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Clinical Study

Rod fracture and related factors after total en bloc spondylectomy

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Abstract

BACKGROUND CONTEXT: Several studies have reported favorable oncosurgical outcomes after total en bloc spondylectomy (TES) for treatment of primary malignant tumors or oligometastatic tumors. Considering that TES is indicated for patients with longer life expectancy, long-term instrumentation-related issues such as rod fracture needs to be addressed.
PURPOSE: To investigate delayed rod fracture and related factors after TES.
STUDY DESIGN: Multicenter, retrospective study.
PATIENT SAMPLE: Thirty-two patients who survived for more than 2 years after TES.
OUTCOME MEASURES: Rod fracture and related factors.
METHODS: The relationships between rod fracture and related factors were investigated using Kaplan-Meier survivorship analysis with log-rank test. The analyzed factors were sex, age (<60 or ≥60), tumor histology (primary or metastatic), location of resected tumor (thoracic [above T11], thoracolumbar [cases including T12-L1], or lumbar [below L2]), number of resected vertebrae (1, 2, or 3), anterior support method (expandable cage, mesh cage, or strut bone graft), rod diameter (5.5 mm or 6.0 mm), and history of radiotherapy including preoperative or postoperative radiotherapy.
RESULTS: The study population consisted of 18 men and 14 women, with a mean age of 49.0 years. Nineteen patients had primary tumors and 13 patients had metastatic tumors. The mean follow-up duration was 49.8 months (range, 24−166 months). Twelve of 32 patients (37.5%) experienced rod fractures at an average of 29.2 months (range, 8−93 months) after TES. Of these 12 patients, 8 underwent revision surgery caused by back pain aggravation (n = 7) or nonunion on computed tomography scan (n = 4). Location of resected tumor and history of radiotherapy were significantly associated with rod fracture (p = .004 and p = .019, respectively).
CONCLUSION: Rod fracture was not a rare complication after TES surgery. History of radiotherapy and TES at lumbar level were significant risk factors related to rod fracture. A robust strategy to obtain solid osseous fusion should be considered when planning TES.

Keywords: Total en bloc spondylectomy; Rod fracture; Radiotherapy; Lumbar level; Risk factor; Revision surgery

The device(s)/drug(s) is/are FDA-approved or approved by corresponding national agency for this indication.

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Introduction

Total en bloc spondylectomy (TES) is a surgical technique to remove spinal tumors with the aim to achieve total tumor removal with minimal tumor contamination. The TES is indicated for patients with primary malignant tumor, solitary metastatic tumor with well-controlled primary cancers, and aggressive benign tumor such as giant cell tumor. Because Tomita and Boriani et al. first described this technique [1,2], TES has been a widely accepted procedure to achieve local cure. With advances of surgical technique, the indications of TES have been expanded to patients with lumbar lesions or multilevel spinal tumors [3−9].

The TES procedure involves the removal of all bone and joints structures such as vertebral body, lamina, discs, and facet joints. Thus, after TES, the spinal column becomes totally destabilized. To restabilize the spinal column, robust instrumentation and bone grafting are needed along with anterior column support. Considering that TES is indicated for patients with longer life expectancy [10], spinal reconstruction should guarantee longevity of the construct, which can be achieved by secure osseous fusion, especially in the anterior column. Failure of secure osseous fusion can cause delayed onset rod fracture that may be associated with pain and neurologic deterioration and can require reoperation [6,11−14].

Although several studies reported favorable oncosurgical outcomes in terms of local cure rate and health-related quality of life after TES [15,16], there have been few studies on long-term instrumentation-related issues such as rod fracture. The purpose of the present study was to investigate delayed rod fracture and related factors after TES for patients with postoperative survival longer than 2 years.

Materials and methods

Study population

This multicenter, retrospective study was performed using data collected from three university-based hospitals. The study cohorts comprised patients who underwent TES for spinal tumors between 2002 and 2015. Patients who underwent piecemeal tumor removal or en bloc sagittal resection of a vertebral body were excluded from the study. During this period, 41 patients with primary or metastatic spinal tumors underwent TES in 3 hospitals. Of these, 32 patients (78.0%) survived for more than 2 years after surgery and were included in this study.

