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MRI underestimates lumbar spinal canal cross-sectional area compared to CT in patients with lumbar spinal stenosis

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Abstract

Objectives Lumbar spinal stenosis (LSS) is a common condition characterized by the narrowing of the spinal canal, often leading to neural compression. Accurate imaging is crucial for diagnosis and surgical planning, with MRI and CT being the primary modalities. While MRI excels in soft tissue visualization, CT is superior for assessing bony structures. This study compares lumbar spinal canal cross-sectional area measurements on MRI and CT in patients undergoing surgery for LSS.

Methods Twenty patients with LSS who underwent lumbar decompression surgery after failed conservative treatment were included. Axial MRI and CT images from L1 to S1 levels were obtained and analyzed using Radiant DICOM Viewer. The spinal canal area was measured and compared between modalities. Statistical analyses assessed the measurement discrepancies, including paired t-tests and Pearson correlations.

Results The mean difference in cross-sectional area between MRI and CT across all levels was 26.5 mm^2, with MRI consistently underestimating the canal area by 15.3%. The correlation between MRI and CT measurements was high (0.775–0.950), yet significant differences were found ($p < 0.001$). MRI underestimation was more pronounced in smaller spinal canals, though this trend was not statistically significant. Agreement between MRI-only evaluations and surgical findings was moderate (Cohen's Kappa = 44%, $p = 0.035$).

Conclusions MRI's underestimation of spinal canal size compared to CT has implications for surgical planning, particularly in severe stenosis. A multimodal MRI and CT approach may improve diagnostic accuracy and surgical outcomes. Future research should involve larger cohorts to elucidate these findings further.

Introduction

Lumbar spinal stenosis is characterized by the narrowing of the spinal canal, which can lead to neural compression and associated symptoms such as pain, numbness, weakness, radiculopathy or spinal claudication. Accurate assessment of the lumbar spinal canal area and the extent of neural compression is critical for the diagnosis, management, and surgical planning in patients with this condition. Computed tomography (CT) and magnetic resonance imaging (MRI) are the primary imaging modalities used to evaluate lumbar spinal stenosis, each with distinct advantages and limitations, but seemingly both are interchangeable in assessing degenerative spinal stenosis.

The initial studies comparing MRI and CT, highlighted the enhanced soft tissue contrast provided by MRI, which was particularly advantageous for assessing neural structures and soft tissue abnormalities in lumbar spinal stenosis [1]. However, CT was noted for its superior

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bony detail, making it valuable for evaluating the bony anatomy of the spine, which is critical in specific clinical scenarios and cases where MRI was not available or contraindicated [1]. Similarly, Saint-Louis et al. emphasized that MRI and CT, along with myelography, each played a unique role in assessing lumbar spinal stenosis, with MRI being beneficial for visualizing the spinal cord and nerve roots, while CT provided better bony detail.

Several studies have found MRI and CT to be equivalent in diagnosing lumbar spinal stenosis, with no clear superiority of one modality. For instance, a systematic review by de Graaf et al. focused on the accuracy of diagnostic tests for lumbar spinal stenosis and concluded that both MRI and CT are valuable diagnostic tools for lumbar spinal stenosis. However, no single modality consistently outperformed the other across all studies [2]. Rapid visual assessment of MRI was found to be as practical as detailed area measurements, suggesting that MRI could be utilized efficiently in clinical practice without compromising diagnostic accuracy [3]. These findings underscore the importance of considering the specific clinical context and the strengths of each modality when choosing between MRI and CT.

In contrast, several studies have demonstrated the superiority of MRI over CT in assessing lumbar spinal stenosis, mainly due to its enhanced ability to visualize soft tissues [4]. Alsaleh et al. found that MRI had higher intra-observer reliability than CT and was less likely to overestimate the degree of stenosis; CT was found to overestimate the degree of stenosis more frequently (20–35%) compared to MRI (2–11%), making it a more reliable tool in clinical practice [5]. Additional studies further supported the use of MRI for its lack of radiation exposure and detailed imaging capabilities, recommending MRI as the preferred modality when soft tissue assessment is critical [6, 7].

Studies comparing metric analysis of spinal structures, specifically the ligamentum flavum, obtained with CT and MRI, found that MRI was more accurate in measuring soft tissue thickness. At the same time, CT was better for bony structures [8], and it was found that MRI sequences were reliable, although variations between T1 and T2 sequences were noted [9].

