Surgical Treatment for Ossification of the Posterior Longitudinal Ligament (OPLL) at the Thoracic Spine: Usefulness of the Posterior Approach

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Abstract:

Various methods via anterior or posterior approach with or without spinal stabilization have been performed in accordance with the level and configuration of ossification of the posterior longitudinal ligament (OPLL) as the decompression surgery for thoracic myelopathy due to OPLL. Among them, anterior decompression at the middle thoracic level (T4/T5-T7/T8) is especially difficult to perform because of the special anatomical structures, where the spinal alignment is kyphotic and the thoracic cage containing circulatory-respiratory organs exist nearby. Of the anterior decompression procedures at this level, the posterior approach has various advantages compared to the anterior one. In the anterior approach, the procedure is complicated and the effect of decompression of the spinal cord can be obtained only by direct resection or anterior floating of the OPLL. However, complications such as spinal cord injury and dural tear are most likely to occur at that time. On the contrary, in the posterior approach, the procedure is simple, and various options to obtain decompression can be selected from, these are, laminectomy, laminoplasty, dekyphosis surgery, staged decompression surgery (Tsuzuki's method), circumferential decompression via posterior approach alone (Ohtsuka's method), and circumferential decompression via combined posterior and anterior approaches (Tomita's method). Among them, in laminectomy, laminoplasty, and dekyphosis surgery, anterior decompression can be obtained to some extent without performing direct procedure on the OPLL. In Ohtsuka's method, complete decompression can be obtained via posterior approach alone, although it is somewhat technically demanding. It is preferable to drop the shaved down and separated OPLL anteriorly instead of trying to remove it completely to avoid complications, especially in patients with severe adhesion between the dura mater and OPLL.

Keywords:

ossification of the posterior longitudinal ligament (OPLL), thoracic spine, surgical treatment, posterior approach

Spine Surg Relat Res 2018; 2(3): 169-176

dx.doi.org/10.22603/ssrr.2017-0044

Introduction

Ossification of the posterior longitudinal ligament (OPLL) is a disease in which the posterior longitudinal ligament is chronically ossified at various vertebral levels, sometimes combined with ossification of the ligamentum flavum (OLF). OPLL and OLF are thought to be presentations of a systematic ossification trait of the ligaments. Thoracic OPLL usually combines with cervical OPLL and/or thoracic OLF and exhibits various types of neurological symptoms in accordance with the compression level of the spinal cord, the nerve roots, and the conus medullaris. The incidence of thoracic OPLL among the Japanese population is about 0.8%[1].

Concerning treatment for thoracic myelopathy due to OPLL, conservative treatment is usually ineffective. In general, myelopathy is caused by static and/or dynamic compression mechanisms. At the cervical spine where dynamic compression force is caused by cervical vertebral movement, the conservative treatment of reducing its movement by using a collar is effective. In contrast, at the thoracic spine where the vertebral movement is smaller than that of the cervical spine because of the rigid connection with the thoracic cage, almost all compression mechanisms are thought to be not dynamic but static. Therefore, the effectiveness of an outer orthosis such as a corset for OPLL is small, and surgical treatment is the only effective option.

The main purpose of surgical treatment for thoracic OPLL is to decompress the thoracic spinal cord, sometimes

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Received: June 2, 2017, Accepted: July 25, 2017, Advance Publication: February 28, 2018

Table 1. Various Surgical Methods for Thoracic Ossification of the Posterior Longitudinal Ligament (OPLL).

Anterior approach
Anterior decompression and stabilization (sometimes with spinal instrumentation)
-----Longitudinal splitting of manubrium sterni approach (T1-T3 level)
-----Extrapleural approach (T4-T12 level)
-----Thoracotomy (T4-T12 level)
Anterior decompression under arthroscope
Posterior approach
Laminectomy (usually combined with spinal instrumentation)
Dekyphosis (combined with laminectomy)
Laminoplasty
-----Conjoint cervical and thoracic laminoplasty (Expansive laminoplasty)
-----Thoracic laminoplasty
Circumferential decompression and stabilization (sometimes with spinal instrumentation) (Ohtsuka's method)
Staged decompression and stabilization (sometimes with spinal instrumentation) (Tsuzuki's method)
Combined posterior and anterior approaches
Staged decompression and stabilization with spinal instrumentation (Tomita's method)

