A reliable measurement for identifying a lumbosacral transitional vertebra with a solid bony bridge on a single-slice midsagittal MRI or plain lateral radiograph

The purpose of this study was to devise a simple but reliable radiological method of identifying a lumbosacral transitional vertebra (LSTV) with a solid bony bridge on sagittal MRI, which could then be applied to a lateral radiograph.

The vertical mid-vertebral angle (VMVA) and the vertical anterior vertebral angle (VAVA) of the three most caudal segments of the lumbar spine were measured on MRI and/or on a lateral radiograph in 92 patients with a LSTV and 94 controls, and the differences per segment (Diff-VMVA and Diff-VAVA) were calculated. The Diff-VMVA of the two most caudal vertebrae was significantly higher in the control group ($25^\circ$ (SD 8) than in patients with a LSTV (type 2a+b: $16^\circ$ (SD 9), type 3a+b: $-9^\circ$ (SD 10), type 4: $-5^\circ$ (SD 7); $p < 0.001$). A Diff-VMVA of $\leq +10^\circ$ identified a LSTV with a solid bony bridge (type 3+4) with a sensitivity of 100% and a specificity of 89% on MRI and a sensitivity of 94% and a specificity of 74% on a lateral radiograph. A sensitivity of 100% could be achieved with a cut-off value of 28° for the Diff-VAVA, but with a lower specificity (76%) on MRI than with Diff-VMVA.

Using this simple method (Diff-VMVA $\leq +10^\circ$), solid bony bridging of the posterior elements of a LSTV, and therefore the first adjacent mobile segment, can be easily identified without the need for additional imaging.

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trained in musculoskeletal imaging and a first-year surgical resident (AA), both measured the vertical mid-vertebral angle (VMVA) and the vertical anterior vertebral angle (VAVA) (Figs 2 and 3) on a sagittal T2-weighted MR image and a lateral radiograph. The VMVA was defined as the angle between the vertical mid-vertebral lines of a segment on a single-slice midsagittal MR scan (all subjects) or lateral radiograph. The mid-vertebral line was drawn through the midpoint of the horizontal lines drawn through the upper and lower endplates. The VMVA of the lowest segment with a fully developed disc (a disc that extended across the full width of a segment), and the next two cephalad segments were measured on MRI in all 92 LSTV cases and in 94 control subjects without a LSTV. The controls were selected randomly from PACS during the same search period. Those with prior surgery or any other conditions other than chronic degeneration were excluded. There were 41 men and 53 women in the control group, with a mean age of 51 years (SD 16; 17 to 81). Lateral radiographs were available in 64 patients with LSTV and 47 control patients. We also calculated the difference in the VMVA of the lowest segment with that of the adjacent cephalad segment (Diff-VMVA). The same procedure was performed for the VAVA.

Statistical analysis. Statistical analysis was performed by the first author (MF). Descriptive statistics were used to describe the demographics of the subjects and the total values of the angles. The interobserver correlation was assessed and reported by calculation of the interclass coefficient (ICC) with 95% confidence intervals (CI). The mean of two observations was used for statistical analysis. Normal distribution was assessed using the Kolmogorov–Smirnov test before applying either Student’s t-test or the Mann–Whitney test for normally distributed or non-parametric data, respectively. The cut-off values of Diff-VMVA and Diff-VAVA were chosen with the aim of achieving maximal sensitivity in order to be able to identify all LSTVs with help of receiver operating characteristic (ROC) analyses. Statistical significance was set at a p-value < 0.05.

Results

The MRI measurements of the VMVA and VAVA were greatest at the most caudal mobile segment and decreased progressively across the more cephalad adjacent segments in normal control subjects, and also, albeit to a lesser extent, in those with a type 2a or 2b LSTV (those with no bony bridge). Whereas the largest angles were seen in normal subjects at the lowest segment, in the case of transitional vertebrae, and particularly in those with a higher type of LSTV (type 3a+b and 4 with a bony bridge), the
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Cephalad adjacent segment tended to have a similar or even larger angle than the transitional segment (Table I). The MRI values of Diff-VMVA were significantly higher in the non-LSTV subjects (25° (SD 8°)) than in the LSTV patients (type 2a+b: 16° (SD 9°); type 3a+b: -9° (SD 10); type 4: -5° (SD 7); all p < 0.001 vs control) (Table II) (Fig. 4). This finding was independent of the imaging modality, as Diff-VMVA values on a lateral radiograph (available for 64 LSTVs and 47 non-LSTVs) were lower in a patient with a LSTV, particularly in those with a bony bridge (type 3 and 4) (Table II).