However, not all studies favour MRI. Some research indicates that MRI may underestimate the extent of lumbar spinal stenosis compared to CT. The study by Bartynski and Lin showed that MRI can underestimate the extent of bony involvement compared to CT myelography [10]. This underestimation of MRI examination, particularly in cases of significant osseous stenosis, highlights the importance of a multimodal approach to imaging in complex cases of lumbar spinal stenosis. Conversely, Suwankong et al. assessed the agreement between CT, MRI, and surgical findings in dogs with degenerative lumbosacral stenosis. They found MRI highly effective in detecting stenosis and the highest agreement with surgical findings, reinforcing its diagnostic value and supporting its use as the primary imaging modality in clinical practice [11].

Degenerative lumbar spinal stenosis usually involves degenerated disc bulge, facet osteoarthritis causing recess stenosis and ligamentum flavum hypertrophy. In our spine practice, we suspected that an MRI underestimated the extent of the lumbar spinal canal cross-sectional area compared to a CT performed at the same period. Patients presented to the Spine clinic with symptoms of spinal claudication or radiculopathy did not have a radiographic correlation on the MRI; only when examining the CT scan did we find recess and central stenosis. This finding correlated to the actual findings during decompression surgery. Today, patients tend to arrive for a surgical consultation with an MRI only, undermining preoperative assessment. This discrepancy has led us to conduct this study measuring the lumbar spine cross-sectional area on axial sections of CT and MRI of patients who underwent lumbar decompression surgery due to failed conservative treatment with documented lumbar spinal claudication.

Methods

This study included 20 patients who underwent lumbar spine surgery after failed conservative treatment for lumbar spinal claudication. Inclusion criteria included adults aged 18 years and older with a diagnosis of lumbar spinal stenosis confirmed by clinical evaluation and imaging, CT and MRI performed within three months of each other. Patients with developmental lumbar spinal stenosis were not excluded, as initial developmental stenosis is not the cause of claudication or radiculopathy but the degenerative changes that develop with age. All patients failed conservative treatment, including physical therapy, pain management, and/or epidural steroid injections, necessitating surgical intervention.

Exclusion criteria included previous lumbar spine surgery or incomplete or poor-quality imaging that prevented accurate measurement. Patients with non-degenerative causes of spinal stenosis, such as tumours, fractures, or infections, were excluded. Patients with other significant spinal pathologies (e.g., scoliosis > 20 degrees, spondylolisthesis > Grade 1) that could affect the cross-sectional area measurements were excluded since imaging slice orientation and reconstruction may cause a measurement bias.

The inclusion and exclusion criteria allowed for a homogenous spinal stenosis cohort that underwent surgery while precluding possible technical difficulties

in ensuring canal dimensions in different imaging modalities.

Imaging Protocol and Measurement: Axial CT and MRI T2 mid-intervertebral disc level images covering the L1-S1 levels were obtained for each patient. The lumbar spinal canal was defined as the area between the intervertebral disc anteriorly, the medial border of the pedicles laterally, and the ligamentum flavum and medial border of the facet joints posteriorly. Foraminal stenosis was not measured. Thus, only central and lateral recess stenosis were measured but not differentiated. The cross-sectional area of the lumbar spinal canal was measured on axial images at each level using the Radiant DICOM Viewer software. The software's closed polygon function was employed to accurately delineate the spinal canal's boundaries (Fig. 1). This function allows for precise, user-defined contouring of the area of interest, ensuring consistent and reproducible measurements. A total of 100 images were examined. The CT and MRI images included healthy and stenosed lumbar segments, acting as a control group.

A senior orthopedic surgery resident performed the lumbar spinal canal cross-sectional area measurements. Each measurement was saved as an image file and reviewed by a fellowship-trained senior spinal surgeon. In cases of disagreement between the resident's and the surgeon's measurements, the spinal surgeon remeasured the area to resolve discrepancies and establish a consensus.

