Computed Tomography Radiographic Measurements and Curative Effect Estimate of Full Endoscopic Surgery in Thoracic Myelopathy Caused by Ossification of the Ligamentum Flavum

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Abstract

Purpose: In this study, computed tomography (CT) radiographic measurements and common clinical scores were used to evaluate the effectiveness of percutaneous posterior full-endoscopic resection of an ossified thoracic ligamentum flavum.

Methods: A prospective study was conducted on 16 patients treated with posterior endoscopy from September 2017 to November 2019. Before the operation, 3 days after the operation and 1 year after the operation, the area of ossification in the ligamentum flavum was assessed by sagittal CT scans and transected to evaluate the decompression effect of posterior endoscopic surgery. The clinical efficacy of the surgery was evaluated at the above time points by using the visual analog scale for pain, modified Japanese Orthopedic Association scale, ODI and Macnab efficacy evaluation.

Results: The area of sagittal ossification in the ligamentum flavum in 16 patients was 116.62 ± 32.72 mm² before the operation, 15.99 ± 12.54 mm² 3 days after the operation, and 16.78 ± 11.49 mm² 1 year later. The sagittal canal invasive proportions were $48.10 \pm 10.04\%$ before the operation, $6.46 \pm 4.86\%$ 3 days after the operation, and $6.83 \pm 4.48\%$ 1 year later. The area of transected ossification in the ligamentum flavum was 141.59 ± 27.25 mm² before the operation, 11.72 ± 8.64 mm² 3 days after the operation, and 10.82 ± 7.57 1 year later. The transected spinal canal invasive proportions were $57.58 \pm 11.37\%$, $4.76 \pm 3.45\%$ and $4.40 \pm 3.01\%$. The mJOA score were 3.50 ± 1.10 , 6.19 ± 0.91 and 9.19 ± 1.38 , with a n average recovery rate of $73.96 \pm 16.58\%$. According to the Macnab evaluation, the recovery status of the 16 patients 1 year after the operation was excellent in 9 patients, good in 5 patients, and fair in 2 patients; the excellent and good rate was 87.50%. The differences were statistically significant ($P < 0.05$). Intraoperative dural tears occurred in 2 of 16 patients, but no complications, such as cerebrospinal fluid leakage, were observed.

Conclusion The measurements of ossification ligamentum flavum area and spinal canal invasive proportion can appropriately evaluate the degree of spinal canal stenosis in thoracic myelopathy caused by ossification of the ligamentum flavum. This method can be used together with other common clinical scores to better evaluate the efficacy of surgery.

Background

Ossification of the ligamentum flavum (OLF) is ossification that occurs in a kind of spinal ligament and is common in the East Asian population. The fibrous tissue in the ligamentum flavum transforms into bone tissue and proliferates and occupies the spinal canal, compressing the spinal cord and nerve roots and causing several clinical symptoms and signs. OLF can occur in the cervical, thoracic and lumbar vertebrae but is most common in the thoracic vertebrae, especially the lower thoracic vertebrae, T9 ~ T12[1–3]. Regarding age, OLF is more common in individuals 45 ~ 65 years old[4–6], as one of the major causes of thoracic myelopathy (TM), OLF often progress in secret without obvious clinical symptoms in the early stage. In the middle and late stages of the disease, the ossified ligamentum flavum compresses

the spinal cord nerve, which can cause trunk and limb sensory motor disorders, and patients often have severe conditions once they have apparent symptoms. If spinal cord nerve decompression is not performed in a timely manner, patients may exhibit permanent loss of nerve function, even paralysis, and poor prognoses. At present, surgery is the only treatment for TM caused by OLF that is considered effective, and the traditional operation most commonly involves laminectomy, as well as semi-laminectomy, laminoplasty and intervertebral foramen surgery[7]. Nerve function is restored by removing the ossified ligamentum flavum and/or expanding the spinal canal to decompress the spinal cord. Although the traditional treatment for thoracic ligamentum flavum ossification has a clear clinical effect, it still has many disadvantages, such as substantial trauma and a high rate of complications (34%~76.7%) [8–13], which often lead to additional pain and financial burden in patients and their families. In recent years, the endoscopic technique has been used for the treatment of ossification of the thoracic ligamentum flavum[14–17]. Compared with traditional open surgery, endoscopic surgery has many advantages, such as minor trauma, lower costs and a smaller influence on spinal stability. However, whether endoscopic surgery can achieve full decompression in the spinal canal is uncertain. To further determine whether spinal endoscopic surgery is clinically efficacious in treating ossification of the ligamentum flavum and whether the degree of spinal canal decompression achieved is adequate, we evaluated the actual spinal canal decompression degree and clinical efficacy of 16 patients with TM caused by OLF before, after and 1 year after translaminar osseous channel–assisted full-Endoscopic flavectomy.

