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Original article

Lower lumbar vertebra size and anatomic variation: An Anatomo-Radiologic Study

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ABSTRACT

Introduction: In routine practice, it is often necessary to use shorter screws in L5 than L4. The present study measured L5 versus L4 vertebral pedicles, to guide surgical strategy.
Material and Method: CT or MRI scans for 95 patients were analyzed. Radiographic measurements (anteroposterior diameter (APD), pedicle length (PL) and pedicle width (PW)) were taken by a spine surgeon. Statistical analysis used R 3.4.3 software.
Results: Ninety-five patients were included: 48 female (50.53%), 47 male (49.47%); mean age, 57 years (range, 19–85 years). Univariate analysis found a strong correlation between right and left PL values in L4 and L5.
Right and left values were pooled, obtaining a mean L4 PL of 55.34 mm (range, 54.23–56.45 mm) and L5 PL of 51.80 mm (44.81–58.80) and L4 PW of 10.48 mm (10.06–10.91) and L5 PW of 9.90 mm (7.43–12.39). Multivariate analysis disclosed significant effects of age and gender, with greater age and male gender associated with greater anteroposterior vertebral diameter. Mean anteroposterior vertebral length was significantly shorter in L5 than L4 by 3.57 mm (range, 4.08–3.06 mm).
Discussion: Anteroposterior pedicle length was shorter in L5 than L4, in line with the literature. This answers the surgeon's question: "Should pedicle screws be shorter in L5 than L4?". From these results, it seems logical to use an L5 screw that is 5 mm shorter than in L4, to secure good intra-body screw fixation.

1. Introduction

Many anatomo-radiologic studies have measured the medullary canal [1] and foramen shape [2] or size [3], but few have focused on anatomic differences between the lumbar vertebrae themselves. According to Demondion et al. [3], anteroposterior pedicle depth decreases from L1 to L5.

Following R. Roy-Camille [4] and R. Louis [5], pedicle screwing has become the gold standard in posterior vertebral fusion, as several studies demonstrated its biomechanical superiority. According to Wittenberg et al. [6], biomechanical screw fixation strength is mainly achieved by entry in the pedicle and screw diameter. Pull-out resistance also depends on bone mineral density [7], which may be diminished in over-60 year-olds. In this age group, a large proportion of posterolateral fusions are lumbar, and most often L4/L5 [8]. 73% of degenerative spondylolistheses lie in L4/L5, according to the 2013 round-table of the French Society for Spine Surgery (SFCR) [9].

With population aging and an increase in geriatric surgery, osteoporosis is stimulating the search for new techniques to combat pull-out and fixation hardware mobility. One idea is to use ever longer screws, sometimes with bicortical fixation [10] [11], especially in the sacrum, to compensate for the relative lack of cortical bone in the sacral pedicles. At higher levels, the risks (notably vascular) of such bicortical fixation should not be overlooked.

In routine practice in lumbar spine internal fixation and fusion, it is often necessary to use shorter screws in L5 than in L4 (Fig. 1). This intraoperative finding raises the question as to whether L5 vertebrae, or at least the pedicles, are shorter than the adjacent lumbar vertebrae. The main aim of the present study was to measure L5 versus L4 vertebral pedicles in the axial plane.

