

# Therapeutic Impact of Percutaneous Pedicle Screw Fixation on Palliative Surgery for Metastatic Spine Tumors

## Abstract

**Background:** Percutaneous pedicle screw (PPS) fixation has been introduced into palliative surgery for metastatic spine tumors; however, the therapeutic effects of PPS on the outcomes of multidisciplinary treatment for such tumors are unclear. Therefore, the therapeutic impact of PPS was investigated among patients with metastatic spine tumors and with revised Tokuhashi scores of  $\leq 8$ . **Materials and Methods:** A total of 47 patients who underwent conventional palliative surgery (posterior decompression and stabilization, 33; posterior stabilization alone, 14) before the introduction of PPS and 38 patients who underwent PPS (posterior decompression and stabilization, 19; posterior stabilization alone, 19) were included. Surgical stress (operative time, blood loss, complications, etc.) and treatment outcomes (postoperative survival time, visual analog scale scores, Frankel classification, and the Barthel index at the final followup) were compared between the conventional and PPS groups. **Results:** The age of the indicated patients significantly increased after the introduction of PPS ( $P < 0.05$ ). Regarding posterior decompression and stabilization, there were no significant intergroup differences in surgical stress or treatment outcomes. As for posterior stabilization alone, there were significant preoperative differences in various parameters between the conventional and PPS groups ( $P < 0.01$ ) and also significant postoperative intergroup differences between surgical stress and treatment outcomes ( $P < 0.01$ ). **Conclusions:** For patients with early-stage metastatic spine tumors, the use of PPS-based posterior stabilization combined with multidisciplinary adjuvant therapy has changed the age range of the patients indicated for surgery and caused significant improvements in surgical stress, postoperative survival time, and Barthel index.

**Keywords:** Metastatic spine tumor; outcome, palliative surgery, percutaneous pedicle screw fixation, survival time

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## Introduction

Patients with metastatic spine tumors often experience severe pain due to spinal instability, and the associated spinal cord compression can also cause paralysis. The incidence of metastatic tumor-induced spinal cord compression is not low, i.e., it occurs in 5%–14% of all cancer patients.<sup>1,2</sup> It has been reported that recovery from complete spinal cord paralysis is difficult to achieve, and so, metastatic tumor-induced spinal cord paralysis should be treated as quickly as possible before it becomes severe.<sup>3-5</sup> Patchell *et al.*<sup>2</sup> and Cole and Patchell<sup>6</sup> reported that direct decompressive surgery is more effective at ameliorating such paralysis than radiotherapy. In addition, spinal stabilization to treat

instability or spinal cord compression by an epidural tumor helps to reduce pain and improves patients' quality of life.<sup>7-12</sup> Therefore, stabilization surgery with or without direct decompression plays a very important role in palliative treatment for spine tumors.

Percutaneous pedicle screw (PPS) fixation is a surgical procedure in which pedicle screws are percutaneously inserted into multiple vertebrae and fixed between rods through the subcutaneous paravertebral muscle. PPS fixation has been reported to be effective and to involve reduced levels of surgical stress.<sup>13-16</sup> In addition, PPS results in superior wound healing than conventional posterior stabilization, and the incidence of postoperative infections is low after PPS. Another benefit of PPS is that patients can start radiotherapy and chemotherapy early.<sup>17</sup> Therefore, PPS is a

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suitable surgical procedure for achieving palliative spinal stabilization with or without decompression.<sup>18</sup>

Recently, PPS has been increasingly used as a palliative procedure for metastatic spine tumors. However, as significant bleeding sometimes occurs when decompression is combined with PPS, there is a question about whether PPS cause less surgical stress than conventional stabilization with decompression.<sup>18</sup> Further, it is unclear whether the ability to start adjuvant therapy early due to the reduction in surgical stress associated with the procedure represents a treatment outcome. In other words, the effects of introduction of PPS on the outcomes of palliative surgery for metastatic spine tumors are still unclear. Thus, we investigated the therapeutic impact of PPS on palliative surgery for metastatic spine tumors.