combined with stabilization using instrumentation with or without reduction of kyphotic alignment of the vertebral column. However, even now, decompression surgery for thoracic OPLL is a great challenge in neurosurgery. Especially, anterior decompression procedure at the middle thoracic level (T4/T5-T7/T8) is difficult to perform because of the special anatomical structures of the thoracic vertebral column, where its alignment is kyphotic and the thoracic cage containing circulatory-respiratory organs exist nearby. However, for thoracic OPLL at these levels, it is reasonable to perform anterior decompression of the spinal cord. Moreover, the prevalence of thoracic OPLL at these levels is most frequent[2,3]. Accordingly, there are relatively more patients indicated for decompression surgery at these levels than at others.

The most important point in surgery for thoracic OPLL is how to safely decompress the spinal cord. The decompression procedures of the thoracic spinal cord are usually performed via anterior, posterior, or combined anterior/posterior approaches (Table 1). Among them, the posterior approach seems to be superior to the anterior one from various viewpoints[4]. In the present paper, the advantages and problems of the posterior approach comparing to the anterior one are presented.

1. The General Advantages of the Posterior Approach in Thoracic Spine Surgery

In thoracic spine surgery, the posterior approach has generally some advantages in comparison with the anterior one as follows: (1) Clear, shallow, and wide surgical field can be obtained and freely extended toward lateral and craniocaudal directions, if necessary, (2) The surgery can be performed with the same procedure despite the difference of the thoracic level, (3) Because of unnecessity of intraoperative handling of the lung, pleura, and diaphragm, respiratory control is clinically easier both during and after surgery, (4) In cases with complications after surgery such as infection and liquor cyst, management is relatively easy because of easier approach to those affected fields.

2. The Special Advantages of the Posterior Approach in Surgery for Thoracic OPLL

Besides the general advantages mentioned above, from the viewpoints of the character of thoracic OPLL and the anatomical characteristics of the thoracic column and spinal cord, the superiority of the posterior approach to the anterior approach becomes more distinct.

1) Decompression mechanism of the thoracic spinal cord

The main purpose of the surgery for thoracic myelopathy due to OPLL is to decompress the spinal cord. In the anterior approach, this purpose can be obtained only by direct procedure on the OPLL such as resection or anterior floating. However, complications such as spinal cord injury and dural tear are most likely to occur at the time of this direct procedure[5,6].

In comparison with the cervical and lumbar spinal cord, the transverse diameter of the thoracic spinal cord is relatively smaller and the area of the gray matter with rich vascularity is narrower. Especially, the upper and middle thoracic levels are just at a watershed zone where the blood flow volume to the spinal cord is relatively low. There, the blood flow comes from two different directions: one is descending flow via the vertebral artery and the other is ascending flow via the intercostal artery and aorta. The spinal cord at the middle thoracic levels (T4-T8) is supplied mainly by the midthoracic radicular branch, which is poorly collateralized, which makes these levels more susceptible to hypovascular conditions[7,8]. This anatomical feature of lower vascularity in the thoracic spinal cord is one of the reasons why paralysis after surgery tends to occur, no matter how carefully the decompression procedure is performed. Moreover, in the anterior approach, interbody fusion is ordinarily mandatory after these decompression procedures, except in arthroscopic surgery.

On the contrary, in the posterior approach, various options can be selected from, these are, laminectomy[9], laminectomy with spinal instrumentation[10-13], laminoplasty[14,15], staged decompression surgery (Tsuzuki's method)[14-16], dekyphosis surgery[17,18], circumferential decompression via posterior approach alone (Ohtsuka's method)[3,9,14-16,19-21], and circumferential decompression via combined posterior/anterior approaches (Tomita's method)[22,23]. Among them, in laminectomy, laminoplasty, and dekyphosis surgery, anterior decompression can be obtained to some extent without performing direct procedure on the OPLL. In staged decompression surgery, in the beginning, the spinal cord is shifted posteriorly by laminoplasty, and thereafter anterior decompression of the spinal cord via posterior approach can be added to improve neurological conditions if the initial laminoplasty is proved not to be so effective. In circumferential decompression, prior to direct procedure on OPLL anteriorly, the spinal cord can be shifted posteriorly by laminectomy. In the posterior approach, interbody fusion is unnecessary, although posterior instrumentation surgery must be added in many cases.

