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Interpars

An Anatomical Examination of the Lumbar Pars Interarticulares with Significance for Spinal Decompression

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Abstract

Background. *Spine procedures continue to increase significantly. As such, a more precise understanding of the anatomy, especially the pars interarticularis (PI) is critical. Current data characterizing the PI level-by-level is lacking. This study analyzed the average PI width at each level of the lumbar spine in order to elucidate statistically significant PI variations between lumbar levels.*

Methods. *The interpars distance, the narrowest distance between the lateral edges of the left and right PI, was measured directly with calipers on 53 complete lumbar specimens and digitally via Fastrack measurements of 30 sets of lumbar vertebrae. For both methods, the mean interpars distances were compared moving down the lumbar spine.*

Results. *For direct measurements, the average interpars distances increased from L2 to L5. Analysis revealed significant differences across all levels. A significant difference was noted between male and female vertebrae only at L1. For Fastrack measurements, the average interpars distances also increased from L2 to L5. An increase in spinal canal width was observed across all but L1-L2, and an increase in the interpars-to-spinal-canal-width ratio was noted at all levels except L1-L2 and L4-L5.*

Conclusions. *The amount of bone in the PI available for surgical removal becomes smaller moving from L5 to L1. There is a larger "margin-for-error" at L4 and L5 when decompressing the spinal canal from one side to the other than there is in the upper lumbar spine. At L1 and L2, decompressing the entire width of the spinal canal leaves only a millimeter of remaining pars on either side. Care should be taken to use "undercutting techniques" in upper lumbar decompressions to preserve the PI.*

Despite a large number of anatomical and morphometric studies of the spine in the literature[1-17] that focus mostly on the vertebral body, spinal canal, and pedicles, there is a surprising paucity of data regarding the pars interarticularis (PI). An increased understanding of the pars interarticularis dimensions along the lumbar spine would help spine surgeons appreciate the window available for providing an adequate central canal decompression while maintaining enough bone in the pars to ensure continuing structural integrity of the vertebral column.

The purpose of this study was to determine whether there is a consistent and reportable difference in the widths between the pars interarticulares in the lumbar spine. We hypothesized that the width between the pars interarticularis is greater at lower levels of the lumbar spine than at higher levels.

Materials and Methods

We have coined the term interpars to define the width between the pars interarticulares, specifically the narrowest distance between lateral edges of the posterior elements (Fig. 1).

Data Acquisition

Measurement of the interpars distance was completed using two separate modalities for two separate sample populations: digital calipers with Population A (described below) and Fastrack electromagnetic 3D coordinate mapping with Population B (described below).

- Population A: For caliper measurements, access was provided to 53 complete lumbar spine specimens (265

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Figure 1 Caliper measurement of interpars distance. Demonstration of caliper measurement of the interpars difference of a lumbar vertebrae. We have defined the interpars distance as narrowest distance between lateral edges of the posterior elements.

total vertebrae) by the American Museum of Natural History (New York, NY). These were mature specimens without degeneration or malformation. Of the 53 specimens measured, 33 were male, 13 were female, and 7 were of unknown gender. Age, height, weight and preparation data were unavailable. The interpars distance was measured using a Tresna® digital caliper accurate to 0.01 mm according to its ISO9001:2000 technical specifications. A single operator performed each interpars measurement three times at each lumbar level for each specimen.

- Population B: The second specimen source was a database of Fastrack electromagnetic 3D coordinate mappings provided by the Laboratoire de Biomécanique, Arts et Métiers ParisTech in Paris, France. For this technique, 178 points are labeled on each vertebra as expressed in a coordinate system developed by Ian Stokes.[18] Studies by the Arts et Métier ParisTech laboratory demonstrated Fastrack to have precision to ± 0.2 mm.[19] The specimens obtained were mature, without degeneration and malformation; however, no sex, height, weight, age, or preparation data were available.[19] Interpars measurements of 30 complete lumbar spines (150 vertebrae) were provided, as well as the maximum axial widths of the spinal canal at each lumbar level for each specimen.

Data Analysis

The specimens from Population A and B were analyzed separately.

- For caliper measurements (Population A), three interpars measurements were performed per lumbar level; these values were averaged and a standard deviation was calculated. This population of specimens was analyzed as a single group as well as according to gender. Interpars distance was compared between each lumbar level (L1 to L2, L1 to L3, etc.). Additionally, level-to-level comparisons (L1 to L1, etc.) were made between male and female vertebrae.
- For the Fastrack measurements (Population B), the interpars distance was similarly compared between each lumbar level (L1 to L2, L1 to L3, etc.). Additionally, canal width across each level of the lumbar spine was compared, and a ratio of the interpars distance to canal width was calculated for each lumbar level.

