New posterior column reconstruction using titanium lamina mesh after total en bloc spondylectomy of spinal tumour

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Abstract

Purpose To investigate the usefulness of titanium lamina mesh for posterior column reconstruction after total en bloc spondylectomy in patients with spinal tumour and evaluate the radiographic outcomes of this method.

Method Eight patients who underwent total en bloc spondylectomy with posterior column reconstruction using titanium lamina mesh and bone graft to treat a spinal tumour were included in this study. The mean age at the time of surgery was 50.6 years (range, 16.5–70.9 years) and the mean follow-up duration was 50.2 months (range, 28.1–68.7 months). The pathological lesions were located from the T2 to L1 vertebrae. There were four patients in each primary and metastatic tumour group. For the posterior column reconstruction, titanium lamina mesh was used and bone graft was applied over the lamina mesh. Radiographic evaluation was used to investigate the displacement of lamina mesh and union of the grafted bone above lamina mesh.

Results At the postoperative six month follow-up, a bony bridge on the titanium mesh between upper and lower adjacent lamina was observed in all cases, except for one with infection. On the last follow-up, there was no collapse or displacement of titanium lamina mesh, and there was no instability or malalignment of the spinal column.

Conclusions Posterior column reconstruction using titanium lamina mesh during total en bloc spondylectomy for spinal tumour was a useful surgical option that provided new lamina reconstruction for stability of spinal column and protection of the neural elements.

Introduction

Many operative methods have been applied to treat primary and metastatic spinal tumours. Among them, total en bloc spondylectomy shows relatively good clinical and radiographic outcomes [1–3]. But, after total en bloc spondylectomy, instability of spinal column and injury of neural elements can occur easily, due to loss of spinal continuity caused by the removal of three columns and exposure of the spinal cord and nerves [4, 5].

In terms of anterior and middle column reconstruction, many studies have reported that the stability can be enhanced by using an autograft, allograft, polymethylmethacrylate (PMMA) and cages. But there have been few reports about posterior column reconstruction to reinforce the stability by maintenance of the posterior structure and provision of the posterior fusion bed to protect the neural structures such as the spinal cord. There are a few reports on using recapping laminoplasty, fibular strut graft and artificial sheets [6–9]. Since the current improved results of spinal tumour treatment have longer survival time than in the past, the reconstruction of the posterior column becomes important in many aspects.

Accordingly, the aim of this study was to identify the outcomes of posterior column reconstruction using titanium lamina mesh after total en bloc spondylectomy for spinal tumour.

Patients and methods

A total of eight primary or metastatic spine tumour patients, who underwent total en bloc spondylectomy with posterior column reconstruction using titanium lamina mesh and bone graft between June 2006 and December 2009 at our institution, were retrospectively studied. In these eight patients,

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four had primary spine tumours and four had metastatic tumours. The four primary tumours were two cases of aneurysmal bone cyst and one case each of multiple myeloma and giant cell tumour. The origins of the metastatic tumour were kidney, lung, prostate and breast. The locations of the pathological vertebrae were thoracic vertebrae (seven cases) and lumbar vertebra (one case). No patients showed metastasis in other vertebrae or internal organs. The study cohort consisted of four men and four women and the mean age was 50.6 years (range, 16.5–70.9 years). The patient's height and weight was recorded and the body mass index was calculated: the average body mass index was 25.7 kg/m² (range, 22.2–39.5 kg/m²). All of the patients were observed for at least two years and the mean follow-up duration was 50.2 months (range, 28.1–68.7 months) (Table 1). Autogenous bone graft was used in the interbody cage and on the titanium lamina mesh. The indications for total en bloc spondylectomy were the onset of neurological deficits, spinal instability and intolerable back pain that could not be relieved by medications or injections.

All patients underwent total en bloc spondylectomy using the posterior approach that was introduced by Tomita [10] in prone position. All operations were performed by a single surgeon. The dissected vertebral bodies were removed at the posterior side and the cylindrical titanium MESH cage (DePuy, Massachusetts, USA), which was filled with bone graft, was then inserted in the space for reconstruction of the anterior and middle columns. We measured the interlaminar space length and width of the resected vertebra level and then we cut the unfolded one millimetre thick, titanium mesh to the measured size. The suitable sized titanium mesh was anchored between upper and lower vertebral lamina, and the bone graft was placed on it (Fig. 1). After surgery, a thoracolumbosacral orthosis was worn for eight weeks.