Methods

I. Inclusion and exclusion criteria

The inclusion criteria were as follows: having received a clinical diagnosis of single-segment OLF, having received indications for surgery, having complete clinical data and imaging examination data, and having been informed of the study details and signed informed consent forms.

The exclusion criteria were as follows: severe internal medical diseases such as cardiovascular and cerebrovascular diseases, respiratory diseases, and liver and kidney dysfunction preventing the patient from tolerating surgery; other severe degenerative diseases; cognitive impairment or mental illness; and incomplete clinical and radiological data.

II. General information

This study included 16 patients. The T11/12 segments were affected in 6 patients, the T10/11 segments were affected in 6 patients, and the T9/10 segments were affected in four patients. All of the cases involved the lower thoracic vertebrae. Of these patients, 7 were men, and 9 were women; the patients were aged 46-68 years, with an average age of 54.31 years. The disease duration was 1-24 months, with an average duration of 7.1 months. The clinical manifestations of the disease were sensory disorders in 14 patients, lower limb muscle loss in 9 patients, sphincter dysfunction in 0 patients, chest and waist band sensation in 1 patient, intermittent claudication in 6 patients, lumbar and leg pain in 11 patients.

III. Surgical methods

All patients were anesthetized with tracheal intubation. After anesthesia, the patient was placed in the prone position. Preoperatively, a C-arm X-ray machine was used for visualization, and the projection of the diseased vertebrae and the adjacent upper and lower vertebrae were marked on the body surface. Routine disinfection was performed, and aseptic towels were spread. A puncture was made by a Kirschner needle at the point 1 cm outside the posterior median line to locate the lateral lamina behind the lesion segment. With the guidance of C-arm visualization, the Kirschner needle was confirmed to be located on the posterior osseous wall of the lamina, and its axis was extended to the ossified ligamentum flavum (Fig. 1a). An incision measuring approximately 7 mm was made on the skin, the Kirschner needle was inserted into the extension rod, and the working catheter was inserted into the posterior wall of the spinal canal. A ring saw was used to remove a piece of the lamina to make a tunnel (fig. 1b), the guide rod, laminar bone piece and ring saw were removed(fig. 1c), and endoscopic system was placed. The ossified ligamentum flavum was then resected by endoscopic rongeur to decompress the spinal cord and nerve(fig. 1d & e). To explore the dural sac, radiofrequency ablation of surrounding soft tissue was performed(fig. 1f). The catheter was removed after saline irrigation, and the skin was sutured. The operative time and the amount of bleeding were recorded, and the changes in symptoms and signs were observed after the operation.

IV. Imaging measurements

A thoracic computed tomography (CT) plain scan was performed before the operation, and thoracic CT scans were performed 3 days and 1 year after the operation. SURGIMAP software was used to measure the area and proportion of the OLF and the proportion of vertebral canal encroachment.

Methods of measurement:

1. The sagittal area of OLF on the CT scans (A_s) was measured as follows:

For the preoperative measurements, the sagittal CT images with the largest magnitude of OLF forward protrusion were selected to mark the upper and lower ends of the ossified ligamentum flavum (the junction of the segment ligamentum flavum and the upper and lower lamina), and the anterior wall of the spinal canal was intersected at two points perpendicular to the posterior wall of the spinal canal. Two straight lines were made with the anterior and posterior walls of the spinal canal to make rectangular regions; that is, the sagittal area. The high-density shadow in the sagittal spinal canal area was outlined, and the area of the ossified ligamentum flavum was measured (fig. 2a & b).