However, laminectomy alone may tend to induce postoperative neurological deterioration, except at the lower thoracic level, because of progression of the kyphotic curve resulting from weakness of the posterior structural support. Matsuyama et al.[24] reported that in the beak-type OPLL, a subtle alteration in the spinal alignment during posterior decompression procedures, may increase spinal cord compression and a potential increase in kyphosis following laminectomy should be avoided by fixation with a temporary rod.

2) Surgery for OPLL at the upper thoracic level (C7/T1-T3/T4)

At the upper thoracic level, the spinal column alignment changes from lordotic curve at the cervical spine to kyphotic curve at the thoracic spine. Therefore, even in cases with large prominent OPLL, the spinal cord can be shifted sufficiently posteriorly after posterior decompression surgery such as laminoplasty. As upper thoracic OPLL combines with cervical OPLL in many cases, by conjoint laminoplasty from the cervical spine to the upper thoracic spine (expansive laminoplasty), the spinal cord can be more effectively shifted posteriorly and separated from the upper thoracic OPLL to the greatest extent possible[14,15].

Anterior decompression via anterior approach at the upper thoracic spine is usually performed by longitudinal splitting of the manubrium sterni[5,6]. The procedure through this approach has many limitations: the most caudal level reached is at most the third thoracic spine (T3) because of the location of the heart and aorta at the midway, and the surgical field becomes gradually deeper and less visible because of the kyphotic alignment of the thoracic spine.

As mentioned above, OPLL at the upper thoracic spine can be managed by laminoplasty via posterior approach except in cases with larger and sharper prominence of the OPLL[24].

3) Surgery for OPLL at the lower thoracic level (T8/T9-T11/T12)

OPLL at the lower thoracic level sometimes combines with OLF at the same and/or adjacent levels and compresses the spinal cord both anteriorly and posteriorly. In such cases, laminectomy and conjoint resection of OLF via posterior approach is usually performed. Because at this level, the spinal column alignment changes from kyphotic curve at the thoracic spine to lordotic curve at the lumbar spine, the spinal cord can be sufficiently shifted posteriorly after posterior decompression by laminectomy. It is very rare that laminectomy at this level induces weakness of the posterior structural support, therefore, additional instrumentation surgery for argumentation is usually unnecessary.

4) Neurological examinations of diseases at the thoracic level

Of course, it is mandatory that the surgical level must be determined before surgery based on neurological and imaging findings. At the cervical and lumbar levels, the pathognomonic level can be relatively easily determined by the neurological findings consisting of the degree of power of the affected muscle, the level of sensory disturbance, and the degree of deep tendon reflex because the relationship between the spinal segmental sign and the affected level is clear. However, at the thoracic level, this relationship is unclear. Even the most cranial level of sensory disturbance and loss of superficial reflex cannot always become indexes for determination of pathognomonic level. Especially in cases with OPLL at multiple thoracic levels, it is more difficult to precisely determine the pathognomonic level. Therefore, it may be reasonable to extend the surgical field to caudal and cranial directions to decompress the spinal cord widely through the posterior approach.

On the contrary, in the anterior approach, the pathognomonic level must be exactly determined before surgery because the surgical field is very limited and the working space is narrow. The surgical field can hardly be extended during operation.

Thus, the posterior approach is proved to be superior to the anterior approach for treatment for OPLL at the upper and lower thoracic spine for the many reasons mentioned above.