Statistical Methods

For all inter-level comparisons (L1 to L2, etc.), statistical analyses consisted of a paired t-test; in order to adjust for Type 1 error, Bonferroni correction was used with level of significance set at 0.005. For level-to-level comparisons between genders (e.g., male L1 to female L1, etc.), a nonparametric Mann-Whitney U test was used to compensate for uneven sample sizes, with significance set at 0.05. All analyses were performed using SPSS software (version 18). Funding was provided via departmental funds. There were no conflicts of interest in this study.

Results

Population A: Caliper Measurements

Considering all specimens, the average interpars distances increased significantly from L1 to L5, with mean values of 24.2, 25.4, 28.4, 32.8, and 40.0 mm ($p < 0.005$). For male specimens, the average interpars distances from L1 to L5 were: 24.4, 25.4, 28.2, 32.9, and 40.7 mm. With the exception of the L1-L2 difference ($p = 0.042$), each one-level comparison was significantly different ($p < 0.005$), and each caudal level difference (L2 vs. L3, L3 vs. L4, etc.) was significantly greater than the preceding level difference. For female specimens, the average interpars distances from L1 to L5 were: 22.9, 24.7, 28.9, 32.6, and 38.7 mm. With the exception of the L3-L4 difference ($p = 0.023$), each one-level comparison was significantly different ($p < 0.005$), and each caudal level difference (L1 vs. L2, L2 vs. L3, etc.) was significantly greater than the preceding level difference. When comparing male and female vertebrae level-to-level, only the L1 interpars distance was noted to

Table 1 Interpars Distance of Population A

Vertebral Level	All Specimens (SD)	Male Specimens (SD)	Female Specimens (SD)
L1	24.2 mm (3.0)	24.4 mm (2.6)	22.9 mm (1.5)
L2	25.4 mm (2.9)	25.4 mm (2.7)	24.7 mm (1.5)
L3	28.4 mm (4.0)	28.2 mm (3.6)	28.9 mm (4.5)
L4	32.8 mm (5.1)	32.9 mm (5.6)	32.6 mm (3.6)
L5	40.0 mm (5.9)	40.7 mm (6.8)	38.7 mm (3.8)
Level Comparison	All Specimens	Male Specimens	Female Specimens
L1-L2	-1.2 mm*	-1.0	-1.8 mm*
L1-L3	-4.2 mm*	-3.8 mm*	-6.0 mm*
L1-L4	-8.6 mm*	-8.5 mm*	-9.6 mm*
L1-L5	-15.8 mm*	-16.3 mm*	-15.7 mm*
L2-L3	-3.0 mm*	-2.8 mm*	-4.2 mm*
L2-L4	-7.4 mm*	-7.5 mm*	-7.8 mm*
L2-L5	-14.6 mm*	-15.3 mm*	-13.9 mm*
L3-L4	-4.4 mm*	-4.7 mm*	-3.7 mm
L3-L5	-11.6 mm*	-12.5 mm*	-9.8 mm*
L4-L5	-7.2 mm*	-7.8 mm*	-6.1 mm*

Average interpars measurements and level-to-level comparisons for each vertebral lumbar level for Population A. These measurements were performed manually with calipers. SD, standard deviation; mm, millimeter.*Values significant at $p < 0.005$.

Table 2 Gender Comparison of Population A Interpars Distance

Vertebral Level	Male Specimens (SD)	Female Specimens (SD)	p-Value
L1	24.4 mm (2.6)	22.9 mm (1.5)	0.047*
L2	25.4 mm (2.7)	24.7 mm (1.5)	0.652
L3	28.2 mm (3.6)	28.9 mm (4.5)	0.990
L4	32.9 mm (5.6)	32.6 mm (3.6)	0.798
L5	40.7 mm (6.8)	38.7 mm (3.8)	0.147

Comparison of interpars distances between male and female specimens in Population A. These measurements were performed manually with calipers. SD, standard deviation; mm, millimeter. *Values significant at $p < 0.05$.

be significantly different in size, male greater than female ($p = 0.047$).