Sagittal OLF area = A_s (OLF)

For the postoperative measurements, the same level of the sagittal CT sagittal images was selected, and the same rectangular area was selected as the sagittal spinal canal area. The residual OLF area was measured (fig. 2c & d).

2. The proportion of OLF on the sagittal CT scans (Ps) was measured as the ratio of the ossified ligamentum flavum area to the spinal canal area.

$$Ps = As(OLF) / As(Canal)$$

3. The cross-sectional area of OLF on the CT scans (Ac) was measured as follows:

For the preoperative measurements, the segment with a lesion on the transected CT image with the largest magnitude of OLF protrusion to the front was selected, and SURGIMAP software was used to outline the spinal canal wall contour, including the posterior wall of the vertebral body, the lamina and the articular process joint. The surrounding area was the Ac area of the canal on cross-section. The high-density shadow in the area of the cross-sectional canal, as the area of OLF on the transected scan, was outlined and measured (fig. 3a & b):

$$\text{Cross-sectional area of OLF} = Ac - OLF$$

For the postoperative measurements, the same location on the image was selected as before the operation in the cross-sectional CT image, the same spinal canal area was selected as before the operation, and the contour of the area was outlined. The residual OLF area was measured (fig. 3c & d):

$$\text{Cross-sectional area of OLF} = Ac - OLF$$

4. The cross-sectional proportion of OLF on the CT scans (Pc) was measured at the above level as the ratio of the ossified ligamentum flavum area to the spinal canal area.

$$Pc = Ac(OLF) / Ac(Canal)$$

V. Clinical Assessment:

The clinical symptoms were evaluated by the modified Japanese Association of Orthopedics scale(mJOA), visual analog scale for pain(VAS), Oswestry lumbar dysfunction index(ODI) and Macnab evaluation before the operation, 3 days after the operation and 1 year after the operation. The Hirabayashi recovery rate of all patients were calculated using the preoperative and final follow-up mJOA scores[18]

Results

Perioperative conditions: Sixteen patients successfully completed full endoscopic surgery. The operative time was 91–260 min, with a average of 137.81 ± 41.98 min; the volume of intraoperative bleeding was 10 ~ 80 ml, with a average of 25.63 ± 17.689 ml; the length of hospital stay was 3 ~ 9 days, with an average of (5.06 ± 1.78) days. The wounds healed well, with no postoperative infections, no perioperative deaths, and two cases of intraoperative dural tears. However, no cases of postoperative CSF leakage were observed. There were no complications, such as nerve injury or incision infection.

The results of radiographic measurements are shown in Table 1.

Table.1 the radiographic measurements in 16 patients at different time points				
<i>Time</i>	<i>Sagittal OLF area(mm2)</i>	<i>Sagittal OLF Proportion(%)</i>	<i>Cross OLF area(mm2)</i>	<i>Cross OLF Proportion(%)</i>
<i>Preoperatively</i>	<i>116.62 ± 32.72</i>	<i>48.10 ± 10.04</i>	<i>141.59 ± 27.25</i>	<i>57.58 ± 11.37</i>
<i>3 days after the operation</i>	<i>15.99 ± 12.54*</i>	<i>6.46 ± 4.86*</i>	<i>11.72 ± 8.64*</i>	<i>4.76 ± 3.45*</i>
<i>1 year after the operation</i>	<i>16.78 ± 11.49*#</i>	<i>6.83 ± 4.48*#</i>	<i>10.82 ± 7.57*#</i>	<i>4.40 ± 3.01*#</i>
*: Compared with the “Preoperatively” data, the differences were statistically significant (P < 0.05) #: There were no statistical difference Compared with the “3 days after the operation” data.				

3. The results of clinical scores are shown in Table 2.

Table 2
the evaluation of the mJOA VAS ODI scores of 16 patients at different time points

<i>Time</i>	<i>mJOA</i>	<i>VAS</i>	<i>ODI (%)</i>
<i>Preoperatively</i>	<i>3.50 ± 1.10</i>	<i>5.94 ± 1.18</i>	<i>45.63 ± 6.90</i>
<i>3 days after the operation</i>	<i>6.19 ± 0.91*</i>	<i>3.38 ± 1.50*</i>	<i>62.13 ± 11.25*</i>
<i>1 year after the operation</i>	<i>9.19 ± 1.38*#</i>	<i>1.19 ± 1.05*#</i>	<i>89.75 ± 5.16*#</i>
*: Compared with the “Preoperatively” data, the differences were statistically significant (P < 0.05) #: Compared with the “3 days after the operation” data, the differences were statistically significant (P < 0.05).			