Statistical analysis compared the cross-sectional area measurements obtained from CT and MRI at each spinal level (L1-S1). The primary statistical tests included the paired t-test to determine if significant differences existed between the cross-sectional areas measured by CT and MRI for each spinal level. A Correlation Analysis was performed to examine the relationship between the MRI-CT differences and the corresponding cross-sectional areas. A logistic regression was used to test how well the MRI values (defined as a cross-sectional area < 1 cm^2) correlate with CT values (cross-sectional area < 1 cm^2), determining if MRI can predict the occurrence of stenosis (a positive event) as detected by CT. Statistical significance was set at a p-value of < 0.05. All statistical

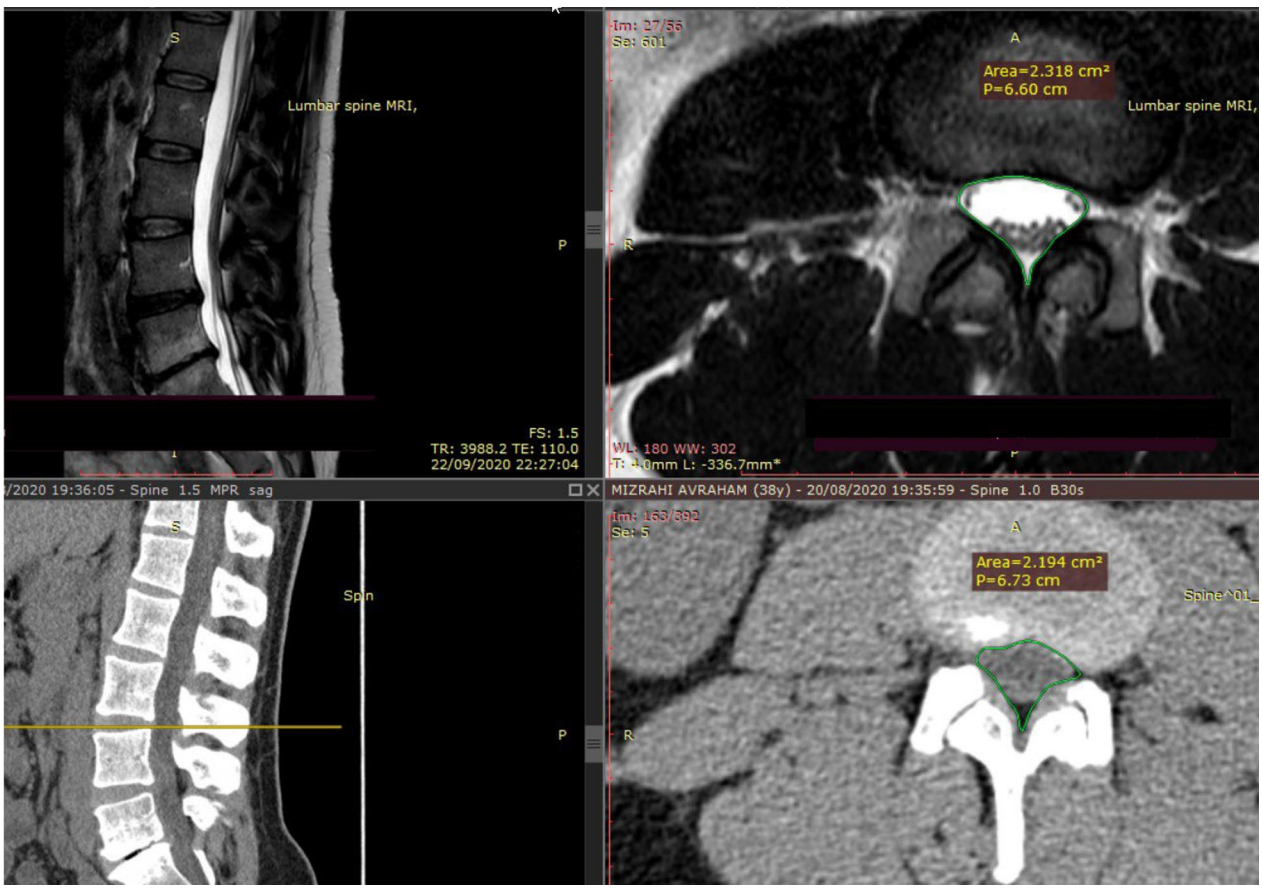

Fig. 1 MRI and CT spinal canal area and perimeter measurements

analyses were performed using SPSS (Statistical Package for the Social Sciences) version 25.0.

