MRI versus CT for the diagnosis of lumbar spinal stenosis
IRM versus TDM pour le diagnostic de sténose du rachis lombaire

Sang Soo Eun a, Ho-Yeon Lee b, Sang-Ho Lee b, Kyeong Hwan Kim a, Wei Chiang Liu c, *

a Department of Orthopedic Surgery, Wooridul Spine Hospital, Seoul, Korea
b Department of Neurosurgery, Wooridul Spine Hospital, Seoul, Korea
c Department of Radiology, Wooridul Spine Hospital, 47-4 Chungdam-dong Gangnam-gu, 135-100 Seoul, Korea

KEYWORDS
Lumbar spinal stenosis; Canal area; MRI; CT; Preoperative examination

Summary
Objective: The purpose of the study was to compare the effectiveness of CT and MRI in visualizing soft tissues in lumbar spinal stenosis (LSS), and to correlate the images with preoperative symptoms.
Materials and methods: A total of 163 patients who had undergone unilateral laminotomy for bilateral decompression to treat LSS at L4–5 were retrospectively analyzed. The narrowed spinal canal area was measured on axial images with CT and MRI, and compared with the acquired dimensions from preoperative Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) scores.
Results: The mean compromised spinal canal areas were 75.08 mm² on MRI and 63.13 mm² on CT, which were significantly different. Mean VAS for back pain was 5.37, and 7.94 for leg pain. Mean ODI was 55.17%. There was no significant correlation noted between clinical parameters and narrowed spinal canal area.
Conclusion: Spinal canal area was more narrowed on CT than on MRI in axial cuts. This finding can be explained by the superior ability of multidetector CT to discriminate cortical bone from soft tissue such as the ligamentum flavum. Our study highlights the value of CT examination in combination with MRI prior to LSS surgery.
© 2011 Elsevier Masson SAS. All rights reserved.

Introduction
Degenerative lumbar spinal stenosis (LSS) is defined as narrowing of the lumbar dural sac due to breakdown of the intervertebral discs, facet joints and ligaments surrounding the vertebral canal together with symptoms of neurogenic
claudication. Computed tomography (CT) and magnetic resonance imaging (MRI) are well-known diagnostic tools for LSS, and both are currently used as standard tools. Although there is no consensus on the gold-standard technology, given the reputation of MRI in visualizing soft tissue, a number of reports [1–3] state that MRI is replacing CT as the first-line imaging test for diagnosing LSS, with additional CT used to evaluate osseous structures such as hard discs [4]. However, with the rapid evolution of multidetector CT (MDCT) technology, which has high spatial and temporal resolution, it appears that MDCT images not only clearly show osseous structures, but also can reveal soft tissues, including disc bulging and hypertrophy of the ligamentum flavum in LSS. In our experience, there is an apparent difference between MDCT and MRI in the degree of visualized stenosis, with CT axial images showing more exaggerated stenosis than seen with MRI in the same patients.

The purpose of the present study was to compare the power of visualizing soft tissues by CT and MRI in LSS, and in correlation with preoperative symptoms. Also compared were the compromised spinal canal areas as revealed by CT and MRI in the same LSS patients. Each compromised spinal canal area was also correlated with preoperative Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) scores to determine whether or not compromised spinal canal areas are related to the severity of symptoms. To our knowledge, quantitative measurements and comparisons of cross-sectional areas of the spinal canal in LSS patients in vivo by CT and MRI have so far not been performed.

Materials and methods

Patients’ data

A total of 163 patients diagnosed with severe degenerative LSS on L4–5, all of whom had undergone unilateral laminotomy for bilateral decompression without discectomy between August 2002 and April 2009, were retrospectively analyzed. The average age of the patients at the time of examination was 55.8 (range: 38–76) years. Level L4–5 was chosen for the study because of the high prevalence of LSS [1] at this location and narrow spinal canal area [5], and also to maintain homogeneous data. All patients underwent MRI and CT preoperatively as per the standard protocol at our hospital. The diagnosis of central spinal stenosis with compression of the dural sac due to hypertrophy of the ligamentum flavum, combined with bilateral lateral recess stenosis, was made by an experienced spine surgeon using additional information on clinical symptoms, such as neurological claudication and pain radiating to the lower extremities. All patients were surgically confirmed as having central stenosis. VAS rankings for leg and back pain, and ODI scores, were acquired preoperatively by a registered nurse who was not involved in the operations.

Excluded were those patients who brought outside MRI or CT scans, and those who were diagnosed with spondylolisthesis, instability, combined far lateral disc herniation, other level disease and previous history of spinal surgery.