4. The overall Hirabayashi recovery rate was 73.96% ± 16.58%, which is comparable to the reported rates of 60.5–65% in the literature[9, 19–21]. According to the Macnab evaluation, the recovery status of the 16 patients 1 year after the operation was excellent in 9 patients, good in 5 patients, and fair in 2 patients; the excellent and good rate was 87.50%.

Discussion

Surgical treatment of TM caused by OLF

OLF is the most common cause of TM and mainly occurs in the lower thoracic segments. Most patients do not have obvious symptoms in the early stage, and it is difficult to diagnose and treat the disease early. After OLF starts to affect the spinal cord or causes severe nerve compression, severe nervous symptoms are often apparent; once diagnosed, decompression should be performed as soon as possible to prevent irreversible spinal cord injury. Although the degree of decompression with laminectomy is

sufficient, the incidence of early postoperative complications is high. Spinal endoscopic system was first used to achieve endoscopic surgery on a case of thoracic myelopathy caused by the ossified ligamentum flavum by Ikuta in 2011[14]. In recent years, some surgeons[15, 17] have reported dozens of cases achieved by endoscopic surgery for the treatment of TM caused by OLF and the application value of endoscopic surgery for this disease has received increasing attention and recognition[22–24]. With the continuous development of medicine and the emergence of various surgical procedures, the indications for endoscopic surgery continuously expanding, and the advantages of endoscopic surgery, including minor trauma, a fast recovery, low costs and no need for internal fixation, is making this technique a hot topic in spinal surgery.

Radiographic assessment criteria for patients with TM caused by OLF

OLF preoperative imaging can help surgeons determine the shape, size and exact location of the OLF and help the surgeons formulate a suitable operation plan. There have been studies on imaging classification systems and evaluations of the degree of cervical and lumbar stenosis[25–28]. The occupied area and Proportion of invasion into the spinal canal have been measured in individuals with diseases such as lumbar disc herniation. Some scholars have also proposed evaluating the residual area proportion of OLF compression in CT spinal canal cross-sections and the severity of ligamentum flavum ossification[29], The area can be accurately measured to assess the degree of spinal stenosis at a single level a. In this study, the transected and sagittal ossification Proportions of the ossified ligamentum flavum were used as the imaging evaluation standards. In 16 cases, the ossification area and canal invasive proportion of the ligamentum flavum were measured accurately regarding the compression of the spinal canal in TM caused by OLF patients and there was a significant correlation between the improvement of symptoms and the decrease of proportions. Based on this finding, with accurate and standard high-density CT scanning and 3D reconstruction technology, it is expected that the occupied proportion of volume of the spinal canal can be used as an evaluation standard of thoracic myelopathy in the future.

Clinical efficacy of translaminar osseous channel–assisted full-Endoscopic flavectomy in the treatment of TM caused by OLF

Treatments for lumbar disc herniation, cervical disc herniation, cervical disc herniation, cervical nerve root canal stenosis and other degenerative diseases in our department have yielded good results, and the clinicians have accumulated a great deal of experience in endoscopic surgery. Because the location, shape and size of OLF lesions vary across individuals, the surgical decisions, surgical approach and overall design need to be determined carefully on the basis of all previous clinical experiences. Moreover, the learning curve for full endoscopic spinal surgery is steep. When applied to TM caused by OLF, because of the unique anatomical characteristics of the thoracic vertebrae, the operation is more difficult and riskier. Surgeons with sufficient experience in full endoscopic spinal surgery are needed.