Table 1 Demographic data

Age	50.6 years (range, 16.5–70.9 years)
Gender	M:F=4:4
Follow-up duration	50.2 months (range, 28.1–68.7 months)
Diagnosis	Primary spine tumour Aneurysmal bone cyst (2) Giant cell tumour (1) Multiple myeloma (1) Metastatic spine tumour Lung cancer (1) Breast cancer (1) Prostate cancer (1) Renal cell cancer (1)
Spondylectomy level	Thoracic spine (7) Lumbar spine (1)

Data collection

All patients were examined at one, three, six and 12 months postoperative follow-up, and once a year thereafter. The radiographic evaluation was done by another spine surgeon who was not involved in the operation.

The antero-posterior, lateral plain radiographs and computed tomography scans were obtained before surgery and at follow-up. Radiographic analysis, including the body height and segmental angle measurements (Fig. 2), was used to investigate the collapse or displacement of the lamina mesh and any instability or malalignment of the spinal column. Union of the grafted bone on the lamina mesh was defined using the follow-up computed tomography scans when a bony bridge between upper and lower adjacent vertebral lamina appeared on more than two sagittal section images.

To evaluate the clinical outcomes, the preoperative and the last follow-up pain was assessed by the McAfee's 4-point scale [11] and neurological assessment was done using the Frankel's classification [12] at each follow-up. Clinical outcomes were determined to understand the condition of the patients and to evaluate the overall results of operation, which includes total en bloc spondylectomy. The postoperative complications were also recorded.

Statistical analysis

Because of the small number of patients, Wilcoxon's signed-ranks test was used to determine whether the intra-group differences of radiographic and clinical outcomes were significant. P values of < 0.05 were regarded to have statistical significance and the statistical analyses were reviewed by a statistician.

Results

There was five level fixation in five cases, six level fixation in one case, and seven level fixation in two cases. The fixation level indicates the screw instrumentation and posterior fusion with bone graft including the level of total en bloc spondylectomy. There was no collapse or displacement of the titanium lamina mesh and no instability or malalignment of spine at the last follow-up in any of the cases. On statistical analysis, there was no significant difference between immediate and latest follow-up values of body height or segmental angle ($p>0.05$) (Table 2). We could also observe on computed tomography scans that the enlarged spaces of the spinal canals were well maintained. Five patients received perioperative radiation therapy or chemotherapy. But, at the postoperative six months follow-up computed tomography, the bony bridge on the titanium

Fig. 1 Intraoperative photograph of suitable sized titanium mesh anchored between upper and lower lamina of total en bloc vertebra (a). Photograph of bone graft placed on the titanium lamina mesh (b). The schematic design showing insertion of the titanium lamina mesh (c)

mesh between upper and lower adjacent lamina was observed in all cases except for one with infection (Figs. 3 and 4).

The preoperative and postoperative McAfee's 4 point scales are shown in Table 3. The two cases that were preoperatively grade 4 improved to grades 0 and 1 after surgery. Among the five cases of preoperative grade 3, one case improved to grade 2, three cases to grade 1, and one case to grade 0. The one case of preoperative

grade 2 improved to grade 0. Among the seven cases that developed neurological symptoms preoperatively, four cases showed complete recovery to grade E and three cases showed change from grade C to grade D according to the Frankel's classification (Table 4). There were significant differences between the pre-operative and post-operative values of McAfee's 4-point scale and Frankel's classification ($p < 0.05$).

Fig. 2 Radiographic measurement. The change of body height reflect the collapse or subsidence ($\text{body height} = (a + b)/2$) (**a**). Segmental angle is the Cobb's angle between line α and β (**b**). (**a** the length from the anterior margin of lower endplate of the superior vertebra to the anterior margin of upper endplate of the inferior vertebra, **b** the length from the posterior margin of lower endplate of the superior vertebra to the posterior margin of upper endplate of the inferior vertebra, α the upper endplate of the superior vertebra, β the lower endplate of the inferior vertebra)

There was one complication of postoperative deep infection. Consequently, anterior fusion was performed using autograft with removal of the anterior cage and the posterior titanium lamina mesh. However, in this case, the primary focus of infection in the postoperative magnetic resonance imaging was the interbody cage with adjacent abscess pocket. Therefore, we consider that the infection was not caused by the titanium lamina mesh. There were no other complications.