Results

Twenty patients who underwent surgery or were recommended surgery for degenerative spinal stenosis or intervertebral disc herniation were recruited for this study. The cohort consisted of 7 females and 13 males. The average age was 63.8 ± 12.3, and the average duration of symptoms was 33.8 ± 29.4 months. The patient's average walking distance was 45.3 ± 32.6 m. Seventy percent of patients suffered from spinal claudication, and 45% suffered from lumbar radiculopathy; four patients had a combination of both. Sixty percent of patients underwent physiotherapy treatments and were treated with non-steroidal drugs, and 90% of patients were treated with opiates. Seventy-five percent had undergone previous selective nerve root blocks, ranging from one to seven injections.

Table 1 reveals that measurement differences between MRI and CT existed at all the spinal levels, ranging from 14.6 to 43.2 mm^2. The average difference between MRI and CT for the L1-S1 segments was 26.5 ± 18.4 mm^2; MRI underestimated the lumbar spinal canal area by 26.5 mm^2 compared to CT. A similar difference was found when the lumbar spinal canal perimeter was measured; the average L1-S1 segment's difference was 20.3 ± 26.8 mm; again, the MRI underestimated the perimeter of the lumbar spinal canal as compared to a CT scan.

MRI-CT spinal canal measurement differences by percent of error were measured by level. The measurement difference by percentage was calculated using the MRI minus CT measurement formula divided by the MRI and CT measurement average. The mean MRI-CT difference was 15.3 ± 11.9%; the MRI underestimated the area of the lumbar spinal canal compared to a CT scan by 15.3%.

Performing Pearson's correlation test, the correlation between CT and MRI measurements was between 0.775 and 0.950, indicating a high correlation between CT and MRI measurements for every level of every examination. However, a paired T-test revealed statistically significant differences between the MRI and CT spinal canal measurements at all the L1-S1 spinal segments, $p < 0.001$.

We examined whether a lower spinal canal area, such as in stenosis, causes a larger difference in MRI-CT measurement differences using Pearson's and Spearman's correlation coefficients. Pearson's correlation coefficient was − 0.99, and 2-tailed significance was 0.688. Pearson's correlation coefficient was − 0.144, and 2-tailed significance was 0.557. Both statistical examinations revealed a negative, non-significant correlation between the spinal canal area and the MRI-CT difference. The statistical calculation by level is presented in Table 2. Overall, there is a trend for a more considerable MRI-CT difference as the lumbar spinal canal area decreases. With a larger cohort size, this trend may become statistically significant. We could not find a spinal canal area threshold cutoff that marks a more considerable MRI-CT difference increase.

We examined the agreement between a blinded spine surgeon's MRI-only appraisal and the actual surgery performed and did not find agreement. In seven cases, there was agreement, but in 13 cases, there was disagreement. In 5 cases, there was overdiagnosis, and in 8 cases, there was underdiagnosis compared to the performed surgery. Using Cohen's Kappa Measure of Agreement, there was a 44% agreement between the MRI and surgery performed, considered moderate agreement, $p = 0.035$.

Discussion

The role of MRI and CT in assessing lumbar spinal stenosis has been extensively debated, with both modalities offering distinct advantages. Early studies emphasized MRI's superior soft tissue contrast, crucial for visualizing neural structures and soft tissue abnormalities in lumbar

Table 2 Paired Spinal canal area MRI-CT Difference by spinal level

Spinal level	Correlation	One-Sided p-value	Two-Sided p-value
L1-2	− 0.430	0.029	0.059
L2-3	− 0.315	0.088	0.175
L3-4	− 0.536	0.007	0.015
L4-5	− 0.032	0.447	0.894
L5-S1	0.310	0.098	0.197

Table 1 Spinal canal area MRI-CT Difference by spinal level (mm^2)