Model description

CT examination was performed, using an MDCT system (Brilliance CT 16-slice, Philips Medical Systems), without the use of oral or intravenous (iv) contrast material. A 16 × 0.75 mm collimation protocol, with 0.5-s rotation time, tube voltage of 140 kV and a tube current time product of 250 mAs, was selected. All datasets were reconstructed with an effective slice thickness of 2 mm and increment of 1 mm. MRI images were obtained in the sagittal and axial planes with the use of a spine surface coil on a 1.5-T unit (Intera Achieva, Philips Medical Systems). The MRI technique for the workup of suspected disc herniation included both T1-weighted (relaxation time [TR], 400–700 ms; echo time [TE], 8 ms) and fast spin-echo T2-weighted (TR, 2000–5000 ms; TE, 120 ms) sequences. Sagittal imaging was performed with a section thickness of 4 mm and a section gap of 0.14 mm, while axial imaging was performed with a 4-mm-thick section and no gap.

Parametric measurements

Two board-certified radiologists reviewed all images on a picture archiving communications system (PACS) workstation monitor. These radiologists had worked mainly as spine radiologists, and had interpreted spine CT and MR images as part of their daily clinical and research practices. The two reviewers identified and characterized the abnormalities. Neither radiologist had received any information pertaining to age, gender, clinical history, symptoms and/or histopathological results at the time of interpretation. The axial images at the L4–5 disc level for both MRI and CT were selected, and T2-weighted images were used for MRI. The images were magnified to improve visualization, and tracings of the compromised spinal canal area boundaries were made within the inner borders of the bulging disc, narrowed foramen and hypertrophied ligamentum flavum (Fig. 1). The boundary demarcates compression of the dural sac from epidural fat tissue. As most patients were diagnosed with severe central spinal stenosis, the shape of the outline was usually triangular. Measurements were calculated from the total number of pixels per cross-sectional area multiplied by a scan correction factor (mm²/pixel) to an accuracy within 0.01 mm². To confirm that there was no discrepancy of measurement between MRI and CT, the same 40-mm syringe filled with dye was used for the MRI and CT examinations. The measurements were the same in both images. Also compared were the acquired dimensions based on preoperative VAS and ODI scores from a retrospective review of medical charts.

Statistical analysis

Statistical analysis was performed using Statistical Package for the Social Sciences, version 14.0.K (SPSS Inc., Chicago, IL, USA) software. Interobserver reliability was evaluated by Cronbach’s α-value. Data were expressed as means (standard deviations [SD]), and P < 0.05 was considered statistically significant. Pearson’s correlation coefficient was expressed from −1 to 1, with numbers close to 1 showing a positive correlation.
Table 1 Compromised spinal canal area (mm$^2$) seen on magnetic resonance imaging (MRI) and computed tomography (CT) in 163 spinal stenosis patients.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean (mm$^2$)</th>
<th>SD</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI</td>
<td>75.08</td>
<td>27.04</td>
<td>0.000</td>
</tr>
<tr>
<td>CT</td>
<td>63.13</td>
<td>24.79</td>
<td></td>
</tr>
</tbody>
</table>

Results

The study group comprised 163 patients — 76 men and 87 women — with a mean age of 64.52 (range: 24–83) years. Cronbach’s $\alpha$-values were 0.866 for MRI and 0.874 for CT, suggesting excellent interobserver reliability for LSS with CT and MRI as measured by the two radiologists. The mean narrowed spinal canal area was 75.08 mm$^2$ (21.09–188.5 mm$^2$) on MRI and 63.13 mm$^2$ (5.68–154.92 mm$^2$) on CT, with a significant difference between the two modalities (Table 1; $P=0.001$). On comparing patients according to age and gender, there were no gender differences in terms of narrowed spinal canal area on MRI ($P=0.978$) nor on CT ($P=0.625$; Table 2). The mean compromised spinal canal areas on MRI and CT according to age groups (Table 3) showed that spinal canal area was more narrowed with increasing age on both CT ($P=0.017$) and MRI ($P=0.033$; Fig. 2).

Mean VAS was 5.14 (SD: 2.904) for the back and 7.44 (SD: 1.799) for the leg, and mean ODI was 56.09% (SD: 16.79%). Leg VAS and ODI showed no significant differences by gender or by age groups (Tables 4 and 5). Back VAS, however, showed a significant difference between male and female subjects ($P=0.014$).

Also evaluated were the correlations between the narrowed spinal canal area and VAS for leg pain, VAS for back pain and ODI to detect any clinical significance, but no significant correlations were found (Table 6).