3. Surgery for OPLL at the Middle Thoracic Level (T4/T5-T7/T8)

According to Matsumoto et al.[25] who reported a multi-institutional retrospective study concerning treatment of thoracic OPLL, it was revealed that choice of surgical methods depended on the thoracic level. In about half of the institutes that joined that study, laminoplasty was performed for upper thoracic OPLL, and laminectomy was performed for lower thoracic OPLL. These strategies are the same as ours. However, for middle thoracic OPLL, there was no consensus as to the surgical method, and various surgeries were performed at each institute, such as laminectomy, laminoplasty, anterior decompression via anterior approach, anterior decompression via posterior approach, and circumferential decompression. This reality suggests that at present there are no definitely superior surgical methods for OPLL at the middle thoracic level, probably because of difficulty in performance due mainly to kyphotic spinal column alignment at that level.

1) Various surgical methods for the middle thoracic OPLL

As decompression procedure for OPLL at the kyphotic middle thoracic spine, anterior decompression of the spinal cord is thought to be reasonable. There are two approaches for anterior decompression: anterior or posterior. Anterior decompression via anterior approach has several problems. These are, difficulty in approach, complication of pulmonary function, and restriction of working space and visual field[5,6].

In anterior decompression via posterior approach, there are two methods from the viewpoint of handling of the OPLL: direct decompression or indirect decompression. The former includes Ohtsuka's method and Tomita's method. In Ohtsuka's method[3,9,14-16,19-21], circumferential decompression is performed via posterior approach alone. In Tomita's method[22,23], circumferential decompression is performed via posterior approach at first, followed by anterior approach. In both methods, complete decompression of the spinal cord can be obtained and the enuclated and thinned OPLL can sometimes be resected directly; however, it takes much time, and the risk of spinal cord injury and dural tear may become higher because of direct handling of the OPLL.

Dekyphosis surgery[17,18] is an indirect decompression procedure via posterior approach through decreasing the degree of kyphotic curve using spinal instrumentation, as opposed to a direct procedure to the OPLL. After laminectomy, a dekyphosis procedure is performed between the placed pedicle screws with the cantilever technique to achieve greater decompression of the spinal cord. In this method, the procedure is easily performed; however, anterior compression of the OPLL remains and complete decompression of the spinal cord cannot be obtained, especially for beak-type OPLL. Therefore, issues of surgical indication and degree of reduction remain to be resolved. Imagama et al.[18] reported that 4 of 70 consecutive patients with beak-type OPLL had no improvement or aggravation after surgery, in whom the rates of severe motor paralysis, nonambulatory status, positive prone and supine position test, no spinal cord floating in intraoperative ultrasonography, and deterioration of intraoperative neurophysiological monitoring at the end of surgery were significantly higher.

Ohtsuka's method and dekyphosis surgery are both performed via posterior approach alone. The question is which decompression procedure is better; direct or indirect. Probably, the selection of surgical method depends mainly on the degree of prominence and shape of the OPLL. In cases with large and beak-type prominence of OPLL, direct decompression such as Ohtsuka's method is necessary even if it is somewhat technically more demanding.

In our 10 consecutive patients who underwent the Ohtsuka's method, anterior decompression was performed for only the most prominent beak-type OPLL, considering that this type of OPLL is pathognomonic and must be eliminated, and that a flat-type OPLL is relatively nonpathognomonic, even though it may exist at multiple levels. Preoperatively, there were 5 patients who had used a wheelchair and 5 patients who had walked with a T-cane. Among the 5 patients using a wheelchair, 3 became able to walk with a T-cane postoperatively. The remaining 2 patients, who had at first recovered ability to walk with a T-cane, worsened again because of appearance of OPLL at other levels. Among the 5 patients using a T-cane preoperatively, 4 became able to walk without it. The remaining 1 patient gradually worsened within a half year after surgery and finally had to use a wheelchair because of formation of syringomyelia and liquor cyst, probably resulting from arachnoid fissure during surgery[16].

Takahata et al.[3] reported the relationship between the surgical outcomes and number of operated levels in circumferential decompression surgery. Statistical analysis showed that a risk factor associated with unfavorable surgical outcomes was decompression of 5 or more vertebral levels. It is certainly true that the greater the number of operated levels, the more the risk factors such as long operation time, blood loss volume, and opportunity for contamination increase. The important issues are at which level and what type of OPLL must be operated.