Surgical procedures

Total en bloc spondylectomy was performed following the procedure described by Tomita et al. [2]. Thoracic lesions were treated by posterior approach alone. Patients who had thoracolumbar or lumbar lesions or anterior extension of thoracic lesions were treated using a combined anterior and posterior approach with anterior release of tumors from the surrounding vascular and visceral structures followed by en bloc removal of the tumor via a posterior approach. The number of resected vertebrae was 1 in 22 patients, 2 in 6, and 3 in 4. The resected tumor was located at the thoracic level (T1−T11) in 23 patients, at the thoracolumbar level (cases including T12 or L1) in 7, and at the lumbar level (L2−L5) in 2.

Spinal reconstruction after tumor resection was performed using anterior structural support and posterior instrumentation. Anterior reconstruction was performed using an expandable titanium cage in 13 patients, mesh titanium cage in 13, and allogenous strut bone graft (diaphysis portion of femur or tibia) in 6. All cages and strut bone grafts were filled with autograft and demineralized bone matrix. No bone morphogenetic protein was used in any cases. Posterior instrumentation and fusion were performed using titanium pedicle screws and rods in all patients. Two-above and 2-below pedicle screw fixation was performed for patients with 1-level TES and 3-above and 3-below fixation was performed for patients with 2- or 3-level TES. To increase spinal stability, pedicle screws adjacent to the resected vertebral body were compressed, producing spinal column shortening.

After surgery, adjuvant radiotherapy was performed when tumor exposure was noticed during surgery or resection margin was positive on final pathology report. Because postoperative radiotherapy was performed as an adjuvant tool rather than curative one, conventional radiotherapy was delivered for patients requiring radiotherapy.

Study analyses

The primary outcome measure was rod fracture, which was determined based on review of the follow-up plain radiographs. After rod fracture occurrence, computed tomography (CT) scan was performed for all patients to evaluate fusion status. The database was also queried for pain on presentation at the time of rod fracture diagnosis and revision surgeries occurring after rod fracture. The relationships between rod fracture and related factors were investigated using Kaplan-Meier survivorship analysis with log-rank test. The analyzed factors were sex, age (<60 or ≥60), tumor histology (primary or metastatic), location of resected tumor (thoracic [above T11], thoracolumbar [cases including T12-L1], or lumbar [below L2]), number of resected vertebrae (1, 2, or 3), anterior support method (expandable cage, mesh cage, or strut bone graft), rod diameter (5.5 mm or 6.0 mm), and history of radiotherapy including preoperative or postoperative. Statistical analysis was performed using SPSS software (version 25.0.0; SPSS Inc., Chicago, IL, USA). All p values less than .05 were considered significant.

Results

Study population

The study cohort consisted of 18 men and 14 women, with a mean age of 49.0 years (range, 9−79 years). The mean follow-up duration was 49.8 months (range, 24−166

Table 1
Details of patients who experienced rod fracture

Case	Sex	Age	Pathology	Resected levels	Anterior support	RT history*
1	F	44	Primary (GCT)	T4	Mesh cage	Yes
2	M	63	Primary (CSA)	T10,T11,T12	Mesh cage	Yes
3	M	60	Primary (UDS)	T12	Expandable cage	Yes
4	F	55	Primary (CSA)	T10	Expandable cage	Yes
5	F	29	Primary (GCT)	L1	Mesh cage	Yes
6	F	46	Primary (OMS)	L5	Strut bone graft	Yes
7	M	66	Primary (GCT)	T9,T10	Mesh cage	Yes
8	M	33	Primary (GCT)	L1	Mesh cage	Yes
9	M	53	Metastasis (Lung)	T4,T5	Expandable cage	Yes
10	M	49	Metastasis (Liver)	L5	Expandable cage	Yes
11	F	65	Metastasis (Breast)	T11	Expandable cage	Yes
12	M	53	Metastasis (Liver)	T12	Mesh cage	Yes

*RT history includes radiotherapy preoperatively or postoperatively.GCT, giant cell tumor, CSA, chodrosarcoma; UDS, undifferentiated sarcoma; OFS, ossifying fibrousmyxoid sarcoma.

months). At the final follow-up, 28 patients were alive. Of 28 patients, 17 showed no evidence of disease, whereas 6 showed local recurrence and 5 showed nonspinal recurrence. Four patients died of disease progression at a mean of 58.4 months (range, 24.3−135.9 months) after surgery.