Discussion

MRI and CT are complementary and both may be necessary for optimal results [6,7]. CT may be the preferred choice if arthrosis is known or suspected, whereas MRI is warranted for almost all spinal problems because of its high-quality soft-tissue visualization. However, our present results show...
MRI versus CT for the diagnosis of lumbar spinal stenosis

Table 3 Compromised spinal canal area (mm²) compared by age.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>n</th>
<th>Mean (mm²)</th>
<th>SD</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI ≤50</td>
<td>12</td>
<td>98.03</td>
<td>19.86</td>
<td>0.033</td>
</tr>
<tr>
<td>51–60</td>
<td>33</td>
<td>93.12</td>
<td>26.25</td>
<td></td>
</tr>
<tr>
<td>61–70</td>
<td>62</td>
<td>77.26</td>
<td>28.17</td>
<td></td>
</tr>
<tr>
<td>71–80</td>
<td>52</td>
<td>88.20</td>
<td>36.97</td>
<td></td>
</tr>
<tr>
<td>≥81</td>
<td>4</td>
<td>72.23</td>
<td>33.91</td>
<td></td>
</tr>
<tr>
<td>CT ≤50</td>
<td>12</td>
<td>80.61</td>
<td>22.40</td>
<td>0.017</td>
</tr>
<tr>
<td>51–60</td>
<td>33</td>
<td>76.19</td>
<td>27.48</td>
<td></td>
</tr>
<tr>
<td>61–70</td>
<td>62</td>
<td>61.53</td>
<td>21.32</td>
<td></td>
</tr>
<tr>
<td>71–80</td>
<td>52</td>
<td>73.48</td>
<td>34.02</td>
<td></td>
</tr>
<tr>
<td>≥81</td>
<td>4</td>
<td>52.17</td>
<td>21.70</td>
<td></td>
</tr>
</tbody>
</table>

Table 4 Visual Analog Score (VAS) and Oswestry Disability Index (ODI) compared by gender.

<table>
<thead>
<tr>
<th>Gender</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAS-B &lt;sup&gt;a&lt;/sup&gt; Male</td>
<td>76</td>
<td>4.55</td>
<td>2.93</td>
<td>0.014</td>
</tr>
<tr>
<td>Female</td>
<td>87</td>
<td>5.66</td>
<td>2.80</td>
<td></td>
</tr>
<tr>
<td>VAS-L &lt;sup&gt;b&lt;/sup&gt; Male</td>
<td>76</td>
<td>7.21</td>
<td>1.83</td>
<td>0.136</td>
</tr>
<tr>
<td>Female</td>
<td>87</td>
<td>7.63</td>
<td>1.76</td>
<td></td>
</tr>
<tr>
<td>ODI Male</td>
<td>76</td>
<td>55.01%</td>
<td>17.59%</td>
<td>0.446</td>
</tr>
<tr>
<td>Female</td>
<td>87</td>
<td>57.03%</td>
<td>16.10%</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Preoperative.  
<sup>b</sup> Postoperative.

that spinal canal area was more narrowed on CT than on MRI. This can be explained by the superior delineation of the ligamentum flavum on CT compared with MRI.

CT accurately demonstrates the osseous dimensions of canals and shows excellent delineation of the posterior elements. Also, degenerative, erosive and destructive changes of the zygapophyseal joints, as well as facet orientation and spondylolysis, are better visualized by CT [4]. In addition, CT is able to differentiate hard versus soft disc pathology [6].

On the other hand, MRI is an excellent tool in evaluating soft-tissue images of the ligaments, spinal cord and disc,
including subtle herniations as well as far lateral herniations [3]. T1-weighted axial images provide anatomical images similar to CT scans, and the myelographic effect of cerebrospinal fluid on T2-weighted images shows the extent and degree of stenosis throughout the entire lumbar spine [1]. However, limitations of MRI include variable signal intensity in degenerative osseous ridges (making it difficult to distinguish hard vs soft disc pathology) and magnetic susceptibility [4]. While gradient-echo pulse sequences are helpful for defining the etiology of stenosis, they are particularly prone to magnetic susceptibility artifacts, which may sometimes obscure the extent of stenosis [6].