Ando et al.[17] reported a new surgical method of dekyphosis surgery combined with Ponte osteotomy. For 10 patients, spinal fusion with an average of 9.8 vertebrae and laminectomy with an average of 7.3 laminae were performed. The kyophotic alignment at the fusion level reduced from 35 to 21 degrees postoperatively. On intraoperative ultrasonograpy, floating of the spinal cord from the OPLL was confirmed in 7 patients. The recovery rate of these patients was 66.0%.

Onishi et al.[26] recommended early surgery for patients with thoracic myelopathy due to simultaneous OPLL and OLF at the same level in the mid-thoracic spine because of poorer surgical outcomes than those of other levels.

2) The concept of staged operation

As intraoperative spinal cord injury tends to occur because of the difficulty of the surgical procedure and the fragility of the thoracic spinal cord, the concept of staged operation has been naturally proposed. The surgical procedure on the spinal cord at the middle thoracic level takes a lot of

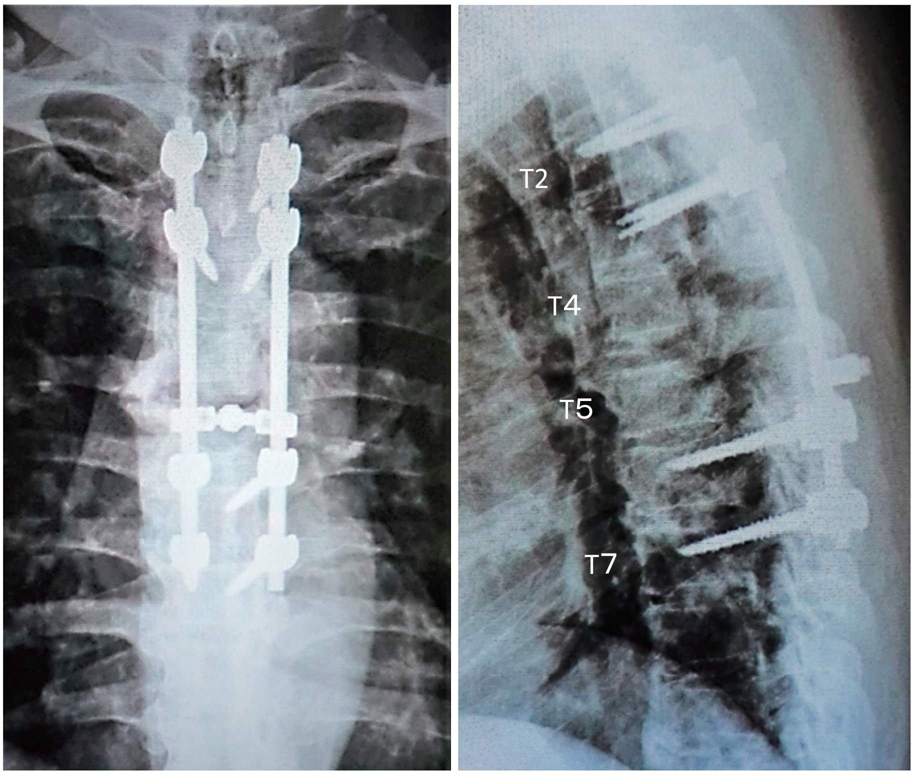

Figure 1. Postoperative X-ray films (65-year-old male, T4/T5), Ohtsuka's method.
After circumferential decompression at T4/T5, posterior fixation between T2 and T7 was performed using spinal instrumentation.

time, and during this procedure the fragile thoracic spinal cord tends to suffer unnoticed damage. The main purpose of the staged operation is to disperse this dangerous condition of the spinal cord chronologically and spatially. Each stage proceeds with an interval.