Spinal level	Minimum (mm^2)	Maximum (mm^2)	Mean (mm^2)	SD	Variance	p-value
L1-2	− 0.26	1.30	0.232	0.352	0.124	< 0.001
L2-3	− 0.03	0.63	0.214	0.206	0.042	< 0.001
L3-4	− 0.16	0.59	0.146	0.212	0.045	< 0.001
L4-5	− 0.08	0.67	0.284	0.227	0.051	< 0.001
L5-S1	− 0.74	1.74	0.432	0.563	0.317	< 0.001

spinal stenosis. Conversely, CT provided enhanced visualization of bony anatomy, making it invaluable for evaluating spinal structures in specific clinical scenarios or when MRI was contraindicated [1, 12]. These findings laid the foundation for the complementary use of both modalities, depending on the patient's diagnostic needs. Other studies have shown that MRI and CT can be largely equivalent in diagnosing lumbar spinal stenosis [2, 3]. This has led to a broader acceptance of both modalities, with MRI often preferred for its non-invasive nature and CT used for cases where bone detail is critical. However, a growing body of evidence has demonstrated MRI's superiority over CT, particularly regarding reliability and accuracy in assessing lumbar spinal stenosis [4, 5].

This study was conducted on twenty patients, seven females and 13 males, who underwent surgery or were recommended surgery for degenerative spinal stenosis or intervertebral disc herniation. The average age was 63.8 ± 12.3, and the average duration of symptoms was 33.8 ± 29.4 months. The patient's average walking distance was 45.3 ± 32.6 m. Seventy percent of patients suffered from spinal claudication, 45% suffered from lumbar radiculopathy, and four patients had a combination of both.

A hundred mid-disc level axial CT and T2 axial MRI images were analyzed for the spinal canal cross-sectional area or the area available for the thecal sac (excluding osteophytes, annulus, ligamentum flavum and facet joints). Measurement differences between MRI and CT existed at all the spinal levels, ranging from 14.6 to 43.2 mm^2. The average difference between MRI and CT for the L1-S1 segments was 26.5 ± 18.4 mm^2, meaning that MRI underestimated the lumbar spinal canal available for the thecal sac by 26.5 mm^2 compared to CT. The mean MRI-CT difference by percentage was 15.3 ± 11.9%; the MRI underestimated the area of the lumbar spinal canal by 15.3%. CT and MRI measurements for every level of every examination were highly correlated, with Pearson's correlation test of 0.775–0.950. However, the differences between the MRI and CT spinal canal measurements at all the L1-S1 spinal segments were statistically significant ($p < 0.001$). There was a trend for a more considerable MRI-CT difference as the lumbar spinal canal area decreased, which did not reach statistical significance.

This study's results confirm significant differences between CT and MRI measurements of the lumbar spinal canal area across the L1-S1 spinal segments. These findings align with previous research that has demonstrated MRI's tendency to underestimate spinal canal dimensions compared to CT, particularly when evaluating the cross-sectional area. Our study's average underestimation of 15.3% suggests that MRI may not fully capture the extent of spinal canal narrowing, which could be critical when diagnosing lumbar spinal stenosis or planning surgical interventions. Our findings suggest that relying solely on MRI to diagnose a patient may lead to an underestimation of the lumbar spinal canal size available for the thecal sac, particularly in patients with severe stenosis, impeding surgical decision-making and possibly may lead to inappropriate surgical planning, potentially necessitating more invasive procedures than deemed by MRI alone.

The trend we observed—more significant MRI-CT differences in smaller canal areas—was not statistically significant, but it mirrors findings from other studies that indicate MRI's limited sensitivity to bony structures, particularly in cases of severe osseous stenosis [20]. This could be attributed to CT's inherently better bone detail, as supported by numerous studies that favour CT over MRI in bony pathologies [1, 10, 12].

Examining the agreement between MRI-only and CT-MRI surgical decision-making, we found only moderate agreement using Cohen's Kappa agreement measurement: 44%, $p = 0.035$. This unique observation, combined with the calculated CT-MRI measurement mismatch, leads us to recommend gathering both CT and MRI before making a Lumbar Spinal Stenosis surgical decision. Assessing CT and MRI may lead to a better correlation of symptoms, clinical findings, and imaging. The current trend of using MRI only preoperatively may cause an underestimation of lumbar stenosis. Performing a single-level minimal invasive surgery based on MRI may underestimate the patient's disease, leading to an incomplete decompression, failed back surgery and a revision surgery. Following this study, we evaluate CT and MRI for every patient assessment.