Discussion

The treatment of spinal tumours over the last 30 years has developed and grown remarkably with the progress of scientific technology. In addition, the short-term and long-term prognoses for spinal tumours have been significantly improved due to the development of treatments for systemic diseases, the introduction of high-tech devices that enable a precise, accurate preoperative diagnosis and staging classification, and the development of new surgical instruments and procedures [13, 14]. But spinal tumours are still difficult to treat with the curettage or extensive radical surgery, because of the complex anatomical structure and risk of injury to the surrounding neural structures, unlike bone tumours that occur in a limb. By comparison, total en bloc spondylectomy is currently a widely accepted surgical procedure for spinal tumours [1–3, 15]. However, solid spinal

reconstruction and complete bone union for absolute stability and safety are essential, because the spinal continuity is completely lost and the spinal cord and nerves are exposed after total en bloc spondylectomy [5, 16, 17]. Due to the relatively long-lasting instability after total en bloc spondylectomy, implant loosening, hardware failure and delay of the healing process can easily occur [18]. Furthermore, it is difficult to achieve fast and complete bone union due to the patient's poor general health. In the past, when the success rate of spinal tumour treatment was low and patient's residual life expectancy was poor, the treatment of spinal tumour was considered sufficient, as Tomita [10] suggested, with only anterior reconstruction and posterior fixation with screws and rods. However the longer survival time of the spinal tumour patients due to the high curability of the primary tumour and high survival rate of the metastatic tumour, makes the reconstruction of the three-columns of spine with additional posterior column reconstruction much more important [16, 17, 19].

Generally, reconstruction of the anterior and middle columns can be done in various ways using autograft such as iliac crest or fibula, allograft, PMMA (polymethylmethacrylate) or cages, and many studies about such reconstruction have been reported [20–22]. But there have been few reports about posterior column reconstruction to obtain the continuity of the posterior structure, reinforce the stability and protect the posterior neural elements such as the spinal cord. Axial stability

Table 2 Radiographic outcomes

	Preop.	Immediate	POD 3mos	POD 1 yr	Last F/U	P value
Body height(mm)	25.9 (17.4–41.1)	29.6 (21.6–47.3)	28.1 (20.8–46.1)	27.6 (20.3–45.8)	27.6 (20.2–45.8)	0.156
*Segmental angle(°)	10.8 (1.0–21.6)	8.1 (–1.9–18.5)	9.2 (–1.0–20.1)	9.7 (–0.7–20.5)	9.8 (–0.5–20.6)	0.107

POD postoperative day, F/U follow-up* Segmental angle (+: kyphosis, –: lordosis)

P value represents the statistical analysis of change between immediate and last F/U outcome

Fig. 3 A 55-year-old woman with primary spine tumour (aneurysmal bone cyst) of the T2 vertebra. Note the MR images (Gd-enhancement) of expansile septated cystic lesion involving the body and right side posterior structure of T2 (**a**, **b**). Radiographs at 28 months after total en bloc spondylectomy. There was no evidence for displacement or collapse of the titanium lamina mesh and malalignment of spine (**c**, **d**). On the CT images, complete bony union was observed above the lamina mesh and inside of the titanium MESH cage (**e**, **f**)

supported by three vertebral columns is essential to sustain the weight and protect the neural structures. Posterior instrumentation using pedicle screws and rod fixation alone is sometimes not enough to withstand the load, and this cannot protect the posterior neural elements completely. Among the other methods of posterior column reconstruction, there are a few reports using recapping laminoplasty, fibular strut graft and artificial sheets. Recapping laminoplasty after the radiation or

Pasteurisation or cryotherapy of the posterior structures has the risk of spreading tumour cells, weakening of the bone structure and low bone union rate. Surgery using fibular graft is complex and takes a long time, introducing additional donor site pain to the patient. It is also difficult to control the size of fibular strut graft [6, 7]. Autogenous fascia or artificial sheet has adhesion-protective effect, but it does not provide stability [8, 9].

Fig. 4 A 68-year-old man with metastatic prostate cancer of the T8 vertebra. The sagittal and axial MR images (T2) shows tumour in T8 vertebra (**a**, **b**). Radiographs at 54 months after total en bloc spondylectomy. There was no evidence of displacement or collapse of the titanium lamina mesh or malalignment of spine (**c**, **d**). On the CT images, complete bony union was observed above the lamina mesh and inside of the titanium MESH cage (**e**, **f**, **g**)

Table 3 4-point scale by McAfee*

Grade	Symptom	Preop. (case)	Last F/U (case)
4	Severe constant pain requiring regular narcotic analgesics	2	
3	Moderate pain controlled with narcotic analgesics	5	
2	Minimal pain requiring non-narcotic analgesics	1	1
1	Minimal pain not requiring medication		4
0	No pain		3

*P value=0.009 (Wilcoxon's signed-ranks test); P value represents the statistical analysis of change between preoperative state and last F/U

