Abstract

Study Design. Retrospective clinical study.

Purpose: To investigate the outcomes after indirect posterior decompression and dekyphosis using multilevel Ponte osteotomies for ossification of posterior longitudinal ligament (OPLL) of the thoracic spine.

Summary of Background Data. There are no previous reports on the use of Ponte osteotomy to treat thoracic OPLL.

Methods: The subjects were 10 patients with an average age at surgery of 47 years who underwent indirect posterior decompression and dekyphosis using multilevel Ponte osteotomies at our institute. Minimum follow-up period was 2 year, and averaged 2 year 6 months. Using radiographs and CT images, we investigated fusion range, pre- and postoperative Cobb angles of thoracic fusion levels, intraoperative ultrasonography and clinical results.

Results: The mean fusion area was 9.8 vertebraes, with average laminectomy of 7.3 laminas. The mean preoperative thoracic kyphosis of fusion levels on standing radiograph measured 35° and was changed to 21° after surgery. The mean number of Ponte osteotomies was 3 levels. The mean pre- and postoperative (at the 1 year follow-up) JOA scores were 3.5 and 7.5 points, respectively, and the recovery rate was 56%. On intraoperative ultrasonography, 7 of the cases were included in the floating (+) and 3 in the floating (-) groups, and the recovery rates were 66.0% and 33.4%, respectively.

Conclusions: ‘The Ponte procedure for indirect spinal cord decompression’ is a novel

concept used for the first time with thoracic OPLL in our study, and we consider it a useful method to achieve more effectively dekyphosis and indirect spinal cord decompression if there is not the spinal cord free from OPLL on intraoperative ultrasonography after only laminectomies.

Introduction

Surgical intervention is necessary when thoracic myelopathy occurs secondary to ossification of the posterior longitudinal ligament (OPLL) because this condition is progressive and intractable to conservative therapy. However, surgical outcomes reported to date have not been satisfactory.[1-3] There have been reports of neurologic deterioration after surgery for thoracic OPLL, all of which exhibited a sharply protruded segmental form of ossification.[4-6] For beak and flat type OPLL accompanied by ossification of the ligamentum flavum and facet destruction, we have been performing indirect spinal cord decompression with primary dekyphosis using instrumentation via a posterior approach.[7] Furthermore, we incorporated Ponte osteotomies[8,9] during surgery for thoracic OPLL to obtain more effective indirect spinal cord decompression. There are no previous reports on the use of this procedure to treat thoracic OPLL. This is the first report employing Ponte osteotomies in the treatment of thoracic myelopathy due to OPLL.

Materials and methods

The subjects were 10 patients (5 men and 5 women) with an average age at surgery of 47 years (18-63 years) who underwent indirect posterior decompression and corrective fusion with Ponte osteotomies at our institute from 2010 to 2012. This study was approved by the institutional review board of the School of Medicine, University of Nagoya, and informed consent was obtained from each patient before enrollment. We followed the patients for a minimum of 2 year and an average of 2 year 6 months (24-36 months).

We performed lateral whole spine radiographs with standing and multi-slice computed tomography (CT) images of the cervical and thoracic spine on all patients. Measurements were standardized and recorded by 2 independent observers and recorded on a study group data sheet. Using sagittal CT images, we classified the ossification types as beak or flat according to the criteria proposed by Matsuyama et al.[4] To calculate the kyphotic angle, we measured the sagittal Cobb angle between the upper endplate of the uppermost vertebra and the lower endplate of the lowest vertebra at the instrumented fusion levels.

We performed follow-up exams 1 year after the surgery using the Japanese Orthopaedic Association Scoring System (JOA score). This has a total of 11 points, consisting of four points each for motor dysfunction of lower extremities; two points each for sensory dysfunction of lower extremities and trunk; and three points for bladder dysfunction. Postoperative recovery rate was determined by Hirabayashi's method as follows: recovery rate = (postoperative JOA score - preoperative JOA score) × 100 / (full score - preoperative JOA score).

We investigated fusion range, osteotomy levels, pre- and postoperative Cobb angles of fusion levels using radiographs and sagittal CT, intra- and postoperative blood loss, operative time, recovery rate and intraoperative ultrasonography findings. Cases in which the spinal cord free from OPLL on intraoperative ultrasonography were defined as the floating (+) group, and those without as the floating (-) group according to Matsuyama et al. [7].

