The association between lumbar rib and lumbosacral transitional vertebrae

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Purpose

The aim of this study is to investigate the incidences of lumbosacral transitional vertebrae (LSTV: lumbarization and sacralization) and rib anomalies (lumbar ribs and agenesis of 12th ribs), and to find out their morphologic relevance by use of the computed tomography (CT) images.

LSTV and rib anomalies might cause the difference in the level of spine, especially in the lumbar spinal level, between the vertebrae numbering methods (one is the counting from C1 or C2 inferiorly, and the other is the counting from L5 superiorly). Identification of incorrect level of spine may lead to surgical errors [1].

LSTV is one of the causes of the difference in the lumbar spinal level. LSTV is common congenital anomalies of the human spine. The prevalence of LSTV in the general population was reported as 4-21% [2-6]. In LSTV, either the fifth lumbar vertebra may show assimilation to the sacrum (sacralization), or the first sacral vertebra may show transition to a lumbar configuration (lumbarization) [7]. Identification of incorrect lumbar level occurred when MRI of lumbar spine was reported without both the sagittal MRI of the lumbar spine and the frontal and lateral lumbar spinal radiographs [6].

Rib anomalies are one of other causes of the difference in the lumbar spinal level. Combined use of the sagittal lumbar spinal MRI and the frontal and lateral lumbar spinal radiographs was reported to be useful to identify correct lumbar level when the counting craniocaudally from C1 or C2 cannot be applied for the lumbar spinal MRI reporting [6]. In our experience, lumbar ribs resembled 12th ribs on the lumbar spinal radiograph. Therefore, lumbar ribs might make it difficult to identify first lumber vertebra in the frontal lumbar radiograph. In the case with both lumbar ribs and lumbarization, lumbar spinal configuration might be interpreted as normal by the frontal lumbar spinal radiograph (Fig.1). Additionally, in the case with lumbar ribs and normal lumbar spinal configuration, it might be interpreted as the case with sacralization by the frontal lumbar spinal radiograph (Fig.2). Therefore, lumbar ribs might cause the difference in the lumbar spinal level between the vertebrae numbering methods (counting craniocaudally from C1 or C2, and counting caudocranially from L5).
Fig. 1: Volume rendering (VR) images of lumbar vertebrae of the case with lumbar rib and lumbarization. A: If most caudal ribs were interpreted as 12th ribs, lumbar spinal configuration might be identified as normal. B: By the counting from C1 or C2 inferiorly, most caudal ribs were identified as lumbar ribs and most caudal non-fused vertebra was as 25th vertebra (S1: first sacral segment).
Fig. 2: VR images of lumbar vertebrae of the case with lumbar rib and normal vertebral configuration. A: If most caudal ribs were interpreted as 12th ribs, lumbar spinal configuration might be identified as sacralization. B: By the counting from C1 or C2 inferiorly, most caudal ribs were identified as lumbar ribs and most caudal non-fused vertebra was as 24th (L5: fifth lumbar vertebra).

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Methods and Materials

Institutional Review Board approved this study.

Materials

This study is a retrospective radiographic analysis of 288 consecutive cases scanned by multi-slice computed tomography (MSCT) before forensic autopsy from October 2009 to June 2011. 226 cases (148 men, 78 women; age range, 17-94 years; mean age, 59.2 years) were included in the study. Cases below the age of 10 and with the severely damaged bodies by fire or traffic accident, or the severely putrefied bodies were excluded from the study.

CT Machines

MSCT scanning was performed on an eight-channel scanner (Aquilion: Toshiba Medical Systems, Tokyo, Japan). Volumetric helical scans were obtained from the vertex to the proximal femur at 120kV with variable mAs, a beam pitch of 0.875, and 2.0-mm collimation. Evaluation of the radiological data was based on a combination of axial images, multi-planar reconstructions (MPR), and 3D reconstruction by a 3D image workstation (Ziostation2; Ziosoft, Tokyo, Japan).

Vertebrae Numbering

The vertebral levels were counted craniocaudally, starting from C1, based on the assumption of 7 cervical, 12 thoracic and 5 lumbar vertebrae. Therefore, 20th and 25th vertebrae were defined as first lumbar vertebra (L1) and first segment of sacrum (S1), respectively.

Lumbar ribs were defined as rib articulates with L1 (Fig.3). Lumbarization was defined as non-fusion of S1 and S2 (second segments of the sacrum, 26th vertebra), it meant that one additional articulated vertebra (Fig.4). Sacralization was defined as anomalous fusion of L5 (fifth lumbar vertebra, 24th vertebra) and S1 (Fig.5).

Statistical analysis

The Fisher exact test was used to compare categorical variables. Differences were assessed with two-sided tests, with an alpha level of 0.05.
Fig. 3: Lumbar ribs. A: VR image of thoracolumbar spine and ribs. Lumbar ribs were clearly shown. B: Axial multi-planar reconstruction (MPR) images of L1, and C: coronal MPR image of lumbar vertebra. Articulations between first lumbar vertebra and lumbar ribs were well demonstrated.