## Materials and Methods

### Subjects

The subjects were patients with metastatic spine tumors and with revised Tokuhashi scores [Table 1] of  $\leq 8$ <sup>19</sup> who were indicated for palliative surgery and had predicted life expectancies of  $\leq 6$  months. As the participants were limited to patients with revised Tokuhashi scores of  $\leq 8$ ,<sup>19</sup> the severity of the disease was similar in each case.

They included 47 patients who were treated with the conventional procedure before the introduction of PPS (from 2007 to 2012; the conventional group) and 38 PPS-treated patients (from 2012 to 2017; the PPS group). In the palliative surgery, a combination of posterior decompression and posterior stabilization was performed although some patients were treated with posterior stabilization alone. As for the implants employed, the XIA<sup>®</sup> and DIAPASON<sup>®</sup> (Stryker Co., Kalamazoo, USA) were used in the conventional procedure, whereas the MANTIS<sup>®</sup> and ES2<sup>®</sup> (Stryker Co., Kalamazoo, USA) were used for the PPS.

Patients with tumor-induced paralysis and spinal cord compression were indicated for posterior decompression and stabilization, which was considered to be the first-choice procedure, providing circumstances permitted it. Patients with no or slight paralysis whose spinal support needed to be reconstructed or maintained were indicated for posterior stabilization alone. Sometimes, the latter procedure was indicated when decompression of the spinal cord could not be conducted due to the circumstances of the case, such as the patient's general condition. Adjuvant therapy (chemotherapy before or after surgery or local radiotherapy after surgery) and bone-modifying agents were administered without restriction based on the patients' wishes.

The study protocol was approved by our institutional ethics committee (approval number: RK-11209-8). Informed consent was obtained from all patients.

**Table 1: Revised Tokuhashi score**

Predictive factor	Score (points)
General condition	
Poor (KPS 10%-40%)	0
Moderate (KPS 50%-70%)	1
Good (KPS 80%-100%)	2
Number of extraspinal bone metastases foci	
$\geq 3$	0
1-2	1
0	2
Number of metastases in the vertebral body	
$\geq 3$	0
2	1
1	2
Metastases to the major internal organs	
Unremovable	0
Removable	1
No metastases	2
Primary site of the cancer	
Lung, osteosarcoma, stomach, bladder, esophagus, pancreas	0
Liver, gallbladder, unidentified	1
Others	2
Kidney, uterus	3
Rectum	4
Thyroid, prostate, breast, carcinoid tumor	5
Spinal cord palsy	
Complete (Frankel A, B)	0
Incomplete (Frankel C, D)	1
None (Frankel E)	2
<b>Total points</b>	<b>Predicted prognosis</b>
0-8	<6 months
9-11	$\geq 6$ months
12-15	$\geq 1$ year

KPS indicates Karnofsky's performance status. The expected survival period was <6 months when the total score was 0-8, 6 months or longer when the total score was 9-11, and 1 year or longer when the total score was 12 or higher

### Epidural spinal cord compression scale

The epidural spinal cord compression (ESCC) scale<sup>20</sup> consists of six grades: grade 0, bone involvement alone; Grade 1, epidural impingement; Grade 2, the retention of cerebrospinal fluid (CSF) is visible despite spinal cord compression; and Grade 3, CSF is not visible due to marked spinal cord compression. Grade 1 is classified into three subgroups: grade 1a, epidural impingement without deformation of the thecal sac; Grade 1b, compression of the thecal sac without spinal cord abutment; and Grade 1c, deformation of the thecal sac with spinal cord abutment in the absence of spinal cord compression.

