Revision Surgery for Instrumentation Failure after Total En Bloc Spondylectomy: A Retrospective Case Series

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Abstract

**Background:**

There have been several reports of instrumentation failure after 3-column resections such as total en bloc spondylectomy (TES) for spinal tumours; nevertheless, clinical outcomes of revision surgery for instrumentation failure after TES are seldom reported. Therefore, this study assessed the clinical outcomes of revision surgery for instrumentation failure after TES.

**Methods:**

This study employed a retrospective case series in a single centre and included 61 patients with spinal tumours who underwent TES between 2010 and 2015 and followed for >2 years. Instrumentation failure rate, back pain, neurological deterioration, ambulatory status, operation time, blood loss, complications, bone fusion after revision surgery, and re-instrumentation failure were assessed. Data were collected on back pain, neurological deterioration, ambulatory status, and management for patients with instrumentation failure, and we documented radiological bone fusion and re-instrumentation failure in cases followed for >2 years after revision surgery.

**Results:**

Of the 61 patients, 26 (42.6%) experienced instrumentation failure at an average of 32 (range, 11–92) months after TES. Of these, 23 underwent revision surgery. The average operation time and intraoperative blood loss were 204 min and 97 ml, respectively. Including the six patients who were unable to walk after instrumentation failure, all patients were able to walk after revision surgery. Perioperative complications of reoperation were surgical site infection (n = 2) and delayed wound healing (n = 1). At the final follow-up, bone fusion was observed in all patients. No re-instrumentation failure was recorded.

**Conclusion:**

Bone fusion was achieved by revision surgery using the posterior approach alone.

**Background**

Total en bloc spondylectomy (TES) was developed for complete surgical resection for spinal tumours [1, 2]. TES was reported to produce less local recurrence and better survival than piecemeal resection
for primary tumours [3–7], aggressive benign tumours [1, 8], or metastatic spinal tumours [1, 9]. TES involves complete resection of the affected vertebra(e) and surrounding musculoligamentous supportive tissues. The surgery presents a challenge for spinal reconstruction owing to the complete discontinuity in the spinal column. To restore spinal stability after resection, robust instrumentation and bone grafting are needed, with anterior column support [10–12]. Because TES is performed in patients with a relatively good prognosis [13], long-term stabilisation of the spine is important. Failure of bone fusion can cause instrumentation failure, causing back pain, neurological deterioration, and decreased performance of activities of daily living (ADL) [13–18]. In most cases, revision surgery is required to improve spinal stability and symptoms.

Since 2010, instead of harvesting autografts from the ilium or fibula, the resected lamina and vertebral body from the TES are frozen in liquid nitrogen and used as grafted bone for spinal reconstruction. This technique has the following benefits: no pain at the bone harvest site, shortened operative time, decreased blood loss, and additional antitumor immune response [19]. In this procedure, the strategy of revision surgery is more important than that in the conventional procedure because the instrumentation failure rate may increase with a decreased bone-fusion rate.

Despite the fact that several studies have examined instrumentation failure after TES [11–14], there are few published reports on revision surgery for instrumentation failure after TES. Therefore, the aim of this study was to determine the rate of instrumentation failure and to document clinical outcomes of revision surgery for instrumentation failure after TES with reconstruction using frozen autografts treated with liquid nitrogen.

Methods
Study population
This retrospective study was approved by our institutional review board, and informed consent was obtained from all patients. Between 2010 and 2015, 114 patients with primary or metastatic spinal tumours underwent TES at our institute. Of these, 33 patients died within 2 years, and 20 patients were lost to follow-up. Finally, 61 patients (53.5%) who could be followed for > 2 years after TES were included and constituted 35 men and 26 women, with a mean age of 52.6 (range 14–73) years. The
mean follow-up period was 60 (range 24–101) months. Of the 61 patients, 10 had primary malignant tumours, 10 had primary aggressive benign tumours, and 41 had metastatic tumours. In 41 patients with metastatic disease, metastases were diagnosed as having oligometastatic cancer. The thoracic, thoracolumbar, and lumbar spines were affected in 27, 27, and 7 patients, respectively.