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**Fig. 4:** Lumbarization and unilateral lumbar rib. A: VR image of lumbar vertebrae. Lumbar vertebrae and lumbarized first sacral segment (S1) were shown. B: Sagittal MPR image of lumbar vertebrae. the lumber type disk at S1-S2 (gray arrow head) and sacrum type disk at S2-S3 (white arrow head) were demonstrated. C: Axial MPR image of first lumbar vertebra (L1). There was a lumbar rib (articulated) at right side and a transverse process (non-articulated) at left. D: axial MPR image of S1. S1 had transverse processes, and resembled L5.
Fig. 5: Sacralization. A: VR image of lumbar vertebrae and sacrum. Anomalous fusion of the transverse processes of the L5 with the sacrum was shown. B: Sagittal MPR image of sacralized L5 vertebral body. There was no disk between L5 and S1 (white arrow). C: Coronal MPR image of L5. Anomalous fusion of the transverse processes of the L5 with the sacrum was shown.

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Results

Lumbar ribs were observed in 13 (5.8%: unilateral rib, 3; bilateral ribs, 10) out of 226 cases. Agenesis of 12th ribs was observed in two cases. Lumbarization and Sacralization were observed in 14 (6.2%) and 6 (2.7%) out of 226 cases, respectively (Table 1).

Lumbar ribs were associated with 11 (78.6%: unilateral rib, 2; bilateral, 9) out of 14 cases with lumbarization, and two (1.0%: unilateral 1, and bilateral 1) out of 206 cases with normal lumbar vertebral configuration. No lumbar rib was observed in 6 cases with sacralization (Table 2).

One case with agenesis of 12th ribs was observed in one out of 6 cases with sacralization. Another case was observed in 206 cases with normal rib configuration (Table 2).

Lumbarization were associated with 11 (84.6%) out of 13 cases with lumbar ribs. Three cases with lumbarization were observed in 211 cases with normal rib configuration (12 pairs of ribs) (Table 2).

One case with sacralization was associated with agenesis of 12th rib, and other five cases were observed in 211 cases with normal rib configuration (12 pairs of ribs) (Table 2).

There was no gender difference in the incidence of lumber ribs or LSTV.
Table 1: Incidences of Rib anomalies and LSTV (lumbosacral transitional vertebrae) 
(Vertebral segments were counted from C1 or C2 inferiorly)

Table 2: Rib configuration vs. LSTV (lumbosacral transitional vertebrae) 
(Vertebral segments were counted from C1 or C2 inferiorly)
Conclusion

There was a strong association in lumbar ribs and lumbarization. Our result showed that 11 out of 14 (78.6%) lumbarization were associated with lumbar ribs. 11 out of 13 (84.6%) cases of lumbar ribs were associated with lumbarization. There was a few report of the association of lumbar ribs and lumbarization. The number of cervical vertebrae, seven, is extremely stable. The number of thoracic vertebrae may be reduced to 11 or increased to 13, and the number of lumbar vertebrae may be from four to six [8]. The variation of thoracolumbar segment has the potential to promote morphological shift of lumbosacral segment, because in embryologically, thoracic spine, lumbar spine, and sacral spine develop craniocaudally [9]. Therefore, once ribs were formed on L1 (20th vertebrae), S1 (25 vertebra) might separate from S2 and result lumbarization. In the case with lumbar ribs and lumbarization, lumbar spinal configuration might be interpreted as normal by the lumbar spinal radiograph. (Fig.6)

The incidence rates of lumbarization and sacralization in this study were 6.2% and 2.7%, respectively. There was little difference between the incidence rates of lumbarization and sacralization in our study and those of the previous studies used the craniocaudal counting of vertebrae (Table3) [4.10.11]. The prevalence rates of LSTV reported showed a wide distribution of 4-21% [2-6]. Difference of the lumbar spinal counting methods and the definitions of LSTV might cause this wide range of LSTV incidence rate.
Fig. 6: A case with lumbar ribs and lumbarization. A: VR image of thoracicolumbar spine and ribs. Lumbar ribs were clearly shown. B: By the counting from C1 or C2 inferiorly, most caudal ribs were lumbar ribs and most caudal non-fused vertebra was identified as 25th (S1: first sacral segment). C: If most caudal ribs were interpreted as 12th ribs, lumbar spinal configuration might be identified as normal.

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Table 3: Incidences of LSTV (lumbosacral transitional vertebrae) (Vertebral segments were counted from C1 or C2 inferiorly)

<table>
<thead>
<tr>
<th>Study</th>
<th>Lumbarization</th>
<th>Sacralization</th>
<th>No. of Patients</th>
</tr>
</thead>
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<tr>
<td>Current study</td>
<td>14 (6.2%)</td>
<td>6 (2.7%)</td>
<td>226</td>
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<td>Hahn PY et al. [4]</td>
<td>9 (4.5%)</td>
<td>15 (7.5%)</td>
<td>200</td>
</tr>
<tr>
<td>Phe WC et al. [10]</td>
<td>9 (7.0%)</td>
<td>8 (6.2%)</td>
<td>129</td>
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<tr>
<td>Paik NC et al. [11]</td>
<td>22 (9.9%)</td>
<td>8 (3.6%)</td>
<td>223</td>
</tr>
</tbody>
</table>

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References