### Preoperative background

The patients' background data are presented according to the procedure performed in Tables 1 and 2. Among the patients who underwent posterior decompression and

**Table 2: Background of the 52 patients with posterior decompression and stabilization**

	Conventional group (n=33)	PPS group (n=19)	P
Sex (male:female)	24:9	15:4	0.6227
Age (years), mean	59.6±13.8	66.3±9.20	0.0412*
Primary site of the cancer, n (%)			
Lung	14 (42.4)	5 (26.3)	0.3061
Liver	2 (6.1)	5 (26.3)	
Stomach	1 (3.0)	2 (10.5)	
Kidney	3 (9.1)	0	
Breast	2 (6.1)	1 (5.3)	
Osteosarcoma	1 (3.0)	0	
Pancreas	1 (3.0)	0	
Colon	1 (3.0)	1 (5.3)	
Thyroid	0	1 (5.3)	
Unknown	2 (6.1)	0	
Others	6 (18.2)	4 (21.1)	
Affected lesion, n (%)			
Thoracic	29 (87.9)	12 (63.2)	0.1565
Lumbosacral	4 (12.1)	6 (31.6)	
Revised Tokuhashi score, mean	5.9±1.6	5.0±2.3	0.1516
Preoperative VAS, mean (range)	79.5±8.3 (38-100)	76.5±10.2 (29-100)	0.5021
Preoperative ESCC scale, n (%)			
1a	1 (3.0)	1 (5.2)	0.061
1b	2 (6.1)	0	
1c	5 (15.2)	0	
2	13 (39.4)	7 (36.8)	
3	12 (36.4)	11 (57.9)	
Preoperative Frankel classification, n (%)			
A	1 (3.0)	0	0.1176
B	6 (18.2)	1 (5.2)	
C	18 (54.5)	11 (57.9)	
D	5 (15.2)	3 (15.8)	
E	3 (9.1)	4 (21.1)	
Preoperative Barthel index, mean (range)	47.7±27.6 (5-85)	49.9±22.9 (20-90)	0.7556
Adjuvant therapy, n (%)			
Chemotherapy	12 (36.4)	11 (57.9)	0.233462
Radiation therapy	15 (45.5)	4 (21.1)	
Only care	11 (33.3)	6 (31.6)	
Bone modifying agent, n (%)	22 (66.7)	19 (100)	

\*Significant differences. Conventional group indicates conventional procedure, PPS group, PPS was applied, VAS=Visual analog scale, ESCC=Epidural spinal cord compression, PPS=Percutaneous pedicle screw

stabilization, there was no significant intergroup difference in the sex ratio, but the age of the patients who were indicated for surgery was significantly higher in the PPS group ( $P = 0.0412$ ). No significant difference in the type of primary cancer, affected level (symptomatic level), revised Tokuhashi score [Table 1],<sup>19,21</sup> visual analog scale (VAS) pain score,<sup>22-24</sup> ESCC scale,<sup>20</sup> Frankel classification,<sup>25</sup> Barthel index,<sup>26</sup> or frequency of adjuvant therapy was noted between the conventional and PPS groups [Table 2].

On the other hand, among the patients who underwent posterior stabilization alone, there were significant differences in age, VAS pain score, ESCC scale, Frankel classification, Barthel index, and frequency of adjuvant

therapy between the conventional and PPS groups [Table 3].

### Outcome assessment

The surgical stress associated with and treatment outcomes of (1) posterior decompression and stabilization and (2) posterior stabilization alone were investigated in the conventional and PPS groups. The numbers of immobilized and decompressed intervertebral segments, operative time, and amount of intraoperative blood loss were investigated as surgical stress parameters. As for treatment outcomes, the postoperative survival time, VAS pain score, severity of paralysis (Frankel classification), and rate of improvement in the Barthel index (as an index of the subjects' ability