Surgical Procedures

Primary surgery (TES) consisted of en bloc laminectomy after transpedicular osteotomy, subsequent en bloc corpectomy, and spinal reconstruction [8, 20]. After en bloc laminectomy, two-above and two-below segmental fixations were performed in all patients. Two rods were used in all patients. Titanium alloy rods (diameter: 5.5 mm) were used in 59 patients. Cobalt chromium rods (diameter: 6.0 mm) were used in two patients. No hooks or wires were used. After posterior instrumentation, anterior reconstruction was performed using a titanium mesh cage (MOSS-Miami; DePuy Motech, Warsaw, Indiana) filled with frozen autografts treated with liquid nitrogen. To increase spinal stability, the posterior instrumentation was adjusted to slightly compress the inserted vertebral cage. Finally, at least two transverse connectors were applied. In all cases, a rigid spinal brace was used for a postoperative period of 3 months, followed by a soft brace for another 3 months.

Revision surgery after instrumentation failure was performed via the posterior approach alone in all cases. Broken rods and broken or loosening pedicle screws were replaced. In some patients, segmental fixation was extended to increase stability. In most patients, a fresh autologous bone strut graft harvested from the iliac crest was placed on the scar tissue of the resected vertebral area to form a bridge between the adjacent laminae (Fig. 1(a), (b)). In some patients, additional fresh autologous bone grafts were placed around the cage. The posterior instrumentation was adjusted to slightly compress the inserted vertebral cage. To increase stability, four rod fixations were applied in most cases (Fig. 1(c)). No patients had cage replacement via an anterior approach. In all cases, a rigid spinal brace was used for a postoperative period of 3 months, followed by a soft brace for another 3 months.

Evaluation

Instrumentation failure was determined based on follow-up plain radiographs. In cases of
instrumentation failure, computed tomography (CT) was performed to determine the details of instrumentation failure. Back pain, neurological deterioration, ambulatory status, and management (conservative or revision surgery) were recorded. Operative time, intraoperative blood loss, and complications of the revision surgery were documented. Finally, we evaluated the extent of radiological bone fusion using multi-planar reconstruction CT in cases of re-instrumentation failure that could be followed for > 2 years after revision surgery. The graft bone in the cage was continuous with the upper and lower adjacent vertebral bodies, and a cage filled with bone tissue was considered bone fusion within the cage.

Results

Of the 61 patients, 26 (42.6%) experienced instrumentation failure at an average of 32 (range, 11 – 92) months after TES. Rod breakage was noted in 20 patients, screw breakage in 2 patients, rod and cage breakage in 2 patients, cage breakage in 1 patient, and screw and cage breakage in 1 patient. However, no evidence of local recurrence was found at the surgical site throughout the follow-up period in all patients. Of the 26 patients, 19 (73.1%) experienced back pain, 8 (30.8%) had lower-extremity neurological deterioration, and 6 (23.1%) were unable to walk because of these symptoms (Table 1). Of the 26 patients, 23 underwent revision surgery, and 3 were followed without revision surgery. In patients without revision surgery, one patient (patient 26; Table 1) with an asymptomatic rod breakage died from cancer 1 year after instrumentation failure. Patients with an asymptomatic cage and screw breakage (patients 24 and 25; Table 1) survived for 1 year and 3 years, respectively. Neither experienced advanced spinal instability or related symptoms. Revision surgery was performed with posterior instrumentation replacement in all 23 patients, posterior bone grafting in 21 patients, and additional bone grafting around the cage in three patients. To increase stability, the procedure was extended by three segmental fixations above and below in three patients, two segmental fixations above and below in one patient, and two segmental fixations above and four segmental fixations below in two patients. Two rods were used in four patients, three rods were used in one patient, and four rods were used in 18 patients. Titanium alloy rods (diameter: 5.5 mm) and cobalt chromium rods (diameter: 6.0 mm) were used in four and 20 patients, respectively. The average
operative time and intraoperative blood loss were 207 ± 45 (range, 121–287) min and 93 ± 81 (range, 20–270) ml, respectively. All patients, including the six patients who were unable to walk due to symptomatic instrumentation failure, maintained or recovered their ambulation function after revision surgery. Perioperative complications of revision surgery were superficial surgical site infection (SSI) in two patients and delayed wound healing in one patient. They were successfully treated with conservative therapies using antibiotics and basic fibroblast growth factor spray.

Eighteen patients could be followed for > 2 years after revision surgery (average follow-up period: 41 months) by radiological evaluation. At the last follow-up, bone fusion was achieved within the anterior cage and at the posterior bone graft in 11 patients, only within the anterior cage in two patients, and only at the posterior bone graft in five patients. There was no re-instrumentation failure after revision surgery (Table 2).