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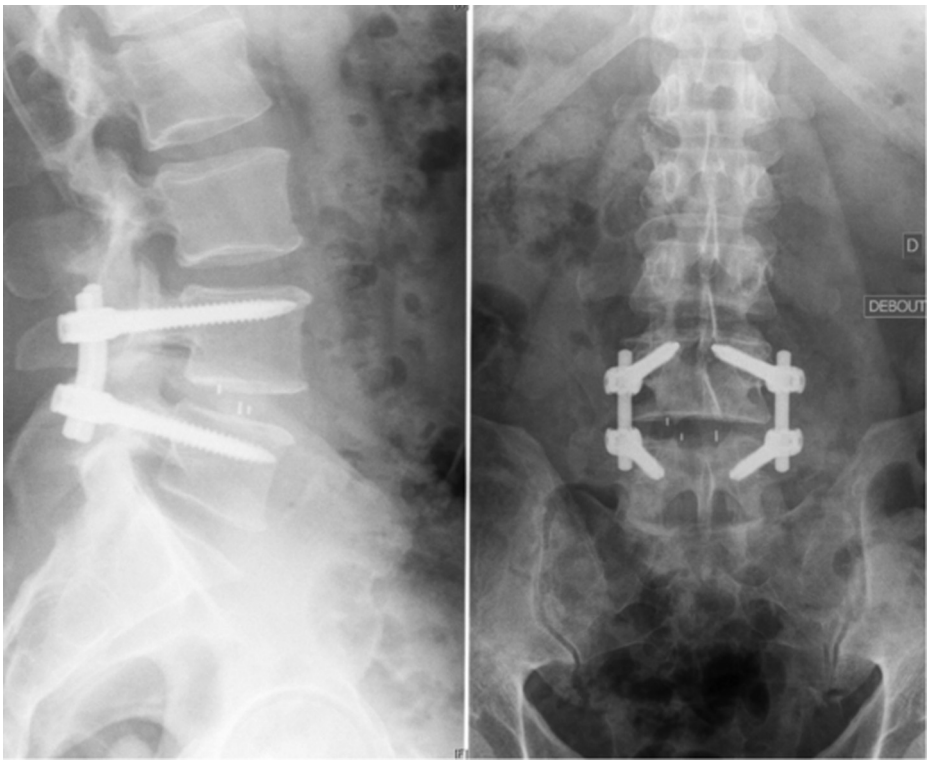

Fig. 1. L4/L5 fusion, with screws 5 mm longer in L4 than L5.

2. Material and Method

2.1. Patients

CT or MRI scans were analyzed from 95 patients. All patients aged 18–85 years undergoing scheduled or emergency thoracic, thoracolumbar or lumbar spinal surgery, with MRI or CT imaging with axial reconstruction, were included; patients without lumbar spine imaging were excluded.

2.2. Radiographic analysis

Radiographic measurements were taken on preoperative images by a spine surgeon, using Centricity Enterprise Web 3.0 software. Following Zindrick et al. [11], measurements comprised:

- APD: vertebral body anteroposterior diameter (Fig. 2), measured as the distance between the anterior and posterior edges through the middle of the vertebral body;
- PL: left and right pedicle length (Fig. 3), measured as the line bisecting the pedicle width (PW) line from the most posterior to the most anterior part of the vertebral body, and corresponding to the length of the pedicle and body along the axis of the body;
- and PW: pedicle width (Fig. 4) at the narrowest part of the pedicle on axial slice.

Both left and right PL and PW were measured.

2.3. Statistical analysis

Statistical analysis used R 3.4.3 software and all necessary applications. Descriptive analysis was performed for quantitative and qualitative variables, with correlations on uni- and multi-variate analysis of measurement values.

Fig. 2. Anteroposterior diameter of vertebral body.

Study variables comprised gender, age and the various measurements: APD L4, PL L4 right, PL L4 left, PW L4 right, PW L4 left, APD L5, PL L5 right, PL L5 left, PW L5 right, and PW L5 left.

3. Results

3.1. Demographic data

95 patients were studied: 48 female (50.53%) and 47 male (49.47%).

Mean age was 57 years (range, 19–85 years) (Table 1).

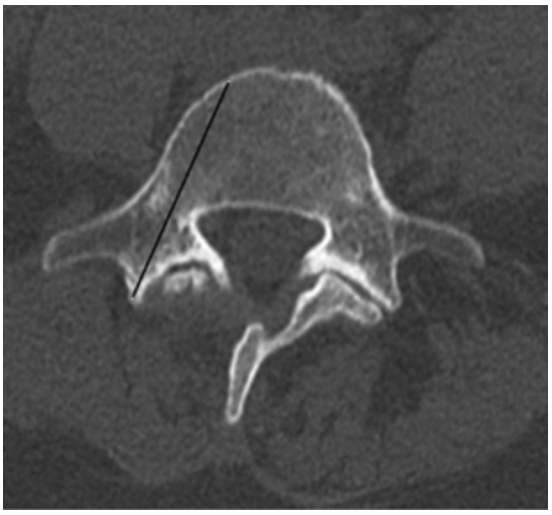

Fig. 3. Right pedicle length.

