Quantification of spine surgery Finite element method for nerve root decompression spine minimally invasive endoscopic surgery

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論文題目

Quantification of spine surgery

Finite element method for nerve root decompression spine minimally invasive endoscopic surgery

（脊椎手術の定量化

神経根減圧脊椎低侵襲内視鏡手術のための有限要素法）

論文要旨

[Introduction]

Diagnosis is the key to improving spinal surgical outcomes. Full endoscopic spinal surgery (FESS) can create new indications when the diagnosis of radiculopathy is improved. We assessed the finite element method (FEM) to visualize and digitize lesions not detected by conventional diagnostic imaging.

[Methods]

The lumbar patient was a 67-year-old woman with a history of rheumatoid arthritis, and with osteoporosis and pulmonary fibrosis. She had left L3 radiculopathy due to an L3 vertebral fracture. The cervical patient was a 61-year-old woman with left C6 radiculopathy due to C5-6 disc herniation. We performed full endoscopic foraminotomy on the patient's request. Based on CT DICOM data of 0.5-mm slices preoperatively and postoperatively, 3D imaging data were reproduced by Mechanical Finder®, and kinetic simulation of FEM was performed.

The characteristics of the bone and soft tissue materials were specified as shown in Young's modulus and Poisson's ratio. The contact was set as follows: the dural canal contacted the posterior vertebral surfaces of the vertebrae, intervertebral discs, yellow ligament, and intervertebral joints preoperatively, and the contact between the bone cutting region and yellow ligament disappeared postoperatively. The total contact areas and changes in the maximum contact pressure preoperatively and postoperatively were analyzed.

[Results]

Postoperatively, their radiculopathy disappeared, improving their activities of daily living, and enabling them to walk and work. The total contact area and maximum contact pressure of the nerve tissue decreased to 30%-80% and 33%-67%, respectively, postoperatively.

[Discussion]

The finding of preoperative equivalent stress on the dural canal investigated by FEM was the presence of approximately 0.2-MPa stress from the posterior side at the L2-3

disc level only on the left side. On the right side, approximately 0.1-MPa stress from the side of the anterior dural canal was present, but almost no stress from the posterior side was loaded. If the neurological and conventional imaging findings were combined with the FEM findings, the preoperative diagnosis may have been left L3 radiculopathy. As FEM presents not only the shape, but also stresses loaded on the nerve root and dural canal as colors, location, and values based on CT data, it provides a new tool for diagnosis. Difficult cases with deviation between the clinical symptoms and imaging diagnosis may be reduced by FEM. FEM may serve as a judgement criterion to effectively identify the responsible lesions.

If data of the equivalent stress on the dural canal from the posterior side were acquired before surgery, we would have completed surgery with left L3 nerve root decompression alone within 80 minutes. Additionally, if foraminotomy simulation was performed in detail at 1-mm units to investigate how small we could cut the bone, it would have been possible to complete surgery within 60 minutes and improve the clinical symptoms. The cervical case's most stressed area was proximal point where we suspected. We had believed distal foraminal area was responsible region from axial and sagittal MRI images. If we had known this FEM simulation report before surgery, we planned additional margin to decompress for proximal responsible C5 lamina area.

In this study, we expressed the effects of nerve root decompression by the color, location, and values, and acquired findings corresponding to improvement of the clinical symptoms. FEM visualizes and quantifies the effects of FESS, and succeeds in justification, which could not be performed by the conventional method. We considered FEM to function as a postoperative evaluation method of surgery after FESS, and it is capable of accurately presenting the following strategy even when decompression is insufficient.

For FEM analysis, Poisson's ratio and Young's modulus of each structure component are necessary. In this analysis, the values used in preceding studies were cited2-10. The subjects of the preceding studies were the femur and scoliosis in middle-aged men. Analysis based on Poisson's ratio and Young's modulus measured in the lumbar vertebra would have been ideal for the present patient, and basic experiments using human degenerated lumbar vertebrae and measurements during surgery increase the accuracy of FEM of degenerative disease of the lumbar spine in the future. However, regarding the detection of changes postoperatively, we considered that if relative changes can be expressed, surgical effects can be expressed and values remain as references, being sufficient as an experimental system.

[Conclusions]

FEM can be a new method for perioperative evaluation and simulation to visualize and

digitize the conditions of the lesion causing radiculopathy. FEM that can overcome both time and economic constraints in routine clinical practice is needed.