normal interspinous widening varied from level to level on lateral radiographs (the UL is 11 mm at L3–L4 and 7 mm at L1–L2). The criteria proposed by Neumann et al. suggested that impending instability and total instability were identified by widening of 20 mm and 33 mm, respectively, on lateral view [19], and any difference greater than 7 mm between two adjacent levels on anteroposterior radiographs indicates a severe and unstable injury [7]. The 7-mm difference between levels was cited by the members of the Spine Trauma Study Group in a recently conducted survey [16].

This information may be directly useful only in the diagnosis of subacute or chronic patients, as it is impractical to use flexion and extension studies in an acute situation. However, these criteria may also work as an upper bound for neutral-lateral X-rays because any spinous process widening greater than what can occur in flexion is likely to be abnormal. The specificity of the threshold can be expected to be lower. Subsequent research would be required to test this hypothesis.

In conclusion, despite the frequent reference to interspinous widening in the literature and clinical practice, there have previously been no criteria for evaluating interspinous widening on lateral X-ray studies of the lumbar spine. This study provides normative data and methods that can be used to better quantify and assess interspinous widening and displacement. Simple rules can be applied to quickly assess interspinous widening, which would be abnormal when greater than 85% of the adjacent level (105% between L5 and S1). These rules need to be further evaluated on the relevant populations of acute, subacute, and chronic patients.

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