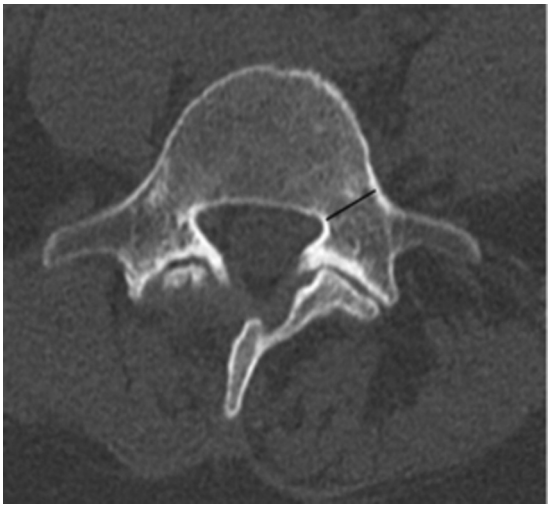

Fig. 4. Left pedicle width.

Table 1
Study population and mean age.

Number	Male	Female	Age (range) in years
95	47 (50.53%)	48 (49.47%)	57 (19–85)

3.2. Radiologic data

Mean values were analyzed for the quantitative variables, as distributions were normal. Values are shown in Table 2.

Univariate analysis disclosed a strong correlation between left and right PL in L4 (Fig. 5) and L5 (Fig. 6). Differences were non-significant. Left- and right-side values in a given vertebra differed due to actual vertebral asymmetry, and to CT slice level and measurement error.

We therefore pooled left and right data, obtaining a mean PL of 55.34 mm (range, 54.23–56.45) in L4 and 51.80 mm (44.81–58.80) in L5, and a mean PW of 10.48 mm (10.06–10.91) in L4 and 9.90 mm (7.43–12.39) in L5 (Table 3).

Multivariate analysis showed that L5 APD was non-significantly shorter by 0.135 mm (range −0.74 to +0.47), while age and gender had significant effects, with increasing age and male gender associated with greater APD.

Mean PL was significantly shorter in L5 than L4 by 3.57 mm (range, 4.08–3.06 mm), with age and gender again showing significant effects (Table 4).

Mean PW was greater in L5 than L4 by 3.24 mm (range, 2.98–3.50), and significantly greater in males.

4. Discussion

The present study showed that pedicle length was shorter in L5 than in L4, in agreement with the literature. The present values were greater than those reported by Ebraheim [12] but close to those of Zendricks [13], who advocated that screw size should take account of pedicle dimensions. Screws should not penetrate the anterior cortex due to risk of hollow organ or large vessel lesions.

The present study compared only L4 and L5, unlike in most of the literature [14], so as to address a very practical question: “Should pedicle screws be shorter in L5 than in L4?”. The answer seems to be “yes”, in the light of the present radiologic and clinical data.

Posterior L4/L5 fusion should avoid degeneration in adjacent levels by joint destruction by the L4 screw head. The L4 screw should not be driven in too far, to avoid joint compression and degeneration.

L5 arthrectomy is often associated to L4/L5 fusion, to release neural structures. This allows a shorter screw to be used in L5. Taken together, these arguments suggest that it is logical to use screws that are 5 mm longer in L4 than in L5.

4.1. Study limitations

Study limitations include the fact that measurements were taken on MRI and not CT in 9 patients. Moreover, CT slices were not always pure axial but rather horizontal, which may have biased measurement.