A number of studies [5,7–11] have concluded that CT and MRI show very close agreement when evaluating LSS. In fact, the combination of CT and MRI has a slightly higher true-positive ratio than either test alone [7]. Nevertheless, the limitations of these studies, acknowledged by the authors, are small sample sizes and methodological biases. In most of the previous studies [9,11,12], CT examination was enhanced by myelography, which is invasive. Other studies [5,13–15] assessed the lumbar spinal canal using linear measurements, such as anteroposterior diameter and interpedicle distance, rather than true cross-sectional areas. Indeed, given the ongoing improvement in technology, further comparative investigations with large sample sizes need to be carried out.

According to the results of the present study, CT can produce sharp clear images of soft-tissue anatomy, especially axial cuts of spinal canal compromised by hypertrophied ligamentum flavum. For this reason, it would be useful to acquire CT images prior to, for example, minimally invasive surgical decompression by unilateral laminotomy for bilateral decompression, as a clear understanding of the posterior element is crucial.

MRI performed less well in our present study due to its inability to discriminate cortical bone from soft tissue [2,14]. Signals from the ligamentum flavum and posterior bony elements are confluent [7]. Sclerotic osteophytes can be confused with adjacent capsuloligamentous structures, particularly at the postero-inferior aspect of the joint, where the capsule demonstrates low signal intensity [16]. The ligamentum flavum usually has a higher signal intensity on MRI than the posterior and anterior longitudinal ligaments due to its higher elastin (80%) and lower type I collagen (20%) contents [16], and stands out from the low signal intensity of cortical bone. In hypertrophied ligaments, severe fibrosis has been observed and the contents may change [17,18]. Modic et al. [7] also emphasized the inability of spin-echo (SE; 600–800/20 TR/TE) sequences to separate cortical bone from the surrounding fibrous or ligamentous structures due to a chemical-shift artifact from adjacent facets. On long TR/short TE (SE 2500–3000/20) sequences, the signal from the ligamentum flavum could not be separated from that of cerebrospinal fluid while, on long TR/long TE images, it could not be separated from that of bone [16]. Because calcification is identified as a signal void on MRI, hypertrophic changes and other abnormalities on the ligamentum flavum are not imaged directly; however, CT is able to visualize them.

Although the present results showed no significant correlation between compromised spinal canal area and clinical symptoms, there have been reports [15,19] that the size of disc herniation correlates with severity of sciatica. Bolender et al. [12] found that the cross-sectional area of the thecal sac correlated best with stenotic symptoms. In our study, CT and MRI indicated that spinal canal area becomes more narrowed with increasing age, which may be a result of degeneration.

Although every effort was made to eliminate bias in the present study, certain potential flaws are apparent. First, only patients with severe central stenosis—in other words, hypertrophy of the ligamentum flavum—were selected, which means that our results are not applicable to the broader definition of LSS patients. Also, focal abnormalities in the lateral recesses and neural foramina need to be evaluated separately, and there was no attempt to influence treatment decisions or to evaluate the diagnostic accuracy of one tool over the other.

Despite these factors, the results of the present study indicate that a technically adequate MDCT examination is equivalent or superior to MRI in diagnosing LSS in axial cuts, with better visualization of the ligamentum flavum.

### Conclusion

MRI and CT are comparable in their abilities to demonstrate LSS. However, CT is more sensitive in demonstrating a narrowed spinal canal in axial cuts. This finding can be explained by the superior ability of CT to discriminate cortical bone from soft tissue such as the ligamentum flavum. Our study confirms the power of CT examination in combination with MRI, especially prior to minimally invasive LSS surgery.

---

**Table 6** Correlation of compromised spinal canal area (mm²) on MRI and CT with Visual Analog Score (VAS) and Oswestry Disability Index (ODI).

<table>
<thead>
<tr>
<th></th>
<th>MRI</th>
<th>CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAS-B</td>
<td>Pearson’s correlation coefficient (r)</td>
<td>0.133</td>
</tr>
<tr>
<td></td>
<td>P-value</td>
<td>0.091</td>
</tr>
<tr>
<td>VAS-L</td>
<td>Pearson’s correlation coefficient (r)</td>
<td>−0.070</td>
</tr>
<tr>
<td></td>
<td>P-value</td>
<td>0.373</td>
</tr>
<tr>
<td>ODI</td>
<td>Pearson’s correlation coefficient (r)</td>
<td>0.067</td>
</tr>
<tr>
<td></td>
<td>P-value</td>
<td>0.393</td>
</tr>
</tbody>
</table>

*Preoperative.

*Postoperative.
Disclosure of interest

This study was supported by a grant from the Wooridul Spine Foundation.

Acknowledgements

We thank Jin-Kyeong Oh, M.S., for the statistical analyses, Je Min Son, B.A., for the illustrative work and In-Sook Cho, B.A., for editorial assistance.

References