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Postoperative recovery course, but not preoperative factors and operative kyphosis correction can predict final neurological outcome of posterior decompression with instrumented surgery for ossification of the posterior longitudinal ligament of the thoracic spine

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Introduction

Ossification of the posterior longitudinal ligament of the thoracic spine (T-OPLL) is relatively rare and possibly causes severe myelopathy. T-OPLL is often difficult to treat because of anatomical features of the thoracic spine, kyphosis, and nearby vital organs. Thoracic kyphosis makes it difficult to obtain sufficient spinal cord decompression using a posterior approach widely performed for cervical and lumbar spine. On the other hand, nearby vital organs including heart, lung, and aorta are major obstacles to an anterior approach [1]. Addition of instrumented fusion to posterior decompression (posterior decompression with instrumented fusion: PDF) can improve surgical outcome for T-OPLL via a posterior approach [2][3][4][5]. PDF is a popular surgical procedure for T-OPLL in Japan because its surgical approach is familiar to most spinal surgeons and there is no need for specific surgical techniques. However, a substantial number of T-OPLL patients have an unfavorable outcome even after PDF surgery is successfully performed. There is the possibility that direct decompression by excision of the ossification foci is mandatory in a substantial number of T-OPLL patients in whom T-OPLL could not be used with indirect decompression by PDF surgery alone. To date, there is no established preoperative predictive factor for surgical outcome of PDF for T-OPLL.

The aim of the present study was to elucidate the factors having a significant impact on poor surgical outcome after PDF for T-OPLL.

Methods

The present study included 38 patients (25 male and 13 female) who underwent PDF surgery for T-OPLL in our institute and were followed-up for at least 1 year (Table 1).

The surgical procedure was as follows. The patients underwent laminectomy at the OPLL levels followed by posterior instrumented fusion with a pedicle screw and rod system. The fused segments were two or three levels above and below the levels of the laminectomy. Posterolateral autologous bone grafting was performed using local bone including resected spinous processes and laminae. We apply posterior fusion in situ with the patient in a prone position instead of intraoperative correction of the spinal alignment by instrumentation. The present series included an initial 5 patients who underwent PDF surgery using a hook and rod system.

Clinical measures included the Japanese Orthopaedic Association (JOA) score for cervical myelopathy (which excluded upper extremity scores) with a possible total of 11 points [6], and the assessment of recovery rate using Hirabayashi's method (recovery rate = [JOA score at follow-up – preoperative JOA score]/[11 – preoperative JOA score] ×100%)[7]. The increment of the JOA score was calculated by the subtraction of postoperative and preoperative JOA scores. The average JOA score increment and recovery rate were assessed.

The morphology of the ossification foci was assessed using computed tomography, and midsagittal, multiplanar, reconstructed (CT-MPR) images were categorized into linear, beaked, continuous waveform, continuous cylindrical, or mixed types according to the classification established by The Research Group for Ossification of the Spinal Ligament sponsored by the Japanese Ministry of Health and Welfare in 1993 [8]. In addition, we added the circumscribed type, which was identified when ossification was localized at the level of the disc without continuation between vertebrae [9]. Maximum compression level was determined using CT and magnetic resonance imaging (MRI), and patients were divided into an upper thoracic (T1–4) group and a middle/lower thoracic (T5–12) group based on a previous report that described how an upper thoracic OPLL resulted in a better recovery than a middle/lower thoracic OPLL [10]. Maximum occupation ratio was calculated as a division of thickness of OPLL by antero-posterior diameter of spinal canal at maximum compression level in CT axial image. Kyphotic angles in fused thoracic spinal segments were measured preoperatively on lateral radiographs obtained with the patients in a standing position (if the patients could not stand up, a lateral X-ray with the patient in a sitting position was obtained instead of in a standing position) using the Cobb method; preoperative CT sagittal reconstruction obtained in supine position was used to evaluate alignment in a supine position; and CT sagittal reconstruction images were obtained with the patient in a supine position approximately 1 week after surgery. Pre- and postoperative CT sagittal reconstructions served for kyphotic angle measurement with the patient in a supine position because lateral X-rays obtained in a supine position were often difficult to interpret. Kyphosis correction angle was calculated by subtracting the postoperative kyphosis angles from preoperative kyphosis angles.