Tsuzuki et al.[14] proposed staged operation via posterior approach alone. For OPLL at the middle thoracic level, at most 3 staged procedure is performed based on the surgical results of the prior stage. The first stage is conjoint laminoplasty from the upper cervical level to the upper thoracic level (expansive laminoplasty) to separate the spinal cord from the OPLL posteriorly to the extent possible. The second stage is laminoplasty from the upper thoracic level to the middle thoracic level about one month later. If improvement cannot effectively be obtained after the first and second stages, the third stage is carried out about one month later. The third stage is Ohtsuka's method (Fig. 1, Fig. 2, Fig. 3). In Ohtsuka's method, after laminectomy at the most affected level, usually where a large beak-type OPLL is prominent, the OPLL is bilaterally enuclated from the posterior-lateral sides. After the OPLL is completely separated from the posterior border of the vertebral body, the enuclated and thinned OPLL is finally dropped anteriorly together with its adhered dura mater, followed by spinal fixation. To decrease the traction force by nerve roots, durotomy and root release are added in some cases.

Tomita's method[22,23] is also one of staged operation. In this method, as the second step via anterior approach following laminectomy via posterior approach in the first step, costotransversectomy is performed in the upper thoracic spine and standard thoracotomy in the middle or lower thoracic spine. Two independent teams of surgeons are in charge of the two steps respectively to shorten the operating time.

4. Complications of Surgery for Thoracic OPLL

The complications of surgery for thoracic OPLL are divided into two types[15]: those occurring during surgery and immediately or early after surgery, and those occurring late after surgery. The former consists of spinal cord damage by direct injury and compression during surgery, dural tear, formation of hematoma, infection, remnant of pathognomonic OPLL, and so on. The latter consists of formation of syringomyelia and liquor cyst resulting from a fissure of dura mater and arachnoid, spinal instability, vertebral column fracture[27], recurrence of myelopathy, deterioration of neurological functions due to OPLL at other levels, and so on[28]. Matsumoto et al.[25] reported that the relatively higher rate of complications included dural tear in 22.1% and worsening of myelopathy immediately after surgery in 11.7%.

Concerning dural tear combined with cerebrospinal fluid (CSF) leakage, Hu et al.[9] reported that treatment included bed rest and compressive dressing after removal of drainage, and 80% resolved during follow-up, and there was no difference in the final JOA (Japanese Orthopaedic Association)

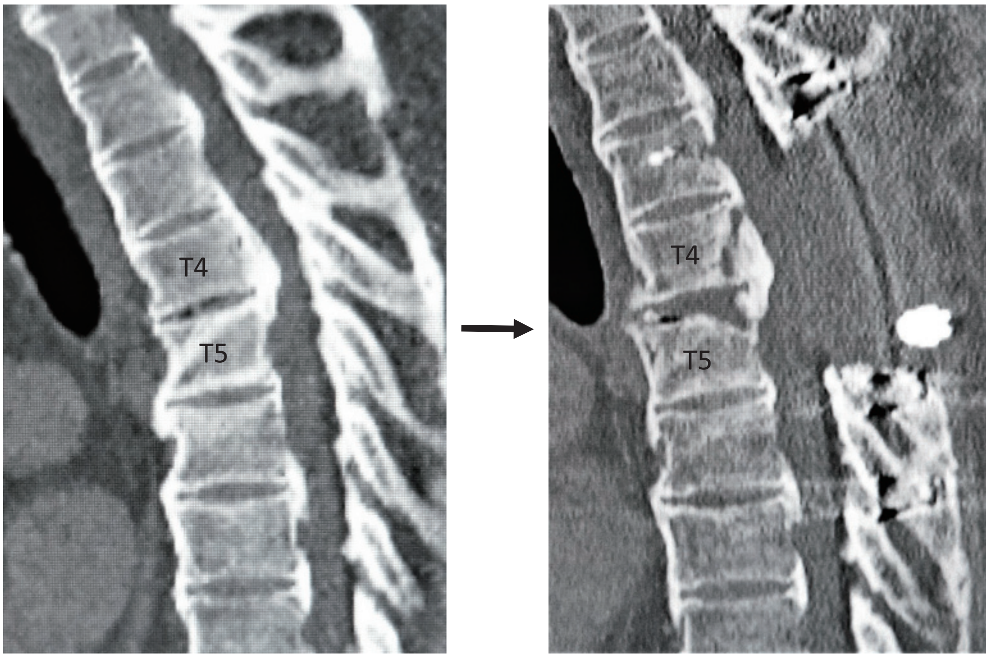

Figure 2. Sagittal view of Computed Tomography (CT) (65-year-old male, T4/T5), Ohtsuka's method.
Postoperatively, a residual OPLL was shifted anteriorly and the spinal canal space became widened.