The finding that age increased APD was surprising in an adult cohort. One reason could be onset of posterior osteoarthritis, but that needs to be confirmed. The small present sample size calls for caution.

Table 2
L4 and L5 APD (anteroposterior diameter), PL (pedicle length: bilateral) and PW (pedicle width: bilateral).

	Mean	Standard deviation	95% confidence interval	Minimum	Maximum
APD L4	34.52	4.21	33.66–35.38	27.27	46.17
APD L5	34.38	4.20	33.53–35.24	25.75	46.78
PL L4 right	55.45	5.79	54.27–56.63	41.83	68.31
PL L4 left	55.23	5.81	54.05–56.42	43.60	67.40
PL L5 right	52.08	5.63	50.93–53.22	40.06	66.62
PL L5 left	51.48	5.85	50.28–52.67	39.82	66.99
PW L4 right	10.50	2.13	10.07–10.94	4.20	16.49
PW L4 left	10.71	2.07	10.29–11.14	4.79	16.90
PW L5 right	13.70	2.31	13.23–14.17	7.24	18.67
PW L5 left	14.00	2.25	13.54–14.45	8.43	18.71

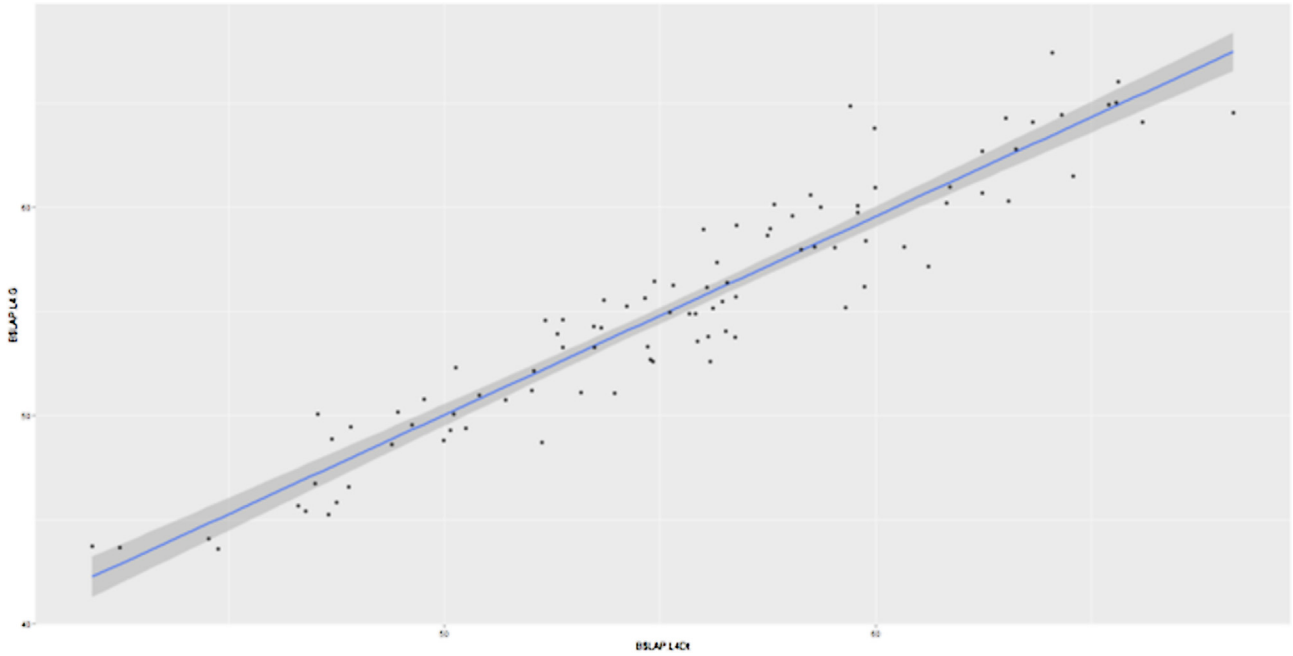

Fig. 5. Correlation between left and right L4 pedicle length.