A receiver operating characteristic (ROC) analysis revealed the optimal cut-off value at a Diff-VMVA of +10° in order to achieve a sensitivity of 100% (Fig. 5a). Therefore, a Diff-VMVA of ≤ +10° clearly identified a
LSTV with a bony bridge (type 3+4) with a sensitivity of 100% and a specificity of 89% on MRI and 94% and 74% on lateral radiographs. For a radiograph with the cut-off set at 8° the specificity increased to 85% while the sensitivity remained at 94%; this would, however, reduce the sensitivity of the MRI to 97.8% (Fig. 5b). The ROC analysis for the Diff-VAVA revealed a cut-off value of 28° for a sensitivity of 100% in identifying a LSTV; however, the Diff-VAVA achieved the lesser specificity of 76% compared with Diff-VMVA.

The ICC between the two independent observers, namely the radiologist trained in musculoskeletal imaging (NAFA) and the first-year surgical resident (AA), was high, with 0.96 (95% CI 0.96 to 0.97) for VMVA and 0.98 (95% CI 0.98 to 0.98) for VAVA on MRI and 0.96 (95% CI 0.95 to 0.97) for VMVA and 0.98 (95% CI 0.978 to 0.986) for VAVA on the lateral radiograph. The correlation of the mean Diff-VMVA measurements on the lateral radiograph and on the MRI was $r = 0.59$ for both VMVA and VAVA.

**Discussion**
We have devised and validated a reliable method of identifying a high-grade LSTV, i.e. one with a solid bony bridge, on MRI and on lateral radiographs. This also identifies the adjacent first 'mobile' segment. The VMVA was preferred to the VAVA because of its higher sensitivity and specificity. Although we believe that the VMVA is a valuable adjunct for the reliable identification of a bony bridging LSTV, its value in differentiating sacralisation from lumbarisation is not yet known and is the subject of current research. Furthermore, the suggested cut-off value of Diff-VMVA (+10°) should be interpreted

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**Table II.** Differences in vertical mid-vertebral angles (Diff-VMVA) and vertical anterior vertebral angles (Diff-VAVA) of the lowest segment and the adjacent cephalad segment, categorised by types of lumbosacral transitional vertebra according to the Castellvi classification.

<table>
<thead>
<tr>
<th>Modality and location</th>
<th>Castellvi classification</th>
<th>Type 2a+b</th>
<th>Type 3a+b</th>
<th>Type 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MRI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diff-VMVA</td>
<td>25 (8)</td>
<td>16 (9)</td>
<td>-9 (10)</td>
<td>-5 (7)</td>
</tr>
<tr>
<td>Diff-VAVA</td>
<td>40 (9)</td>
<td>28 (11)</td>
<td>-3 (16)</td>
<td>3 (12)</td>
</tr>
<tr>
<td>Lateral radiographs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diff-VMVA</td>
<td>19 (9)</td>
<td>13 (7)</td>
<td>-5 (8)</td>
<td>0 (10)</td>
</tr>
<tr>
<td>Diff-VAVA</td>
<td>33 (11)</td>
<td>26 (10)</td>
<td>1 (13)</td>
<td>9 (9)</td>
</tr>
</tbody>
</table>
and used with caution owing to the limitations of our study. The control group may not reflect the normal population, as the indication for MRI in this group required them to be symptomatic. It is plausible, but not yet proven, that there is no difference in VMVA or VAVA between symptomatic subjects and a normal asymptomatic cohort.

The Diff-VMVA method is able to identify a LSTV with 100% sensitivity and sufficient specificity on a single-slice midsagittal MRI scan and is independent of the experience of the observer. It showed a slightly lower sensitivity and specificity on a lateral radiograph and correlated only moderately with MRI. This lower sensitivity may be a result of the radiological summation effect of structures with decreasing precision of identification of the vertical vertebral angles, and the moderate correlation could be caused by different positions of the subject during radiological examination (lying for the MRI and standing for the lateral radiograph). Although slightly less sensitive, the Diff-VMVA method on radiographs could be highly valuable, particularly for spinal surgery, where lateral image intensification with the patient supine is used for the identification of levels.

In conclusion, measurement of VMVAs is a reliable method of identifying a LSTV on a single-slice midsagittal MR scan or lateral radiograph, and correlates with the degree of mechanical connection of the LSTV. A Diff-VMVA ≤ +10° clearly identifies bony bridging of the posterior elements of a non-mobile LSTV and hence the first adjacent mobile segment.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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References