Surgical Planning

The basic fusion area was three vertebrae above and below the OPLL lesion with segmental screw. Axial and sagittal CT images were used to determine the osteotomy levels. Usually, there were some areas of ligamentum flavum ossification (OLF) adjacent to an OPLL level (Fig. 1a). Because of this non-mobile segment at the OPLL level, osteotomies were performed to OLF areas at the mobile level adjacent to the OPLL.

Surgical Procedure

Surgical procedure was performed as described by Matsuyama et al. [10].

In short, Luer bone rongeur forceps, bone punch and diamond bur are used to perform Ponte osteotomies followed by screwing, in situ rod placement and decompression. This is continued to the foramen at each level. Rod placement on the other side, at the beginning of the proximal end, then follows as the in situ rod is detached from the screw at the same level of the other rod placement. The reduction is a combination of cantilever and compression at each osteotomy level. Posterior fusion is completed with decortication and local bone grafting. Rehabilitation with a brace is started two days after surgery.

Results

The average pre- and postoperative (at the1 year follow-up) JOA scores were

3.5 (0–10) and 7.5 (6–11), respectively, and the recovery rate was 56%. The fusion areas were C7–T11 in one case, C7-T12 in one case, T1–T12 in 2 cases, T2–T10 in 2 cases, T2–L3 in one case, T5–T12 in one case, T7–T12 in one case and T9–L2 in one case. The mean fusion area was 9.8 vertebraes, with average laminectomy of 7.3 laminas (3–10). Four cases received cervical laminoplasty simultaneously with their fusions. We performed osteotomies both rostrally and caudally to the OPLL level in 7 cases (T1/2 and T6/7/8/9 in one case; T4/5, T6/7 and T8/9 in one case; T8/9 and T10/11 in one case; T3/4/5 and T9/10 in one case; T3/4 and T10/11/12 in one case; T9/10 and T11/12 in one case; and T3/4 and T5/6 in one case). We performed osteotomies to just the caudal side in 2 case (T6/7/8 and T9/10) and to only the rostral side in one case (T4/5/6/7/8). The average number of osteotomy levels was 3 (1-4). Preoperative kyphosis at the fusion level averaged 35° (20°–60°) on radiograph and 29° (20°–47°) on CT with a correction to 21° (7°–38°) after surgery. The mean operative time was 9 h and 50 min (6 h 50 min–11 h 10 min), with average blood loss of 2328 ml (251–11,731 ml) (Table 1).

On intraoperative ultrasonography, 7 cases were included in the floating (+) and 3 in the floating (-) groups, and the recovery rates were 66.0% and 33.4%, respectively. Those in the floating (+) group as determined by ultrasonography tended to have good results although there was no significant difference between the two groups (P=0.173) (Table 2).

No patient had a decrease of amplitude on intraoperative spinal cord monitoring during the Ponte osteotomies, cantilever and compression procedures. Regarding intra- and postoperative complications, cerebrospinal fluid leakage and wound infection was noted in one case with adhesion between the dura and ossified ligamentum flavum, but it was treated with irrigation.

Illustrative Case

Case 1. 49-year-old woman with continuous-type OPLL from T1-3 and T4-10 and OLF at the T3/4 and T10/11/12 regions had progressive myelopathy (Fig. 1a). MR images revealed severe canal stenosis at several of the OPLL and OLF locations (Fig. 1b). Laminoplasty from C3 to C7 was performed for cervical canal stenosis followed by screwing and in situ rod placement from T1 to T12. Intraoperative ultrasonography revealed compression of the spinal cord by the OPLL anteriorly after laminectomy of T1–T11 (Fig. 2a). We performed Ponte osteotomies at T3/4 and T10/11/12, and the kyphosis was corrected and fixed with cantilever and compressive forces with instruments. The preoperative kyphotic angle of T1-12 of 48° was corrected to 37° after surgery (Fig. 1b). Ultrasonography showed that spinal cord compression decreased (Fig. 2b). Neither neurological aggravation nor improvement occurred after the surgery.