Table 1

| No. | age | Sex | resection level | broken parts in instrumentation failure | duration after TES (mo) | back pain | neurological d |
|-----|-----|-----|----------------|-----------------------------------------|------------------------|-----------|----------------|
| 1   | 39  | M   | T4             | 2 rods                                  | 42                     | +         | -              |
| 2   | 63  | F   | T4, 5, 6       | 1 rod                                   | 74                     | +         | -              |
| 3   | 57  | F   | T5, 6          | 2 rods                                  | 92                     | +         | -              |
| 4   | 59  | F   | T6, 7          | 2 rods                                  | 24                     | -         | bilateral leg w |
| 5   | 68  | M   | T7             | 2 rods                                  | 51                     | -         | bilateral leg w |
| 6   | 24  | M   | T7, 8          | 1 rod                                   | 29                     | +         | -              |
| 7   | 41  | F   | T8, 9          | 2 rods                                  | 37                     | +         | -              |
| 8   | 68  | M   | T8, 9          | 2 rods                                  | 18                     | +         | -              |
| 9   | 59  | M   | T8, 9, 10      | 2 rods                                  | 11                     | +         | -              |
| 10  | 59  | M   | T8, 9, 10      | 2 rods and cage                         | 25                     | +         | bilateral leg w |
| 11  | 66  | F   | T9             | 1 rod                                   | 17                     | +         | -              |
| 12  | 26  | M   | T10            | 2 rods                                  | 34                     | +         | bilateral leg p |
| 13  | 40  | M   | T10            | 1 rod                                   | 38                     | -         | -              |
| 14  | 45  | M   | T10            | 1 rod                                   | 32                     | +         | -              |
| 15  | 70  | M   | T10, 11        | 2 rods                                  | 11                     | +         | -              |
| 16  | 14  | M   | T12            | 2 screws                                | 22                     | -         | -              |
| 17  | 48  | M   | T12, L1        | 2 rods                                  | 19                     | +         | bilateral leg p |
| 18  | 66  | F   | L1             | 1 rod                                   | 18                     | +         | -              |
| 19  | 16  | M   | L1, 2          | 2 rods and cage                         | 21                     | +         | -              |
| 20  | 64  | M   | L2             | 1 rod                                   | 23                     | +         | -              |
| 21  | 49  | F   | L4, 5          | 2 rods                                  | 39                     | +         | bilateral leg p |
| 22  | 25  | F   | L4             | cage and 1 screw                        | 31                     | +         | bilateral leg p |
| 23  | 50  | M   | L5             | 2 rods                                  | 24                     | +         | bilateral leg p |
| 24  | 21  | F   | T11            | cage                                    | 24                     | -         | -              |
| 25  | 41  | F   | L3             | 2 screws                                | 35                     | -         | -              |
| 26  | 70  | M   | L3             | 1 rod                                   | 30                     | -         | -              |
| No. | resection level | operation time(min) | bleeding (ml) | the number of rod | composition of rod |
|-----|----------------|---------------------|---------------|-------------------|-------------------|
| 1   | T4             | 240                 | 50            | 2                 | Ti                |
| 2   | T4, 5, 6       | 214                 | 40            | 4                 | Cocr              |
| 3   | T5, 6          | 173                 | 120           | 4                 | Cocr              |
| 4   | T6, 7          | 248                 | 20            | 4                 | Cocr              |
| 5   | T7             | 222                 | 50            | 3                 | Cocr              |
| 6   | T7, 8          | 213                 | 110           | 2                 | Cocr              |
| 7   | T8, 9          | 208                 | 250           | 4                 | Ti                |
| 8   | T8, 9          | 132                 | 40            | 4                 | Cocr              |
| 9   | T8, 9, 10      | 121                 | 120           | 4                 | Cocr              |
| 10  | T8, 9, 10      | 239                 | 130           | 4                 | Cocr              |
| 11  | T9             | 164                 | 50            | 4                 | Cocr              |
| 12  | T10            | 168                 | 130           | 4                 | Cocr              |
| 13  | T10            | 150                 | 20            | 4                 | Cocr              |
| 14  | T10            | 156                 | 30            | 4                 | Cocr              |
| 15  | T10, 11        | 235                 | 270           | 2                 | Ti                |
| 16  | T12            | 224                 | 30            | 4                 | Cocr              |
| 17  | T12, L1        | 203                 | 20            | 4                 | Cocr              |
| 18  | L1             | 143                 | 50            | 4                 | Cocr              |
| 19  | L1, 2          | 287                 | 80            | 4                 | Cocr              |
| 20  | L2             | 216                 | 50            | 4                 | Cocr              |
| 21  | L4, 5          | 262                 | 115           | 4                 | Cocr              |
| 22  | L4             | 241                 | 220           | 2                 | Ti                |
| 23  | L5             | 239                 | 250           | 4                 | Cocr              |