**Table 3: Background of the 33 patients with posterior stabilization**

	Conventional group (n=14)	PPS group (n=19)	P
Sex (male:female)	8:6	14:5	0.3377
Age (years), mean	55.3±14.7	69.1±9.3	0.0055*
Primary site of the cancer, n (%)			
Lung	2 (14.3)	9 (47.4)	0.1037
Liver	1 (7.1)	4 (21.1)	
Stomach	0	1 (5.3)	
Kidney	0	0	
Breast	3 (21.4)	1 (5.3)	
Osteosarcoma	1 (7.1)	1 (5.3)	
Pancreas	0	1 (5.3)	
Colon	1 (7.1)	1 (5.3)	
Thyroid	0	1 (5.3)	
Unknown	4 (28.6)	0	
Others	2 (14.3)	0	
Affected lesion, n (%)			
Thoracic	9 (64.3)	7 (36.8)	0.1190
Lumbosacral	5 (35.7)	12 (63.2)	
Revised Tokuhashi score, mean	4.9±2.2	5.7±1.7	0.3299
Preoperative VAS, mean (range)	76.5±9.9 (30-100)	79.4±8.4 (39-100)	0.4982
Preoperative ESCC scale, n (%)			
1a	0	5 (26.3)	<0.001*
1b	1 (7.1)	4 (21.1)	
1c	2 (14.3)	4 (21.1)	
2	3 (21.4)	4 (21.1)	
3	8 (57.1)	2 (10.5)	
Preoperative Frankel classification, n (%)			
A	1 (3.0)	0	<0.001*
B	4 (18.2)	0	
C	6 (54.5)	1 (5.3)	
D	1 (15.2)	9 (47.4)	
E	2 (9.1)	9 (47.4)	
Preoperative Barthel index, mean (range)	37.1±17.8 (15-60)	65.8±19.9 (10-100)	0.0028*
Adjuvant therapy, n (%)			
Chemotherapy	4 (18.2)	10 (52.6)	0.0027*
Radiation therapy	5 (35.7)	9 (47.4)	
Only care	4 (18.2)	0	
Bone modifying agent, n (%)	2 (14.3)	19 (100)	

\*Significant differences. Conventional group indicates conventional procedure, PPS group, PPS was applied, VAS=Visual analog scale, ESCC=Epidural spinal cord compression, PPS=Percutaneous pedicle screw

to perform activities of daily living [ADL]) at the final postoperative followup (the Barthel index was evaluated at regular intervals until death) were assessed.

**Ethics**

Institutional review board approval was obtained from Nihon University Itabashi Hospital (RK-11209-8).

**Statistical analysis**

For comparisons between pairs of items or groups, the *t*-test, Welch’s method, paired *t*-test, or Mann–Whitney U-test was used. Survival rates were calculated using the Kaplan–Meier method and analyzed using the log-rank

test. Statistical analyses were performed using StatMate V® (Atoms Co.; Tokyo, Japan), and *P* < 0.05 was regarded as statistically significant.

**Results**

**Posterior decompression and stabilization**

*Surgical stress*

The number of instrumented and decompressed segments did not differ significantly between the conventional and PPS groups. In addition, there were no significant differences in the operating time, amount of intraoperative blood loss, transfusion use, or frequency of perioperative

complications between the conventional and PPS groups ( $P > 0.05$ ) [Table 4].

**Treatment outcomes**

The mean postoperative survival time did not differ significantly between the conventional and PPS groups ( $P = 0.9568$ ) [Table 3], and no significant intergroup difference in the survival rate was noted ( $P = 0.4242$ , log-rank test) [Figure 1].

Pain was evaluated using a VAS. Significant improvements in the subjects' pain scores were noted after surgery ( $P < 0.001$  in both groups). No significant intergroup difference in the pain score was detected at the final postoperative followup (pain was evaluated at regular intervals until death) ( $P = 0.6234$ ) [Table 4].

The severity of paralysis was assessed using the Frankel classification. The postoperative severity of paralysis did not differ significantly between the two groups, as was found before surgery ( $P = 0.0610$ ) [Table 4].