Discussion

Symptomatic ossification of the posterior longitudinal ligament for the thoracic vertebrae requires surgical treatment. Matsumoto et al. reported that the combined use of instrumentation with surgery was associated with significantly better outcomes in a multicenter study in Japan; This procedure stabilized the thoracic spine to prevent the progression of or even to correct thoracic kyphosis thereby enhancing spinal cord decompression [11]. Kawahara et al reported the usefulness of the circumferential decompression of thoracic cord with dekyphosis stabilization for thoracic OPLL[12]. An anterior approach using an extra- or transpleural approach has been recommended by several authors, as it allows for direct decompression of the spinal cord by excising or floating the OPLL[13]. In the multicenter study, Matsumoto et al reported the recovery rate tended to be higher among patients undergoing anterior decompression and fusion via an anterior approach or circumferential decompression and fusion than among those undergoing posterior decompression and fusion or anterior decompression via a posterior approach and fusion[14]. However, they reported posterior decompression and fusion was the most common procedure because this technique is less technically demanding, is associated with a lower risk of neurological complications and requires less intensive patient care after surgery [14]. We have been performing indirect spinal cord decompression combined laminectomy and dekyphosis using instruments via a posterior approach [10]. This surgical procedure not only stabilizes the thoracic spine, but also facilitates indirect decompression to the vulnerable spinal cord by dekyphosis of the thoracic. Furthermore, we reported The OPLL morphology, as seen on sagittal CT images, was discontinuous across the disk space between the rostral and the caudal ossification regions. Postoperatively, this discontinuity disappeared with the connection of the OPLL segments in all patients without further thickening of the OPLL[15]. Micromotion may lead to OPLL progression even within the essentially immobile thoracic spine segments. In contrast, the connection may provide the efficient spinal cord recovery.

Alberto Ponte has been advocating a posterior-only procedure consisting of posterior column shortening via multiple, wide, segmental osteotomies and posterior compression instrumentation and fusion [8,9]. The Ponte procedure with segmental posterior shortening osteotomies and segmental pedicle screw fixation provides good correction of the deformity in Scheuermann kyphosis [16]. We have corrected the kyphosis seen with thoracic OPLL using only the cantilever technique. However, this technique puts a significant load on the pedicle screws. Therefore, we incorporated the Ponte procedure to correct the kyphosis without causing significant screw loads. As a result, correction angle on radiograph with this procedure averaged 14°, whereas past surgical methods without the Ponte procedure averaged 7° [7].

This correction angle may not be as large as some reports on the Ponte procedure for the deformity [16-18]. However, the mean angle of the fusion level was 35° preoperatively, and the main purpose of this surgery was indirect decompression to the vulnerable spinal cord by correcting the thoracic kyphosis. The difference between the Ponte procedure when used for thoracic OPLL and when used for deformity is the levels receiving osteotomies. Whereas, multiple Ponte osteotomies are usually performed with maximum width at the deformity apex, we performed the osteotomies for thoracic OPLL at the levels adjacent to the OPLL because of the non-mobile segment at the OPLL level. Usually, some OLFs are adjacent to an OPLL level, and Ponte osteotomies are less difficult and less technically demanding after removing the OLF. In addition, no patient had a decrease of amplitude on intraoperative spinal cord monitoring during the Ponte osteotomies, cantilever and compression procedures.

70% in the present study acquired the floating (+) on intraoperative ultrasonography, on the other hand 60% in our past study [7]. The recovery rate tended to be higher among patients in the floating (+) group than among those in the floating (-) group as determined on intraoperative ultrasonography. Although there may not be satisfactory outcomes in all cases using the Ponte procedure for indirect posterior decompression and corrective fusion, it seems to be a more effective method for dekyphosis and achieving indirect spinal cord decompression. 30% in the present study who could not acquire the floating (+) on intraoperative ultrasonography and good recovery rate may be performed the removal of OPLL.

In conclusion, we performed the Ponte procedure to achieve indirect posterior decompression and fusion for thoracic OPLL. 'The Ponte procedure for indirect spinal cord decompression' is a novel concept used for the first time with thoracic OPLL in our study, and we consider it a useful method to achieve more effectively dekyphosis and indirect spinal cord decompression if there is not the spinal cord free from OPLL on intraoperative ultrasonography after only laminectomies. We believe that a comparative study of surgical outcomes between the groups treated by posterior decompression and fusion with and without Ponte osteotomies is needed to clarify the efficacy of Ponte osteotomies in the surgical treatment of OPLL.

1. Tomita K, Kawahara N, Baba H, et al. Circumspinal decompression for thoracic myelopathy due to combined ossification of the posterior longitudinal ligament and ligamentum flavum. *Spine (Phila Pa 1976)* 1990;15:1114-20.

2. Tsuzuki N, Hirabayashi S, Abe R, et al. Staged spinal cord decompression through posterior approach for thoracic myelopathy caused by ossification of posterior longitudinal ligament. *Spine (Phila Pa 1976)* 2001;26:1623-30.

3. Yonenobu K, Korkusuz F, Hosono N, et al. Lateral rhachotomy for thoracic spinal lesions. *Spine (Phila Pa 1976)* 1990;15:1121-5.