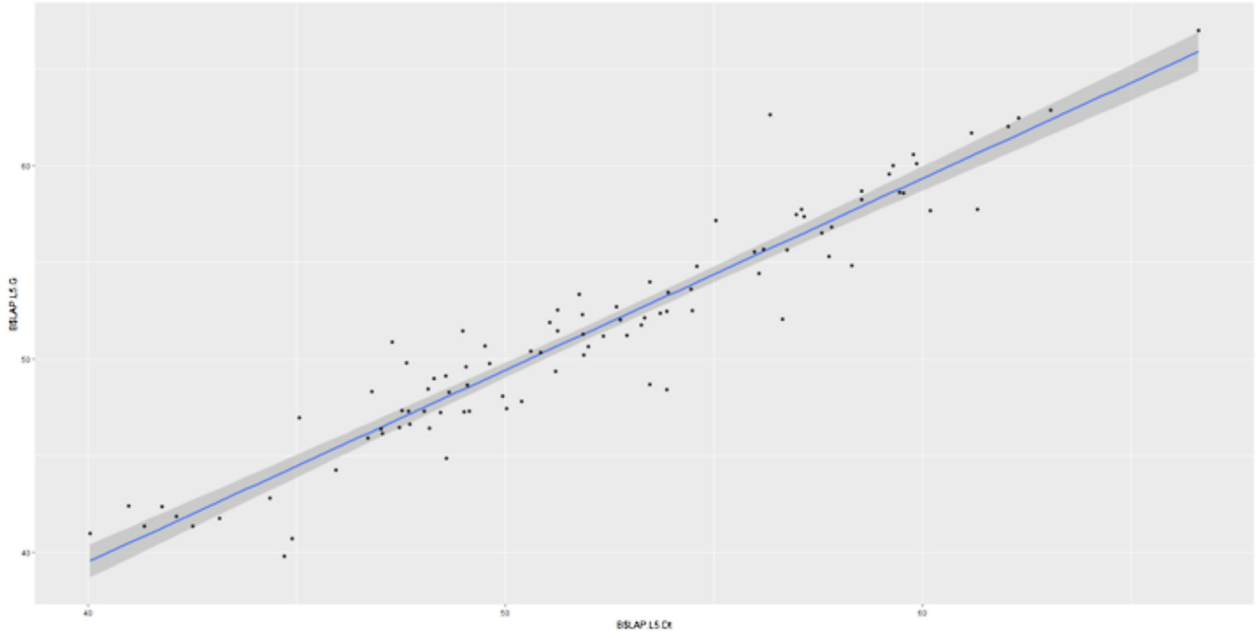

Fig. 6. Correlation between left and right L5 pedicle length.

Table 3
Mean left + right pedicle length (PL) in L4 and L5, and mean pedicle width (PW).

	Distance (mm)	95% CI
PL L4	55.34	54.23–56.46
PL L5	51.76	50.67–52.88
PW L4	10.61	10.21–11.01
PW L5	13.85	13.45–14.25

Table 4
Comparison of APD (anteroposterior diameter), PL (pedicle length) and PW (pedicle width) between L4 and L5.

	Mean	95% CI	
APD L4 vs L5	0.135	−0.74 to 0.47	NS
PL L4 vs L5	3.57	−4.08 to −3.06	< 0.000 1
PW L4 vs L5	3.24	2.98 to 3.50	< 0.000 1

5. Conclusion

In the present study, anteroposterior diameter was 3.57 mm longer in L4 than L5. In the light of this, and furthermore to avoid L3/L4 compression, we advocate using screws that are 5 mm shorter in L5 than L4. The study thus confirms the need to modify technique in lumbar fusion involving L5.

Disclosure of interest

The authors declare that they have no competing interest.

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Author contributions

Pauline Cantogrel: author.
Sebastien Schuller: co-author.
Francois Lefebvre: statistical analyses.
Yann Philippe Charles: supervision.
Jean Paul Steib: supervision.

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