To elucidate the independent factors that have a significant impact on poor surgical outcome, statistical analyses were conducted as follows. (1) Patients belonging to the lowest one-third of all patients according to the rank order of the recovery rate of JOA score were considered to have a poor outcome. (2) Correlation between a poor outcome and all the preoperative factors including patient factors (age, sex, and preoperative JOA score) and imaging assessments described above (type of OPLL, kyphosis angle, difference of preoperative kyphosis angle between a standing or sitting position and CT obtained with the patient in a supine position (Δkyphosis angle), maximum OPLL occupation ratio) was analyzed with univariate analysis. Surgical factors including kyphosis correction angle were also analyzed with univariate analysis. Next, we compared the recovery course over time after surgery between patients with poor and satisfactory outcomes using a Student *t* test. Values are expressed as mean ± SD and differences with $p < 0.05$ were considered significant. All the statistical analyses were conducted using JMP (version 10.0.2; SAS Institute, Cary, NC, USA).

Results

The average preoperative JOA score was 3.6 points (range 1–6.5) and the average postoperative JOA score was 7.5 points (range 5–10). As a result, the average increase in JOA score was 3.7 (range 0.5–8.5) and the average recovery rate of JOA score was 48.7 ± 22.7% (Table 1). Postoperative JOA score gradually recovered with time and reached a peak recovery 9 months after surgery. Results of imaging analyses were shown in Table 2. As for spinal alignment, average kyphosis angle within the fused segment was 28.0 ± 10.9° in a standing/sitting position preoperatively, 24.1 ± 10.7° on CT with sagittal reconstruction obtained in a supine position preoperatively, 29.7 ± 9.0° in postoperative CT sagittal reconstruction, resulting in a kyphosis correction angle of –1.7 ± 9.0°. The average kyphosis angle was 28.0 ± 10.9° (range 10.1–43°) before surgery, 29.7 ± 9.0° (range 18–40°) immediately after surgery, and 32 ± 10.7° (range 28–57°) at the final follow-up visit (Table 2). The kyphosis angle at the final follow-up was smaller than it was in the preoperative radiographs with the patient sitting or standing. Follow-up sagittal CT reconstructed images revealed there had been no apparent progression of OPLLs after surgery.

The statistical analyses indicated there is no apparent independent preoperative factor that has an impact on poor surgical outcome. Neither surgical factors including kyphosis correction angle and level of decompression and fusion, nor preoperative factor had a significant impact on poor surgical outcome. Comparison between patients with poor outcome and those with satisfactory outcome revealed that the average acquired JOA score at 3 months after surgery in patients with satisfactory outcome was 2.9 ± 0.7 and was 0.7 ± 1.3 in patients with poor outcome, and therefore significantly lower in the patients with poor outcome than in those with satisfactory outcome ($p = 0.03$). In other words, patients who show more than 2 points recovery of JOA score during the first 3 months after surgery showed satisfactory final surgical outcome, whereas patients with poor surgical outcome showed less than 1 point recovery during the first 3 months after surgery.

Discussion

The principal findings of the present study were as follows. (1) No predictive preoperative or surgical factors could be determined for surgical outcome in the present study. (2) Acquired JOA score at 3 months after surgery was significantly lower in patients with a poor outcome than in those with a favorable outcome.

In the present study, we could not find factors that have a significant negative impact on surgical outcome of PDF for T-OPLL; consequently it is impossible to determine the appropriate surgical indication for direct anterior decompression instead of PDF surgery alone. Several previous reports described the possible predictive preoperative and intraoperative factors for good neurological recovery after PDF surgery for T-OPLL [10][11]. The discrepancy between the present result and the previous ones might be attributed to the difference of surgical procedures and factors analyzed and, etc.