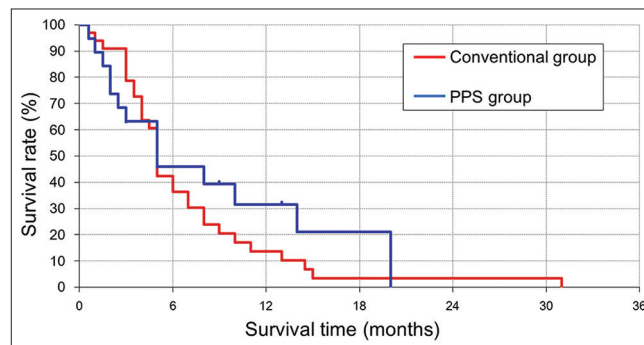
The subjects' ability to perform ADL was examined using the Barthel index. It was significantly improved after surgery in both groups ( $P < 0.001$ ), and no significant intergroup difference in the final Barthel index was noted ( $P = 0.7519$ ) [Table 4].

In total, 36.4% and 31.6% of the patients were discharged home after surgery in the conventional group and PPS group, respectively ( $P = 0.5300$ ) [Table 4].

**Posterior stabilization alone**

**Surgical stress**

The number of instrumented and decompressed segments did not differ significantly between the conventional and PPS groups. The operating time was significantly longer in the PPS group than in the conventional group ( $P < 0.001$ ). On the other hand, although transfusion use did not differ significantly between the groups, significantly less intraoperative blood loss occurred in the PPS group than in the conventional group ( $P < 0.001$ ). No significant



**Figure 1:** Survival analyses of patients that underwent posterior decompression and stabilization based on Kaplan–Meier plots. In the log-rank test, no significant difference was noted between the two groups ( $P = 0.4242$ ). Conventional group, the patients treated with the conventional procedure before the introduction of percutaneous pedicle screw fixation (PPS); PPS group, the PPS-treated patients. PPS = Percutaneous pedicle screw fixation

**Table 4: Operative and outcome data comparing among posterior decompression and stabilization**

	Conventional group (n=33)	PPS group (n=19)	P
Instrumented segments, mean (range)	5.5±2.1 (2-12)	6.5±2.1 (4-11)	0.1469
Decompressed segments, mean (range)	2.0±0.8 (1-4)	2.1±1.1 (1-5)	0.8558
Operating time (min)	227.8±51.9	253.7±54.4	0.1159
Blood loss (g)	694.5±926.3	528.7±486.4	0.4481
Transfusion, n (%)	11 (33.3)	2 (10.5)	0.0674
Perioperative complications, n (%)			
Wound infection	2 (6.1)	1 (5.3)	0.6784
Dural tear	2 (6.1)	1 (5.3)	
Neurological complication	2 (6.1)	1 (5.3)	
Lung infection/complications	1 (3.0)	1 (5.3)	
Brain infarct/complications	1 (3.0)	0	
Instrumentation failure/complications	0	0	
Survival time, mean (range), months	6.7±5.6 (0.6-21)	6.8±6.1 (0.6-20)	0.9568
Postoperative VAS, mean (range)	26.3±10.8 (0-52)	23.5±8.5 (0-45)	0.6234
Postoperative Frankel classification, n (%)			
A	5 (15.2)	0	0.0610
B	10 (30.3)	4 (12.1)	
C	4 (12.1)	4 (12.1)	
D	8 (24.2)	4 (27.2)	
E	6 (18.2)	7 (48.4)	
Postoperative Barthel index, mean (range)	67.6±27.7 (10-100)	64.7±31.9 (15-100)	0.7519
Discharge to home, n (%)	12 (36.4)	6 (31.6)	0.5300