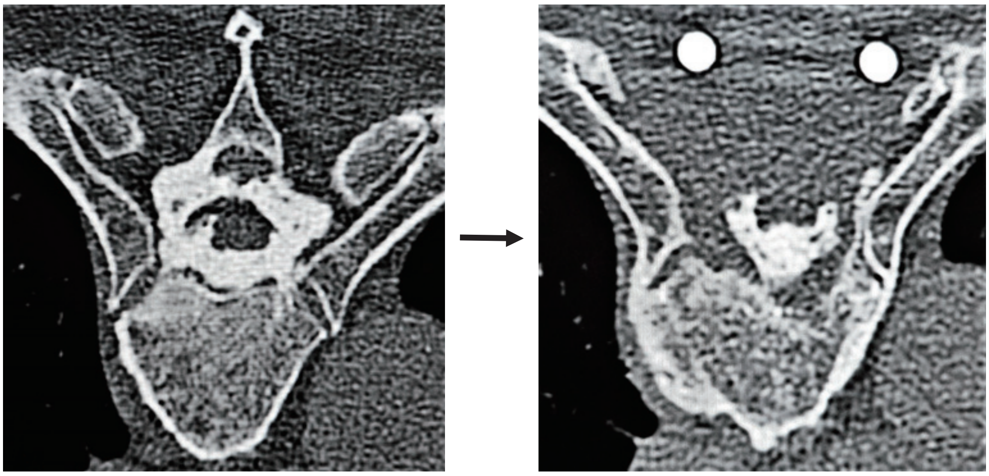

Figure 3. Axial view of CT (65-year-old male, T4/T5), Ohtsuka's method.
Postoperatively, a residual OPLL was shifted anteriorly accompanied with adhesion of the ossified dura mater.

score and recovery rates between the subjects with or without CSF leakage. However, it is needless to say that it must be avoided. In Ohtsuka's method, dural tear tends to occur at the time of resection of the OPLL from the adhesive dura mater or dropping of the OPLL anteriorly in patients in whom separation of the most cranial and caudal ends of the OPLL from the vertebral body is incomplete. Because this is a completely blind procedure, the degree of separation and adhesion must be judged by tactile sensation from a probe[16].

To reconfirm adequate decompression of the spinal cord, intraoperative ultrasound is useful[9,17,20,24]. This can promptly identify the remnant OPLL and de novo appearance of compression of the spinal cord due to kyphotic change of vertebral alignment during surgery. To avoid intraoperative complications such as spinal cord damage by direct injury and compression, it is mandatory to carry out the procedure under electrophysiological monitoring[18,24,25].

In conclusion, even now, the surgery for OPLL at the middle thoracic level is a great challenge and many complications such as paralysis tend to occur no matter how carefully decompression is performed. However, some complications such as dural tear can be avoided. In laminoplasty and dekyphosis surgery, anterior decompression can be obtained to some extent without performing a direct procedure on the OPLL. The staged operation in which each decompression procedure proceeds with intervals is one option. In Ohtsuka's method in which circumferential complete decompression can be obtained via posterior approach alone, it is preferable to drop the thinned and separated OPLL anteriorly instead of trying to remove it completely, especially in patients with severe adhesion between the dura mater and OPLL. As the OPLL itself is usually progressive, a long term follow-up is necessary to examine deteriorated neurological functions caused by newly formed OPLL.

Acknowledgement: The authors wish to express their gratitude to Mr. Larry Frumson for his proofreading of this manuscript.

Conflicts of Interest: The authors declare that there are no conflicts of interest.

Author Contributions: Shigeru Hirabayashi performed the operations and wrote the manuscript. Tomoaki Kitagawa, Iwao Yamamoto, Kazuaki Yamada, and Hirotaka Kawano performed and assisted in operations and collected the data for this manuscript.

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