4. Matsuyama Y, Yoshihara H, Tsuji T, et al. Surgical outcome of ossification of the posterior longitudinal ligament (OPLL) of the thoracic spine: implication of the type of ossification and surgical options. *J Spinal Disord Tech* 2005;18:492-7; discussion 8.

5. Yamazaki M, Koda M, Okawa A, et al. Transient paraparesis after laminectomy for thoracic ossification of the posterior longitudinal ligament and ossification of the ligamentum flavum. *Spinal Cord* 2006;44:130-4.

6. Yamazaki M, Okawa A, Koda M, et al. Transient paraparesis after laminectomy for thoracic myelopathy due to ossification of the posterior longitudinal ligament: a case report. *Spine (Phila Pa 1976)* 2005;30:E343-6.

7. Matsuyama Y, Sakai Y, Katayama Y, et al. Indirect posterior decompression with corrective fusion for ossification of the posterior longitudinal ligament of the thoracic spine: is it possible to predict the surgical results? *Eur Spine J* 2009;18:943-8.

8. Albert P. Posterior column shortening for Scheuermann's kyphosis. *In: Haher TR,*

Merola AA, eds. Surgical Techniques for the Spine. 1st ed. New York: Thieme Verlag 2003:107-13.

9. Ponte Albert VB, Siccardi GL. Surgical Treatment of Scheuermann's Hyperkyphosis. In: Winter RB, ed. Progress in Spinal

Pathology: Kyphosis. *Bologna: Aulo Gaggi* 1984:75-80.

10. Matsuyama Y YH, Tsuji T, Sakai Y, Nakamura H, Katayama Y, Ishiguro N. Surgical treatment for ossification of the posterior longitudinal ligament of the thoracic spine: outcomes of one stage posterior decompression with corrective fusion surgery. *OPLL, 2nd edition Springer, Heidelberg* 2006:259–64.

11. Matsumoto M, Chiba K, Toyama Y, et al. Surgical results and related factors for ossification of posterior longitudinal ligament of the thoracic spine: a multi-institutional retrospective study. *Spine* 2008;33:1034-41.

12. Kawahara N, Tomita K, Murakami H, et al. Circumspinal decompression with dekyphosis stabilization for thoracic myelopathy due to ossification of the posterior longitudinal ligament. *Spine* 2008;33:39-46.

13. Fujimura Y, Nishi Y, Nakamura M, et al. Myelopathy secondary to ossification of the posterior longitudinal ligament of the thoracic spine treated by anterior decompression and bony fusion. *Spinal cord* 1997;35:777-84.

14. Matsumoto M, Toyama Y, Chikuda H, et al. Outcomes of fusion surgery for ossification of the posterior longitudinal ligament of the thoracic spine: a multicenter retrospective survey: clinical article. *Journal of neurosurgery. Spine* 2011;15:380-5.

15. Ando K, Imagama S, Ito Z, et al. Radiologic evaluation after posterior instrumented surgery for thoracic ossification of the posterior longitudinal ligament: union between rostral and caudal ossifications. *Journal of spinal disorders & techniques* 2014;27:181-4.

16. Geck MJ, Macagno A, Ponte A, et al. The Ponte procedure: posterior only treatment of Scheuermann's kyphosis using segmental posterior shortening and pedicle screw instrumentation. *Journal of spinal disorders & techniques* 2007;20:586-93.

17. Halanski MA, Cassidy JA. Do multilevel Ponte osteotomies in thoracic idiopathic scoliosis surgery improve curve correction and restore thoracic kyphosis? *Journal of spinal disorders & techniques* 2013;26:252-5.

18. Grevitt M, Kamath V, Avadhani A, et al. Correction of thoracic kyphosis with Ponte osteotomy. *Eur Spine J* 2010;19:351-2.

Figure Legends

Figure 1. **a.** CT shows continuous-type OPLL at the T1-3 and T4-10 regions and OLF at the T3/4 and T10/11/12 regions. **b.** MR images show severe canal stenosis at several OPLL and OLF locations. **c.** Postoperative CT shows the kyphotic angle of T1-12 was corrected from 48° to 37° after surgery. **d.** CT shows Ponte osteotomies at T10/11/12.

Figure 2. **a.** Intraoperative ultrasonography revealed spinal cord compression from the OPLL anteriorly after laminectomy of T1–T11. **b.** Spinal cord compression has decreased.

Table 1. Clinical and Demographic Results

Table 2. Intraoperative ultrasonography Findings