Conclusion

The clinical results of percutaneous posterior spinal endoscopy TM caused by OLF in 16 patients showed significant improvements in the operation time, intraoperative blood loss, hospitalization time, recovery of function regarding getting out of bed, postoperative pain, spinal stability, injury of muscle and ligament structures, and recovery of postoperative nerve function. There were no complications, such as cerebrospinal fluid leakage, deep venous thrombosis of the lower extremities, nerve injury or incision infection. The mJOA score, VAS score and ODI score significantly improved from preoperatively to 1 year after the operation. The Macnab excellent and good rate was 87.5%. Compared with traditional open surgery (34.6–76.7%)[8], this method may have obvious advantages. The above results serve as strong evidence of the clinical treatment effect of posterior full endoscopic surgery on TM secondary to OLF.

Endoscopic treatment for thoracic OLF leads to a short hospitalization time, a small volume of intraoperative bleeding, small surgical incisions, rapid recovery, and few postoperative complications. During the operation, the intraspinal structure can be clearly observed, the location of the lesion can be identified, and the possibility of spinal cord, nerve and dural injury can be reduced, thus improving the safety of treatment. Compared with open surgery, this surgery can achieve full decompression without damaging paravertebral muscle tissues or reducing spinal stability. The OLF area and spinal canal invasive proportion 1 year after the operation were compared with the values preoperatively. Five cases showed relatively significant exacerbating trends, indicating that after full endoscopic surgery, OLF still has the possibility of progressing further. This finding should be verified by longer-term follow-up data.

There are some limitations of this study, including the following: the sample size was limited, and larger sample sizes are needed to assess OLF in the later stage; the follow-up time was short, and additional studies on the long-term efficacy, complications, etc. are needed; more studies on imaging measurements, studies aiming to determine whether endoscopic techniques are adequate for OLF resection and spinal canal decompression, and comparative studies on traditional surgical methods are needed.

Moreover, according to the specific conditions of the patients, we should make individualized diagnosis and treatment plans, integrate medical imaging with clinical medicine organically, and strive to develop more accurate and suitable diagnosis and treatment methods so that this disease can be prevented in the early stage of onset in the majority of patients and the patients with obvious clinical symptoms can experience better treatments effects with lower treatment costs.

List Of Abbreviations

CT: Computed tomography

TM: thoracic myelopathy

OLF: ossification of the ligamentum flavum

mJOA: the modified Japanese Association of Orthopedics scale

VAS: visual analog scale for pain

ODI: Oswestry lumbar dysfunction index.

Declarations

Ethics approval and consent to participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards, and the ethics committee in affiliated hospital of Zunyi Medical University approved this study. And the Informed Consent (written) was obtained from all patients included in this study.

Consent for publication

Not applicable

Availability of Data and Material

The datasets used during the current study are available from the corresponding author on reasonable request.

Competing interests

No benefits in any form have been or will be received from a commercial associations related directly or indirectly to the subject of this manuscript. None of the authors have non-financial conflict of interest too.

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Authors' contributions

Jialin He and Qian Du contributed to the writing of the paper and drafting of the manuscript. Wenbo Liao and Zhijun Xin contributed to the study design. Menghan Cai and Wandong Hu collected and analyzed the data. Wenbo Liao reviewed and edited the manuscript. All authors read and approved the final manuscript.

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Figures

Figure 1

(a) A Kirschner needle was located on the posterior osseous lamina behind of the lesion segment; (b) A ring saw was used to remove a piece of the lamina to make a tunnel; (c) a piece of lamina was removed to get adequate operational space; (d) The ossified ligamentum flavum was resected by endoscopic rongeur; (e) The space around the dural sac was wide and decompression was adequate; (f) Collected samples of ossified ligamentum flavum.

Figure 2

(a) diagram of preoperational sagittal measurements; (b) An actual preoperational measurement, the area of OLF was 59.1 mm², the area of canal was 117.2 mm², and the invasive proportion was 50.43%; (c) diagram of postoperational sagittal measurements; (d) An actual postoperational measurement, the area of OLF was 0 mm², the area of canal was 117.2 mm², and the invasive proportion was 0%.

Figure 3

(a) diagram of preoperational cross-sectional measurements; (b) An actual preoperational cross-sectional measurement, the area of OLF was 187.4 mm², the area of canal was 233.3 mm², and the invasive proportion was 80.33%; (c) diagram of postoperational cross-sectional measurements; (d) An actual postoperational cross-sectional measurement, the area of OLF was 14.7 mm², the area of canal was 233.2 mm², and the invasive proportion was 6.30%.