Population B: Fastrack Measurements

No male to female breakdown was available for the Fastrack measurements. The interpars distance from L1 to L5, were 23.8, 24.9, 27.2, 32.1, and 40.9 mm (Table 3). With the exception of the L1-L2 difference ($p = 0.007$), each one-level comparison was significantly different ($p < 0.005$), and each caudal level difference (L2 vs. L3, L3 vs. L4, etc.) was significantly greater than the preceding level difference. Regarding spinal canal width, mean distance from L1 to L5 were 21.5, 21.5, 22.3, 23.7, and 28.5 mm. With the exception of the L1-L2 difference ($p = 0.787$), each one-level comparison was significantly different ($p < 0.005$), and each caudal level difference (L2 vs. L3, L3 vs. L4, etc.) was significantly greater than the preceding level difference. Concerning the relationship between the interpars distance to the spinal canal width, the average ratios were moving from L1 to L5: 1.1, 1.2, 1.2, 1.4, and 1.4. With the exception of the L1-L2 difference ($p = 0.009$) and L4-L5 difference ($p = 0.005$), each one-level comparison was significantly different ($p < 0.005$), and each caudal level difference (L2 vs. L3, L3 vs. L4, etc.) was significantly greater than the preceding level difference.

Discussion

The pars interarticularis has been shown in myriad studies to play an integral role in maintaining the structural integrity of the spinal column: A finite element analysis conducted by Ranu[20] on in-tact and post-laminectomy vertebrae determined that the region of the pars interarticularis is subject to

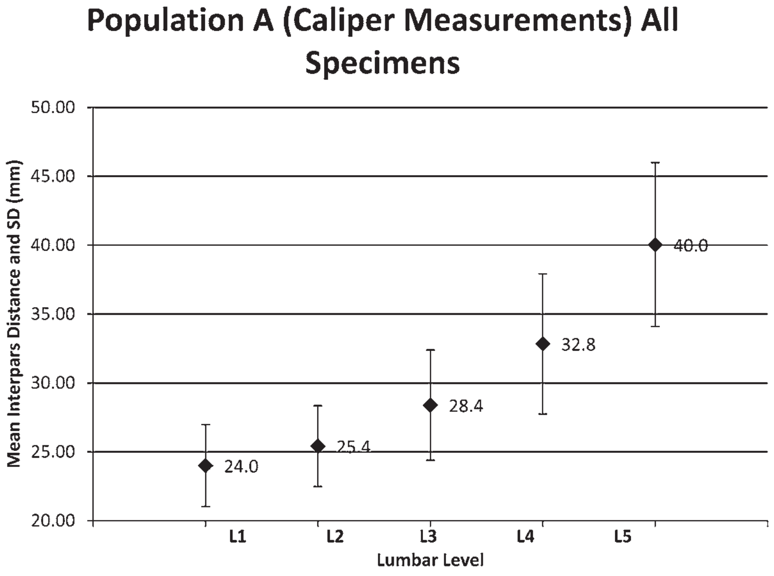

Figure 2 Mean Interpars Distance of Population A (all specimens). Graphical representation of the mean interpars distance at each lumbar level for all specimens in Population A (Male + Female + Unknown). These measurements were performed manually with calipers.

high stresses, which increase when posterior elements are removed. The vulnerability of the pars was also highlighted in a study that described the susceptibility of the pars to fracture by fatigue due to repetitive stresses.[21] That study was conducted on an intact lumbar spine model, suggesting that iatrogenic spondylolysis would only further enhance the vulnerability of the spine to instability. Several studies have shown this to be the case. Ivanov and coworkers[22] conducted a finite element analysis of L3-S1 vertebrae and discovered that unilateral removal of the lateral one-half of the pars resulted in significantly higher stresses in the neural arch, much more so than the removal of the lateral one-fourth of

Table 3 Interpars Distance and Spinal Canal Widths of Population B

Vertebral Level	Interpars Distance (SD)	Spinal Canal Width (SD)	Interpars Distance/ Spinal Canal Width Ratio (SD)
L1	24 mm (2.3)	22 mm (2.0)	1.1 mm (0.1)
L2	25 mm (2.1)	22 mm (1.8)	1.2 mm (0.1)
L3	27 mm (3.2)	22 mm (1.9)	1.2 mm (0.2)
L4	32 mm (4.5)	24 mm (2.3)	1.4 mm (0.2)
L5	41 mm (4.4)	29 mm (3.2)	1.4 mm (0.1)
Level Comparison	Difference	Difference	Difference
L1-L2	-1.1 mm	0.0 mm	-0.1 mm
L1-L3	-3.4 mm*	-0.9 mm*	-0.1 mm*
L1-L4	-8.3 mm*	-2.2 mm*	-0.2 mm*
L1-L5	-17.1 mm*	-7.0 mm*	-0.3 mm*
L2-L3	-2.3 mm*	-0.8 mm*	-0.1 mm*
L2-L4	-7.2 mm*	-2.2 mm*	-0.2 mm*
L2-L5	-16.0 mm*	-6.9 mm*	-0.3 mm*
L3-L4	-4.9 mm*	-1.3 mm*	-0.1 mm*
L3-L5	-13.7 mm*	-6.1 mm*	-0.2 mm*
L4-L5	-8.8 mm*	-4.8 mm*	-0.1 mm