According to the present result, PDF surgery is thought to be the first choice for all types of T-OPLL patients at present, followed by anterior decompression if the patient shows insufficient recovery after PDF surgery. Several previous reports have revealed that neurological recovery after PDF surgery for T-OPLL is slow. Peak recovery times from this surgery are reported as approximately 9 months after surgery, resulting in a long waiting period to determine whether insufficient neurological recovery warrants additional anterior decompression. According to the present results, the waiting period to determine insufficient neurological recovery might be shortened to 3 months after the PDF surgery. Specifically, if a patient undergoes PDF surgery for T-OPLL and the acquired JOA score is less than one point during 3 months after surgery, additional anterior decompression should be considered because patients in such a category have an unfavorable final outcome. Although the prediction of final outcome at an earlier time point after surgery is ideal, we could not establish an earlier checkpoint because there is no precise data to predict the course of recovery less than 3 months after PDF surgery. Precise neurological evaluations need to be performed early after surgery to clarify this issue.

The present series showed that the postoperative kyphosis angle was not reduced to preoperative supine alignment, but was almost the same as that with the patient in a preoperative standing or sitting position. Because there is no correlation between neurological recovery and postoperative kyphosis correction, the need for intraoperative kyphosis correction is doubtful. Several investigators have claimed that intraoperative kyphosis correction is needed to obtain better decompression and to improve neurological outcome [11][12][13][14][15]. To date, we apply fusion in situ with the patient in a prone position instead of intraoperative kyphosis correction. Further exploration is needed to elucidate the impact of intraoperative kyphosis correction on surgical outcome of PDF for T-OPLL.

Conclusions

There is currently no preoperative factor for prediction of neurological outcome. Moreover, postoperative change of kyphosis had no significant impact on the neurological outcome. Thus, PDF surgery without intraoperative kyphosis correction is the first choice for T-OPLL. If a patient undergoes PDF surgery for T-OPLL and the consequent acquired JOA score is less than one point during 3 months after surgery, additional anterior decompression should be considered because patients in such a category have an unfavorable final outcome.

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Figure Legends

Figure: Neurological recovery course in patients with poor and satisfactory outcomes.

(A) Pre- and post-operative JOA score in both groups. (B) Postoperative acquired JOA score in both groups. We compared the recovery course over time after surgery between patients with poor and satisfactory outcomes using a Student *t* test. Values are expressed as mean ± SD. *: $p < 0.05$, **: $p<0.01$.

Table 1: Patient demographics

Table 2: Imaging analyses
This table shows preoperative imaging findings and surgical correction of kyphosis.