Several limitations to this study should be acknowledged. First and foremost, the relatively small sample size of 20 patients and 100 CT and MRI images examined may limit the generalizability of our findings. A larger cohort would increase the study's statistical power and may reveal more nuanced trends, such as the relationship between canal area and MRI-CT measurement discrepancies. Second, while our measurements were rigorously verified by an orthopedic resident and a fellowship-trained surgeon, human error and subjective interpretation may still have influenced the results. The use of a single software tool, RadiAnt DICOM Viewer, may also introduce bias in measurement methodology, although this tool has been validated for clinical use. Additionally, this study focused solely on the cross-sectional area of the spinal canal without considering other relevant factors, such as neural compression, which could impact clinical decision-making. Future studies should incorporate a broader range of imaging

metrics and clinical correlates, such as patient-reported outcomes or functional assessments.

In conclusion, this study highlights significant differences between MRI and CT in measuring the lumbar spinal canal area in patients undergoing surgery for lumbar spinal stenosis. MRI consistently underestimated the spinal canal area compared to CT, which could impact surgical planning and outcomes. While MRI remains indispensable for its soft tissue visualization, CT should be considered when accurate bone detail is critical, particularly in cases of severe stenosis. A multimodal approach that leverages the strengths of both imaging modalities is recommended to ensure the most accurate assessment and optimal patient management. Future research with larger cohorts and broader clinical outcomes will help clarify the diagnostic accuracy of MRI and CT in lumbar spinal stenosis.

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Author contributions
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Availability of data and materials
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Declarations

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Edith Wolfson Medical Center gave IRB approval, Holon, Israel, Affiliated to the Faculty of Medicine, Tel Aviv University, Tel Aviv, Israel IRB committee.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Schnebel B, Kingston S, Watkins R, Dillin WJS. Comparison of MRI to contrast CT in the diagnosis of spinal stenosis. Spine. 1989;14(3):332–7.
2. de Graaf I, Prak A, Bierma-Zeinstra S, Thomas S, Peul W, Koes BJS. Diagnosis of lumbar spinal stenosis: a systematic review of the accuracy of diagnostic tests. Spine. 2006;31(10):1168–76.
3. Lønne G, Ødegård B, Johnsen LG, Solberg TK, Kvistad KA, Nygaard ØPJESJ. MRI evaluation of lumbar spinal stenosis: is a rapid visual assessment as good as area measurement? Eur Spine J. 2014;23:1320–4.
4. Eun SS, Lee H-Y, Lee S-H, Kim KH, Liu WC. MRI versus CT for the diagnosis of lumbar spinal stenosis. J Neuroradiol. 2012;39(2):104–9.
5. Alsaleh K, Ho D, Rosas-Arellano MP, Stewart TC, Gurr KR, Bailey CSJESJ. Radiographic assessment of degenerative lumbar spinal stenosis: is MRI superior to CT? Eur Spine J. 2017;26:362–7.
6. Steurer J, Roner S, Gnannt R, Hodler J. Quantitative radiologic criteria for the diagnosis of lumbar spinal stenosis: a systematic literature review. BMC Musculoskelet Disord. 2011;12:1–9.
7. Morita M, Miyauchi A, Okuda S, Oda T, Iwasaki M. Comparison between MRI and myelography in lumbar spinal canal stenosis for the decision of levels of decompression surgery. Clin Spine Surg. 2011;24(1):31–6.
8. Schulte T, Heidenreich J, Schilling A, Stendel R, Pietilä T, Hopfenmüller W, Brock M, Wolf KJ. Comparison of metric analysis of spinal structures, exemplarily of the ligamentum flavum, obtained with CT and MRI. Eur J Radiol. 2004;52(3):224–8.
9. Cheung JP-Y, Shigematsu H, Cheung KM-C. Verification of measurements of lumbar spinal dimensions in T1-and T2-weighted magnetic resonance imaging sequences. Spine. 2014;J14(8):1476–83.
10. Bartynski WS, Lin L. Lumbar root compression in the lateral recess: MR imaging, conventional myelography, and CT myelography comparison with surgical confirmation. Am J Neuroradiol. 2003;24(3):348–60.
11. Suwankong N, Voorhout G, Hazewinkel HA, Meij BP. Agreement between computed tomography, magnetic resonance imaging, and surgical findings in dogs with degenerative lumbosacral stenosis. J Am Vet Med Assoc. 2006;229(12):1924–9.
12. Saint-Louis LAJCO, Research® R (2001) Lumbar spinal stenosis assessment with computed tomography, magnetic resonance imaging, and myelography. 384:122–136

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