Average measurements and level-to-level comparisons for interpars distance, spinal canal width and the ratio of interpars distance-to-spinal canal width for each vertebral lumbar level of Population B. These measurements were performed digitally via Fastrack electromagnetic 3D coordinate mappings. SD, standard deviation; mm, millimeter. *Values significant at $p < 0.005$.

the pars. In a biomechanical analysis of unilateral spondylolysis, Sairyo and colleagues[23] noted that stresses in the contralateral pars interarticularis increased in all motions. Further, they studied 13 adolescent athletes with unilateral pars fractures and discovered that 53.8% had radiologic evidence of contralateral stress fracture or sclerotic changes near the pars or pedicle.[23]

Given the key role that the pars interarticularis plays in solidifying the architecture of the spinal column, there is not much anatomic data available on this region in the spine literature. While numerous anatomic and morphometric studies of the spine have been published,[1-17,24] most focus on the vertebral bodies, pedicles, and spinal canal dimensions. Specifically, to the investigators' knowledge, there is no data available regarding the relationship of the interpars distance to the width of the spinal canal. This information would be helpful to spine surgeons because it would allow for an appreciation of the window available for sufficiently decompressing a stenotic spinal canal while preserving a reasonable amount of bone in the pars, helping to prevent postoperative spinal instability.

The results of this study suggest that the width between the pars interarticulares, or interpars distance, does indeed increase in size as it descends the lumbar spine. Analysis of 265 vertebrae based on the caliper measurements demonstrated that the interpars distance increased gradually from L1 to L4, then more dramatically across L4-L5 (Table 1, Fig. 2). This trend was similar in both male and female vertebrae (Table 2). A similarly significant increase in width was observed from the Fastrack measurements of the interpars distance (Table 3).

The Fastrack database also afforded an opportunity to measure the spinal canal width. The only one-level difference in canal width that did not reach significance was between L1 and L2. However, the respective increase in spinal canal width across the lumbar vertebrae was still less than the respective increase in interpars distance at the same levels. The result of this differing rate of increase for these two parameters is the ratio of interpars distance to spinal canal width. This ratio reached statistical significance across all level-to-level comparisons except L1-L2 and L4-L5 (Table 3).

Limitations in this study include the inability to combine or compare study populations. This is due to the different modalities used to measure the respective populations as well as the probable inherent variability between two such different populations. Even though the findings from both populations were similar, combining them would be statistically unreliable. Additionally, the specimens used in this study were only included if they demonstrated no obvious disease, including stenoses, arthrosis, and spondylolistheses, microscopic or otherwise indiscernible degeneration is potentially present. Also of note, three fewer specimens were available to the Fastrack arm of this study than were used in the Semaan study from which they were acquired.

The practical implication of the trends identified in this study are that in the caudal lumbar spine there is a significantly wider window available to provide a complete canal decompression that is compatible with long-term integrity of the spinal column. Given that spondylolysis and degenerative disc disease most commonly occur at the fifth lumbar vertebra,[21,25] spine surgeons will benefit from the knowledge of the margins available with which to work in this region. In the proximal lumbar region, greater care must be taken when decompressing the canal in order to avoid introducing an iatrogenic instability. Increased awareness of these ratios will help spine surgeons treating patients with lumbar stenosis avoid postoperative intractable back pain, listheses, and other signs and symptoms of severely altered spinal biomechanics. Care should be taken to use "undercutting techniques" in upper lumbar decompressions to preserve the pars, including microsurgical methods to achieve PI width conservation, such as posterior and transforaminal lumbar interbody fusions. Further biomechanical experimental or numerical investigations need to be performed in order to assess what remaining percentage of pars interarticularis is necessary for long-term stability.

Disclosure Statement

None of the authors have a financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

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