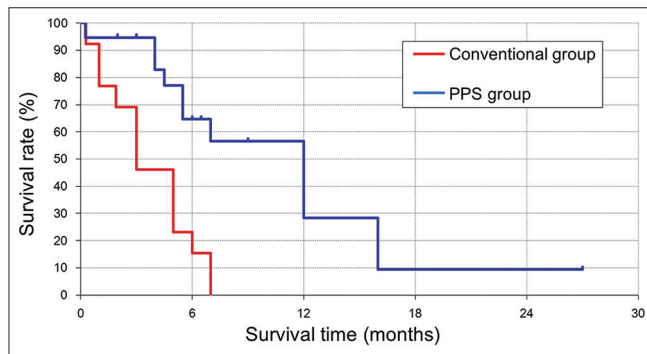
\*Significant differences. Conventional group indicates conventional procedure, PPS group, PPS was applied, VAS=Visual analog scale, PPS=Percutaneous pedicle screw

difference was noted in the incidence or type of surgical complications ( $P = 0.2964$ ) [Table 5].

**Treatment outcomes**

Although the preoperative revised Tokuhashi score did not differ significantly between the groups, the mean postoperative survival time was longer in the PPS group than in the conventional group ( $P < 0.001$ ) [Table 5]. The survival rates of the two groups also differed significantly ( $P = 0.00178$ , log-rank test) [Figure 2].

Significant improvements in the pain score were seen in both groups after surgery ( $P < 0.001$  in both groups).



**Figure 2: Survival analyses of patients that underwent posterior stabilization alone based on Kaplan–Meier plots. In the log-rank test, a significant difference was noted between the two groups ( $P = 0.00178$ ). Conventional group, the patients treated with the conventional procedure before the introduction of PPS; PPS group, the PPS-treated patients. PPS = Percutaneous pedicle screw fixation**

No significant intergroup difference was noted in the pain score at the final postoperative followup (the subjects’ pain scores were measured at regular intervals until death) ( $P = 0.5632$ ) [Table 5].

It was difficult to compare the degree of improvement in paralysis between the groups because the state of paralysis and the ESCC scale differed significantly between the groups before surgery ( $P < 0.001$ ) [Table 3]. The postoperative severity of paralysis differed significantly between the two groups as was found before surgery ( $P < 0.001$ ) [Table 5].

It was also difficult to compare the degree of improvement in the Barthel index between the two groups because the preoperative Barthel indices of the two groups differed significantly ( $P = 0.0028$ ) [Table 3]. The Barthel index improved significantly after surgery in both groups (conventional group:  $P = 0.0228$ , PPS group:  $P < 0.001$ ). The Barthel index of the PPS group at the final postoperative followup (it was evaluated at regular intervals until death) was  $82.4 \pm 26.8$ , which was significantly different from that of the conventional group ( $P = 0.0070$ ) [Table 5 and Figure 3].

In total, 28.6% and 68.4% of patients were discharged home after surgery in the conventional group and PPS group, respectively ( $P = 0.0717$ ) [Table 5].

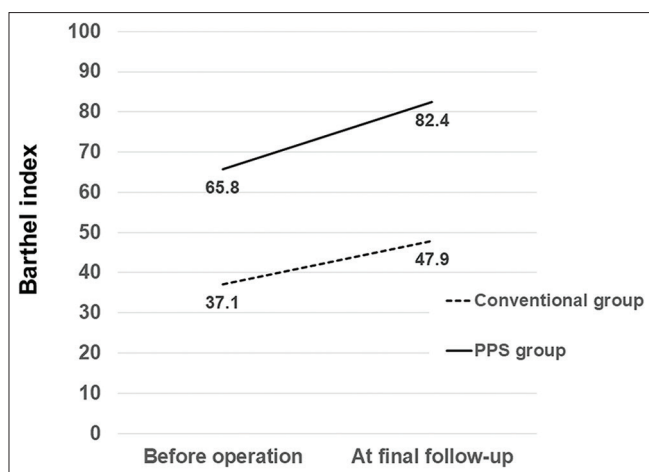
**Discussion**

The use of PPS-based posterior stabilization alone combined with multidisciplinary adjuvant therapy to treat