Nineteen patients had primary tumors, comprising giant cell tumor in 7 patients, osteosarcoma in 5, chondrosarcoma in 4, undifferentiated spindle cell sarcoma in 1, ossifying myxofibrous sarcoma in 1, and lymphoma in 1. Thirteen patients had metastatic tumors from breast cancer in 3 patients, hepatocellular carcinoma in 2, renal cell carcinoma in 2, thyroid cancer in 2, adrenal cancer in 1, lung cancer in 2, and leiomyosarcoma in 1.

Six patients had a history of radiotherapy before TES and 16 patients underwent adjuvant radiotherapy after TES. Two patients received radiotherapy both preoperatively and postoperatively.

Rod fracture

Twelve of 32 patients (37.5%) experienced rod fracture at an average of 29.2 months (range, 8−93 months) after TES (Tables 1 and 2). There were 11 patients with rod fracture alone and 1 patient with rod and screw fracture. All rod fractures occurred within the resected tumor level. According to Kaplan-Meier survivorship analysis, the rod fracture-free survival rates was estimated as 90.6% at 12 months, 81.3% at 24 months, and 58.1 % at 48 months (Fig. 1).

For 12 patients who underwent rod fracture, CT scan showed fusion between endplates and anterior support structure in 8 patients, and nonunion in 4 patients (Table 2). Of these 12 patients, 8 underwent revision surgery and 4 did not. Revision surgeries were performed for patients with back pain aggravation (n = 7) or nonunion between the endplate and anterior support structure on CT scan (n = 4). There were no patients who experienced neurologic deterioration after rod fracture. During revision surgeries, broken rods were changed to cobalt-chrome rods, and autologous bone graft was placed around the adjacent remnant laminae. There were no cases of replacement of anterior support structures. After revision surgery, there were no further rod fractures in 7 patients. However, 1 patient experienced refracture of rods at 20 months after revision surgery. He underwent rerevision surgery (case number 2, Fig. 2).

Risk factor analysis

Risk factors related to rod fracture were analyzed using the log-rank test of Kaplan-Meier survivorship analysis (Table 3). Sex, age, tumor histology, number of resected vertebrae, anterior support method, and rod diameter were not significantly related to rod fracture, although location of resected tumor and history of radiotherapy were significantly associated with rod fracture. In terms of tumor location, TES at the lumbar level had the highest risk of instrumentation failure, followed by thoracolumbar and thoracic levels. Patients (n = 8) who did not undergo radiotherapy preoperatively or postoperatively did not experience rod fracture, whereas half of the 24 patients who had a history of radiotherapy experienced rod fracture. When further analysis was performed for patients who received radiotherapy, there was no difference in total radiation dose between patients with and without rod fracture (46.2 Gy and 42.8 Gy, respectively, $p = .577$).

Discussion

Although, TES is considered a fairly aggressive surgical procedure, it has become the treatment of choice for primary malignant tumor, highly aggressive benign tumor, and solitary metastatic tumor. With advances of surgical technique, there is a growing body of evidence supporting long-term good local control and longer survival rates [15−18]. However, given that TES is usually indicated for patients with longer life expectancy [10], longevity of the spinal construct should be considered. Therefore, the current study was designed to investigate long-term instrumentation-related issues focusing on rod fracture.

Table 2
Details of patients who experienced rod fracture (continued)

Case	Number of broken rods	Time from TES (mo)	Back pain aggravation	CT finding*	Revision surgery
1	1	18.1	No	Fused	No
2	1	8.6	Yes	Not fused	Yes
3	1	17.9	No	Fused	No
4	1	32.9	Yes	Fused	Yes
5	1	47.6	Yes	Fused	Yes
6	1	9.0	No	Fused	No
7	2	24.4	No	Not fused	Yes
8	2	93.4	No	Fused	No
9	2	33.8	Yes	Not fused	Yes
10	2	23.9	Yes	Not fused	Yes
11	2	32.3	Yes	Fused	Yes
12	2	8.2	Yes	Fused	Yes

"Fused" means the presence of a bony bridge between the endplates and anterior support materials. "Not fused" means a lack of bony bridge between the endplates and anterior support materials.