Cocr: cobalt chromium, Ti: titanium alloy, SSI: surgical site infection
* follow up period after revision surgery was 2 years or less

**Illustrative Case (case 18)**

The patient was a 66-year-old woman with a solitary spinal metastasis from breast cancer. She underwent TES of L1 with 2-above and 2-below segmental fixation using two titanium alloy rods. At 18 months after TES, radiography revealed an increased local kyphosis angle between T12 and L2. Breakage of the left rod was noted on CT. Revision surgery was performed using a single posterior approach. The rod on the left side was broken at the proximal level of the L2 pedicle screw. Transverse connectors and bilateral rods were removed, and the loosening pedicle screw at the left T11 level was replaced. Spinal fixation was performed using four cobalt chromium rods (diameter: 6.0 mm). An autologous strut bone graft was placed on the scar tissue of the resected L1 lamina area and the adjacent T12 and L2 laminae. The posterior instrumentation was adjusted to slightly
compress the inserted vertebral cage. No perioperative complications occurred. The patient re-acquired ambulatory function, without aid, 1 week after the revision surgery. At 42 months after the revision surgery, bone fusion within the cage and at the posterior bone graft was found on CT (Fig. 2).

Discussion

We reported the instrumentation failure rate of patients with instrumentation failure after TES with reconstruction using frozen autografts treated with liquid nitrogen. Revision surgery was performed using the posterior approach alone. Bone fusion was achieved, and there was no re-instrumentation failure in any patient at the follow-up period of > 2 years.

With continuing advances in cancer therapy, acceptable long-term prognosis can be expected even in patients with metastatic spinal tumours [21–24]. In TES, en bloc resection of a tumour-bearing vertebra can be curative, leading to longer-term survival, and achieving bone fusion of the reconstructed vertebral body is essential [25]. However, instrumentation failure caused by unsuccessful bone fusion is not a rare complication. Park et al. reported that 12 (37.5%) of 32 patients experienced rod breakage at an average of 29.2 (range, 8 – 93) months after TES [10]. Sciubba et al. reported instrumentation failure in nine (39.1%) of 23 patients who underwent lumbar-spine TES [14]. Matsumoto et al. reported instrumentation failure in 6 (40%) of 15 patients who underwent TES [12]. In our study, instrumentation failure following the TES procedure was identified in 26 (42.6%) of 61 patients at an average of 32 (range, 11 – 92) months after TES, which was comparable to that of other studies.

The previously reported incidence of instrumentation failure after TES using the same reconstruction method as ours (except using fresh autologous bone for bone grafting) was 8/47 (17.0%) [11]; in the present study, instrumentation failure rate after TES using frozen bone occurred in 26/61 (42.6%). It was reported that bone formation tended to be delayed when frozen bone autografts were used compared to fresh bone autografts [25]; therefore, the instrumentation failure rate in the present study was higher than that previously reported [11]. Although bone fusion was delayed, it was previously demonstrated that complete bone fusion within the cage was obtained in the TES model canine using frozen bone [25]. The instrumentation failure rate following the first procedure was
higher in the present study; however, stability was maintained for a long time in 35 (57.4%) of 61 patients. Considering the advantages of using liquid nitrogen-treated bone, we continue using frozen bone autografts in spinal reconstruction during TES. To decrease the incidence of instrumentation failure, we recently began using a more robust cage and cobalt chrome rods to create a stiffer construct of the operated spine.