**Table 5: Operative and outcome data comparing among posterior stabilization**

	Conventional group (n=14)	PPS group (n=19)	P
Instrumented segments, mean (range)	5.1±1.7 (2-12)	6.1±3.1 (4-11)	0.1482
Operating time (min)	133.6±11.1	194.3±64.5	<0.001*
Blood loss (g)	372.4±127.1	125.2±152.6	<0.001*
Transfusion, n (%)	1 (7.1)	0	0.2368
Perioperative complications, n (%)			
Wound infection	0	1 (5.3)	0.2964
Dural tear	0	0	
Neurological complication	0	0	
Lung infection/complications	0	0	
Brain infarct/complications	0	0	
Instrumentation failure/complications	0	2 (10.5)	
Survival periods, mean (range), months	3.7±2.3 (0.3-7)	8.3±6.4 (0.3-27)	<0.001*
Postoperative VAS, mean (range)	23.8±10.7 (0-44)	26.5±9.5 (0-49)	0.5632
Postoperative Frankel classification, n (%)			
A	2 (14.3)	0	<0.001*
B	6 (42.9)	0	
C	3 (21.4)	1 (5.3)	
D	0	7 (36.8)	
E	3 (21.4)	11 (57.9)	
Postoperative Barthel index, mean (range)	47.9±25.3 (15-85)	82.4±26.8 (0-100)	0.0070*
Discharge to home, n (%)	4 (28.6)	13 (68.4)	0.0717

\*Significant differences. Conventional group indicates conventional procedure, PPS group, PPS was applied, VAS=Visual analog scale, PPS=Percutaneous pedicle screw



**Figure 3: Change in the Barthel index after posterior stabilization. The Barthel index improved significantly after surgery in both groups ( $P < 0.001$ ). A significant difference in the final Barthel index was noted between the two groups ( $P = 0.0070$ ). PPS = Percutaneous pedicle screw**

patients with early-stage metastatic spine tumors resulted in improvements in the level of surgical stress, age range of the patients indicated for surgery, postoperative survival time, and Barthel index. PPS was initially used during external fixation of the spine by Jeanneret and Magerl in 1982,<sup>27</sup> and Foley *et al.* reported a system for performing percutaneous fixation (from screw insertion to the connection of the rod through a small incision) in 2001.<sup>28</sup> Systems for percutaneously fixing multiple intervertebral segments have since become commercially available and have been used in the clinical setting.

Reductions in intraoperative blood loss and muscle damage can be achieved by performing PPS as it makes it possible to immobilize multiple intervertebral segments without dissecting the paraspinal muscles from the laminae. As for the disadvantages of PPS, it is difficult to carry out sufficient bone grafting via the posterior approach because the zygapophyseal joint cannot be exposed using this procedure, the cervicothoracic junction cannot be readily observed under fluoroscopy, and the resultant spinal cord decompression is likely to be insufficient. Therefore, this minimally invasive procedure, which is capable of immediately stabilizing the spine, is best for patients that are indicated for palliative surgery, who do not require long term spinal stability because of their limited life expectancy. It has been reported that surgical spinal cord decompression and stabilization followed by radiotherapy are effective at aiding recovery from paralysis.<sup>2,29</sup> Furthermore, the risk of wound-related complications is low in PPS-treated cases, and radiotherapy can be initiated early after surgery involving PPS.

Therefore, the advantages of this method exceed its disadvantages for patients with metastatic spine tumors who have limited life expectancies. Maintaining quality of life using minimally invasive surgery has been reported to

be important for patients with short life expectancies.<sup>30,31</sup> However, the effects of the introduction of PPS on the outcomes of such treatment in patients with metastatic spine tumors are still unclear.<sup>17</sup>

In the present study, posterior decompression and stabilization did not result in a significant reduction in surgical stress. Basically, the spinal cord decompression and tumor curettage procedures have not been changed by the introduction of PPS, and this reality must not be ignored when considering surgery for metastatic spine tumors. On the other hand, the introduction of PPS has resulted in a significant expansion of the age range of the patients indicated for palliative surgery for metastatic spine tumors.

