Accuracy Verification of 3-dimensional (3D) Lumbosacral Nerve Images Using Artificial Intelligence (AI) Technology ~ Epidemiological Study of Lumbosacral Nerve Root Anomalies in 1,500 Cases~

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INTRODUCTION: Lumbosacral nerve root anomalies are relatively rare, but can be a risk factor for intraoperative iatrogenic nerve injury. Two-dimensional (2D) magnetic resonance images (MRI) are often used for preoperative diagnostic imaging, which are difficult to differentiate nerve root. Because, for example, a spinal canal stenosis lesion may cause the nerve root trajectory to meander or other abnormalities may be present. We focused on a technique for 3D imaging of the lumbosacral nerve that manually extracts nerve roots from MRI volume imaging data and creates a 3D image of the lumbosacral nerve using the volume rendering (VR) technique. Although evaluation with 3D images is beneficial, the method of creating such images is very complicated, time-consuming, and labor-intensive. Therefore, we have developed a software program that automatically generates 3D images from MRI lumbosacral nerve volume data using artificial intelligence in collaboration with Fujifilm Co., Ltd. In this study, we conducted an epidemiological study on the presence and morphology of lumbosacral nerve root anomalies using this software, and evaluated the accuracy and clinical usefulness of this modality.

METHODS: We evaluated the 3D nerve images using AI software in 1,500 patients (642 males, 858 females, mean age: 60.5 years) who underwent MRI exam for lumbar diseases at our hospitals from Apr. 2016 to Sep. 2022. The diseases included 474 cases of lumbar canal stenosis, 370 cases of lumbar intervertebral disc herniation, 293 cases of degenerative lumbar spondylolisthesis, 167 cases of combined lumbar canal stenosis and so on. A 1.5T-MR imaging system (Signa Creator; General Electric [GE] Healthcare) was used, and the imaging sequence was 3D Multiple Echo Recombined Gradient Echo with fat suppression by water-selective excitation. The images were created using an image analysis workstation "SYNAPSE VINCENT" (Fujifilm Co., Ltd.), which extracts 3D lumbosacral nerve root images automatically using deep neural networks from volume imaging data containing lumbosacral nerves [1] (Figure 1). The frequency of nerve root anomalies, the right and left sides of localization, the lumbosacral spinal level of incidence, and the morphology using the Neidre-MacNab classification were evaluated. We also evaluated the accuracy of the 3D images by comparing with those manually generated using conventional methods in all 1,500 cases. We obtained written informed consent from all subjects.

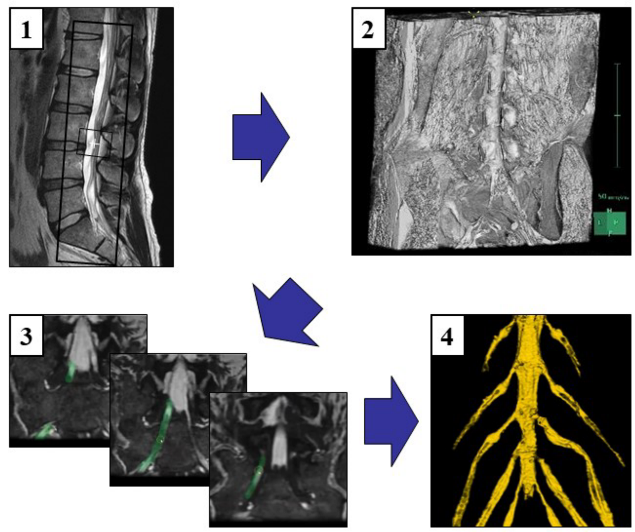

Figure 1. The production process of 3D lumbosacral nerve images. (1, 2) MRI volume data including lumbosacral nerve, bone, and muscles. (3) Plotting the location of the nerve root in all coronal images. (4) Creating 3D images by accumulating nerve location information.

RESULTS: The incidence of nerve root anomalies was 53 (3.5%) out of 1,500 cases, a total of 58 nerve roots. Regarding right and left localization, 33 cases (62.3%) were right-sided, 15 cases (28.3%) were left-sided, and 5 cases (9.4%) were bilateral. As to spinal level localization, 35 nerve roots (60.3%) were located at L5-S1 level, 19 nerve roots (32.8%) were located at S1-S2 level. In morphological evaluation, 23 nerve roots (39.7%) were classified as Neidre-MacNab Type 1A and 24 nerve roots (41.4%) as Type 1B, 1 nerve root (1.7%) was Type 2B, and 10 (17.2%) were Type 3. That is, Type 1, a conjoined nerve root, was the majority, with 47 nerve roots (81.0%). There were 7 cases (0.5%) that did not match the conventional method, all of which were anomalies. Five of the seven cases had Neidre-MacNab classification Type 3, one had Type 1a, and one had Type 1b. On the other hand, in all normally running cases without nerve root anomalies, the images were consistent between the two groups.

DISCUSSION: The frequency of lumbosacral nerve root anomalies has been reported to vary from 0.5% to 30% based on anatomy and imaging evaluation, and conjoined nerve roots are considered to be the most common type. In this study, the incidence of nerve root anomalies was 3.5%, and more than 80% were conjoined nerve root, which were not significantly different from previous studies. Localization was also similar to previous reports, demonstrating the validity of this method. In addition, the images matched in 1,493 out of 1,500 cases (99.5%) between the two methods, and the AI software detected 7 cases of nerve root abnormalities. These results suggest that the accuracy of the AI technology is 99.5% compared to the conventional methods as the comparative criteria. In spine surgery, including spinal endoscopic surgery, nerve root anomalies are a risk factor for iatrogenic nerve root injury, so preoperative image evaluation is very important. The images obtained by this method facilitate the 3D understanding of the nerve runways, and the simplicity of the image preparation makes it highly useful in clinical practice.

SIGNIFICANCE/CLINICAL RELEVANCE: The 3D images automatically generated by this method using AI technology have simplicity and accuracy. This imaging modality is highly useful and convenient in clinical practice where safety is required.

REFERENCES: [1] Yamada et al. Eur Spine J. 2021.

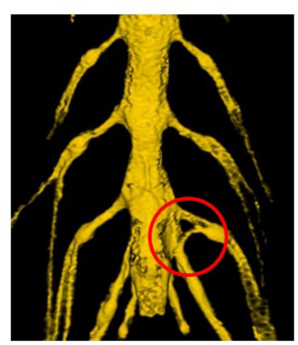

Figure 2. Neidre-MacNab classification type 3.