In this study, we reconstructed a new lamina by fixing the appropriately sized titanium mesh over the lamina to secure sufficient space for the spinal cord, and to protect the exposed spinal cord from compression and adhesion to surrounding soft tissue. We could also improve the immediate stability of the posterior vertebral column postoperatively and, by providing posterior fusion bed for additional bone grafting, we obtained the permanent stability of the new lamina with bony continuity after union. Also, because the titanium lamina mesh is easily cut to size, it can be used for any vertebral level lamina reconstruction. Titanium has the special advantage of high strength and biocompatibility. Titanium has an oxide surface film which is remarkably resistant to corrosion, and it is much better than other metals in a chloride environment, namely in vivo environment. Titanium has a lower elastic constant than other metals, which allows a reduction of stress shielding when a load is transmitted to bone [23, 24]. At the six months follow-up computed tomography, a definite bony bridge on the titanium mesh between upper and lower adjacent lamina was observed in all cases except for one case of mesh removal for infection. The result of our study showed a better than expected rate of bone union. There were five patients who underwent perioperative chemotherapy or radiation therapy. Only one patient who underwent postoperative radiation therapy had infection, and seven patients showed bony union within six months. We observed high bony union rate, defined as, a bony bridge over the lamina mesh on more than two sagittal sections on the computed tomography scan, and displacement of titanium mesh will not occur after formation of a bony bridge. Addition of one or two transverse links may increase the strength of the

reconstruction frame and decrease the risk of early or late implant failure. But our technique is one of the new surgical options that provide not only stability resulting from new lamina reconstruction, but also protection of the spinal cord against compression and adhesion to surrounding soft tissue.

There are known complications of total en bloc spondylectomy, such as instability, perioperative tissue damage, contamination dissemination during tumour resection, neurovascular injury, infection, and so on [3, 5, 14, 25]. In our study, there was one complication of postoperative infection. However, the primary focus of infection was the interbody cage with an adjacent abscess pocket, so we consider that the infection was not caused by the titanium lamina mesh. Therefore, it should not increase the infection rate especially, considering the short time required for positioning the titanium mesh.

Our study has some limitations. First, the number of cases was too small to provide enough statistical power. However, the surgery was performed in a single institution by one surgeon and we could not use the multi-institutional databases because this technique was a new idea. We will expand the number of the cases to reinforce our results. Second, although we performed total en bloc spondylectomy for the spine tumour, the inclusion criteria was broad because the cases were mixed with primary and metastatic tumour, thoracic and lumbar vertebra. Third, the length of follow-up after treatment of spinal tumour was relatively short. But the purpose of this study is to introduce the new surgical option of lamina reconstruction after total en bloc spondylectomy using titanium lamina mesh. Therefore, our focus was on the successful reconstruction of the new posterior column, rather than the treatment outcome of

Table 4 Neurological status change: classification by Frankel*

Grade	Symptom	Preop. (case)	Last F/U (case)
A	Absent motor and sensory function		
B	Sensation present, absent motor function		
C	Sensation present, motor function present but not useful (Grade 2–3/5)	4	
D	Sensation present, motor function present but not useful (Grade 4/5)	3	3
E	Normal motor and sensory function	1	5

*P value=0.011 (Wilcoxon's signed-ranks test); P value represents the statistical analysis of change between preoperative state and last F/U

spinal tumour itself. As shown in the follow-up computed tomography, all other cases showed new lamina reconstruction six months postoperatively except for the one case of infection. Thus, the second limitation of broad inclusion criteria could be an advantage, and third limitation would not be considered as a significant limitation. Also, some surgeons may feel that stability could be achieved without the titanium mesh or that our technique is not always necessary. However the advantages to be obtained by investing little time, it could prove to be one of the favourable options in various surgical conditions, including total en bloc spondylectomy. The point of our study is that, by the investment of a brief time using titanium mesh, we can easily obtain postoperative early stability reinforcement, scaffold for the bone graft, sufficient space and protection for the posterior neural elements, prevention of adhesion, and permanent stability from the new lamina reconstruction after union of the bone graft, bearing in mind the extended survival time of the spinal tumour patients. We will conduct additional studies on the biochemical aspects of the titanium mesh and the effect of the titanium mesh on the perioperative radiation therapy.

We believe that this study provides a good assessment of the posterior column reconstruction using titanium lamina mesh in all cases which need posterior column reconstruction including total en bloc spondylectomy.

Conclusion

New posterior column reconstruction using titanium lamina mesh after total en bloc spondylectomy of spinal tumour is an easy, safe and effective procedure that provides spinal stability and protects the posterior neural elements.

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