Among the patients who underwent posterior stabilization alone in the current study, there were significant preoperative differences in the VAS score, ESCC scale, Frankel classification, Barthel index, and frequency of adjuvant therapy between the conventional and PPS groups [Table 3]. Therefore, it was not possible to perform simple intergroup comparisons. That is to say, among the patients who were treated with posterior stabilization alone, pain, spinal cord compression, paralysis, and disturbances of ADL were significantly less severe in the PPS group than in the conventional group. In addition, the PPS group received more intensive adjuvant treatment than the conventional group. In other words, the patients in the PPS group had significantly earlier stage disease than their counterparts (i.e., patients with the same type of metastatic spine tumor) in the conventional group.

Of course, combining PPS with multidisciplinary adjuvant therapy might have significant beneficial effects on the postoperative survival time and/or the Barthel index. The increase in the survival time after posterior stabilization alone seen in the PPS group was of course due to recent developments in multidisciplinary treatment, and the frequency of the combined use of surgery and radiotherapy and/or chemotherapy (as adjuvant therapy) was significantly higher in the PPS group ( $P = 0.0027$ ). However, the role of surgery in making adjuvant therapy possible is very significant; i.e., PPS surely contributed to the observed increase in the frequency of adjuvant therapy. Rao *et al.* pointed out that PPS might lead to an improvement in prognosis because it allows adjuvant therapy to be used to treat primary and metastatic lesions early after surgery.<sup>32</sup> Kim *et al.* also observed a higher frequency of adjuvant therapy after surgery involving PPS.<sup>33</sup> Fortunately, despite the number of patients being small in the present study, survival after posterior stabilization alone was significantly prolonged in the PPS group.

It was difficult to perform intergroup comparisons of the rates of improvement in paralysis and the Barthel index in the current study because differences in the preoperative severity of paralysis/the Barthel index were

detected between the two groups. However, it is well known that the outcomes of treatment for metastatic spine tumors depend on the grade of paralysis and/or the patient's ability to perform ADL.<sup>34,35</sup> Therefore, from the viewpoint of palliative treatment, it is important to start treatment as early as possible. If possible, it is desirable to ensure that the patient's ability to perform ADL is maintained at a high level and to prevent paralysis. Hence, in the current study, posterior stabilization involving PPS combined with multidisciplinary adjuvant therapy was demonstrated to produce superior functional results in patients with earlier stage metastatic spine tumors.

This study had several limitations. Although the severity of the subjects' systemic conditions was matched using the Tokuhashi score, this was a retrospective study, and the number of patients was small. Furthermore, because the subgroups were treated in different time periods, the types (severity) of symptoms that were indicated for surgery and the modality of the adjuvant treatment varied between them. A randomized controlled study involving a large number of patients might be necessary in the future.

Since the outcomes of palliative surgery for metastatic spine tumors are determined by the type of primary cancer and the era in which the surgery is performed because cancer treatment progresses, e.g., molecule-targeting drugs have recently been developed, careful evaluation of our findings is necessary.

## Conclusions

Performing posterior decompression and stabilization with PPS did not result in a significant reduction in surgical stress, and the outcomes of such surgery were not significantly better than those achieved by conventional posterior decompression and stabilization. However, compared with conventional stabilization alone, combining PPS-based posterior stabilization alone with multidisciplinary adjuvant therapy expanded the age range of the subjects indicated for surgery and had significant beneficial effects on surgical stress, postoperative survival time, and Barthel index in patients with earlier stage metastatic spine tumors.

## Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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## Conflicts of interest

There are no conflicts of interest.

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