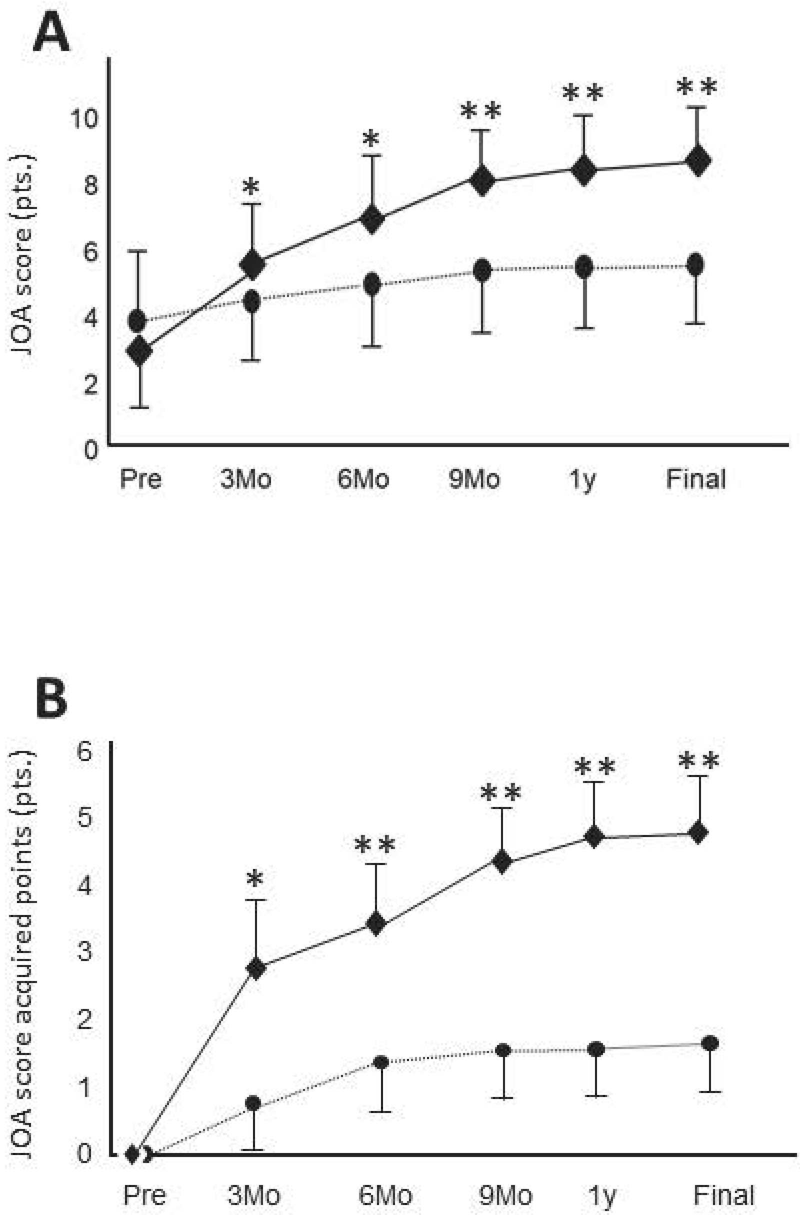
Table 3: Statistical analyses
Correlation between a poor outcome and all the preoperative factors including patient factors and imaging assessments and surgical factors including kyphosis correction angle were analyzed with univariate analysis. There was no apparent independent preoperative factor that has an impact on poor surgical outcome.

	All patients (n=38)
Age at surgery (y.o.)	52.9 (32-74)
Sex (male: female)	25: 13
Follow-up period (Mo)	95.9 (12-302)
No. of levels fused	9.1 (6-12)
JOA score	
Pre-op. (pts.)	3.6 (1-6.5)
Post-op. (pts.)	7.5 (5-10)
Recovery rate (%)	48.7 ± 22.7

Imaging analyses

Types of OPLL (No. of patients)	
Beaked	6
Continuous waveform	22
Continuous cylindrical	4
Circumscribed	6
Maximum compression level (No. of patients)	
Upper thoracic (T1-4)	6
Middle-lower thoracic (T5-12)	32
Maximum occupation ratio (%)	52.4 ± 15.0
kyphosis angle (degree)	
Pre-Op.	
Sitting/standing	28.0 ± 10.9
CT	24.1 ± 10.7
post-Op.	29.7 ± 9.0
final follow-up	32 ± 10.7

Univariate analysis	*p*-value (*: $p<0.05$)
Patient factors	
age	0.25
sex	0.45
pre-Op. JOA score	0.11
Imaging factors	
type of OPLL	0.23
kyphosis angle	0.88
Δkyphosis angle	0.55
maximum occupation ratio	0.12
Surgical factor	
kyphosis correction	0.64


A
JOA score (pts.)
0
2
4
6
8
10
Pre
3Mo
6Mo
9Mo
1y
Final
B
JOA score acquired points (pts.)
0
1
2
3
4
5
6
Pre
3Mo
6Mo
9Mo
1y
Final