In the present study, back pain and neurological deterioration caused by instrumentation failure developed in 19 (76.1%) and eight (30.8%) patients, respectively. Matsumoto et al. reported that all six (100%) patients experienced back pain, and one (16.7%) experienced neurological deterioration at the time of instrumentation failure. Park et al. reported that back pain developed in seven (58.3%) patients, and no patients had neurological deterioration at the time of instrumentation failure. These findings suggest that most patients with instrumentation failure experienced significant clinical symptoms. Revision surgery is necessary to prevent decreased performance of ADL among symptomatic patients with instrumentation failure.

Instrumentation failure is caused by delayed union between the cage and the vertebral body [11], and revision surgery is performed to achieve robust restabilisation and bone fusion. In the present study, in most patients, we performed robust restabilisation by replacing titanium rods with cobalt chromium rods and by increasing the number of rods. We also performed bone grafting at the posterior aspect of the spine. During the primary surgery, bone grafting at the posterior element was difficult because there was no bed for bone grafting at the level of the resected vertebra. Moreover, because the space was covered with scar tissue, bone grafting was straightforward and secured during the revision surgery.

In the present study, 13 (72.2%) of 18 patients with > 2 years follow-up after revision surgery achieved bone fusion within the cage, and the remaining five did not achieve bone fusion; nevertheless, bone resorption within the cage was improved. This finding indicates that replacement of the cage using the anterior approach is unnecessary when the cage is restabilised using a stiffer construction by exchange and supplement of posterior instruments. In cases with a severely damaged cage (not observed in this study cohort), cage replacement using the anterior approach should be
This study has some limitations. The small and heterogeneous cohort with several tumour histologies and adjuvant therapies, and the retrospective manner of data collection, can introduce bias and errors. The follow-up time was limited as well. Longer follow-up is required to determine the accurate incidence of instrumentation failure after revision surgery. Although all patients were diagnosed as having oligometastatic cancer in the present study, the indications for TES remain controversial because less invasive surgeries (e.g. separation surgery) have shown significant results recently. Despite these limitations, this study demonstrated the rate of instrumentation failure after TES with reconstruction using frozen autografts treated by liquid nitrogen and described a relatively simple and effective strategy for revision surgery and its favourable outcomes. The results obtained from this study will contribute to revision surgery for instrumentation failure after TES.

Conclusions
In patients with instrumentation failure after TES, posterior instrumentation replacement and posterior bone grafting were performed during revision surgery. In this study, bone fusion was observed in all patients with > 2 years follow-up after revision surgery, and no re-instrumentation failure was observed during follow-up. Our findings suggest that bone fusion can be achieved by revision surgery using the posterior approach.

Abbreviations
ADL
activities of daily living
CT
computed tomography
SSI
surgical site infection
TES
total en bloc spondylectomy

Declarations
Ethics approval and consent to participate:
All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki
Declaration and its later amendments or comparable ethical standards. The study was approved by the Ethics Committee of the Graduate School of Medical Sciences, Kanazawa University. Informed consent was obtained from all individual participants included in the study.

Consent for publication:
Patients signed informed consent regarding publishing their data and photographs.

Availability of data and material:
The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests:
The authors declare that they have no conflict of interest.

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Authors’ contributions:
All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by KS and TS. The first draft of the manuscript was written by KS, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Figure 1

Schema of revision surgery after instrumentation failure (a) The scar tissue of the resected vertebral area and the adjacent laminae is exposed. (b) Fresh autologous bone strut graft harvested from the iliac crest is placed on the scar tissue of the resected vertebral area to form a bridge between the adjacent laminae. (c) To increase stability, additional rods are applied.
Case no. 18 A 66-year-old woman with breast cancer metastasis at L1. (a) Preoperative sagittal T2 magnetic resonance image revealing tumour involvement at L1. (b) Lateral radiograph revealing pathological fracture at L1. (c) Lateral radiograph after total en bloc spondylectomy. (d) Radiographs at 18 months after surgery revealing increased local kyphosis angle between T12 and L2. (e) Coronal computed tomography (CT) scan revealing breakage of the left rod. (f) Posterior instrumentation is exposed using the previous midline incision. (g) The left rod is broken at the area proximal to the L2 pedicle screw. (h) Loosening pedicle screw at the left T11 level is replaced, and four cobalt chromium rods are inserted. (i) Autologous bone graft is placed on adjacent T12 and L2 lamina and scar tissue of the resected L1 lamina area. (j), (k) Radiograph after revision surgery. (l) Sagittal CT scan at 42 months after revision surgery revealing bone fusion within the cage and at the posterior bone graft.