* CT was performed after rod breakage was noted.

In our study, rod fracture after TES was identified in 37.5% of patients at an average of 29.2 months (range, 8−93 months) after TES, suggesting that such an event is not a rare complication related to this procedure. The failure rate in the present study was similar to the previous reports. Matsumoto et al. evaluated 15 patients who underwent TES and survived for more than 1 year and observed 6 patients (40%) with instrumentation failure [14]. Sciubba et al. reported that instrumentation failure occurred in 9 (39.1%) out of 23 patients who underwent TES at the lumbar spine [6].

Although instrumentation failure can occur as various forms such as screw loosening, screw back-out, cage breakage, screw fracture, or rod fracture, the most common reported instrumentation failure mode after TES was rod breakage in the literature [6,14,17]. Given that rod fracture reflects pseudoarthrosis within spinal reconstruction structures, it should be considered important because it can be related to aggravating back pain or neurologic deterioration and may require revision surgery. Fortunately, the sequelae associated with this complication are reported not catastrophic. According to Matsumoto's study, there were no patients who experienced severe neurologic deterioration although all of the patients with failed instrumentation experienced moderate to severe back pain [14]. In the present study, no patients with rod fracture also had neurologic symptoms, although 7 patients with rod fracture suffered from aggravated back pain.

Of 12 patients, 8 underwent revision surgery in which broken rods were replaced with cobalt chrome rods and

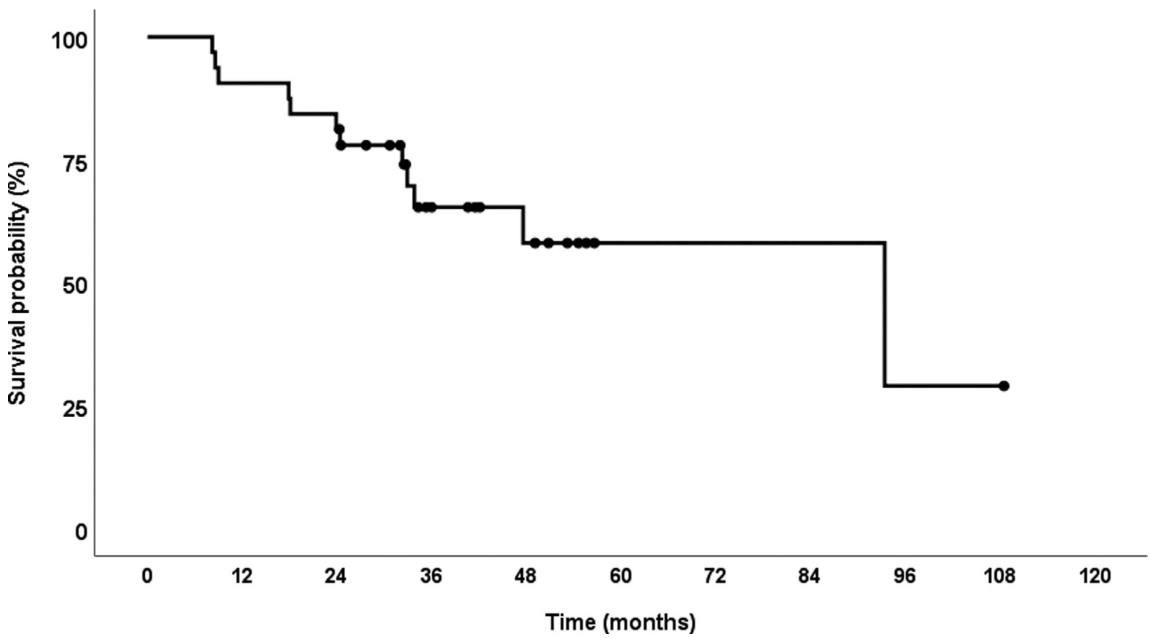

Figure 1. Kaplan-Meier survivorship curve showing rod fracture-free survival probability for all patients (n=32).

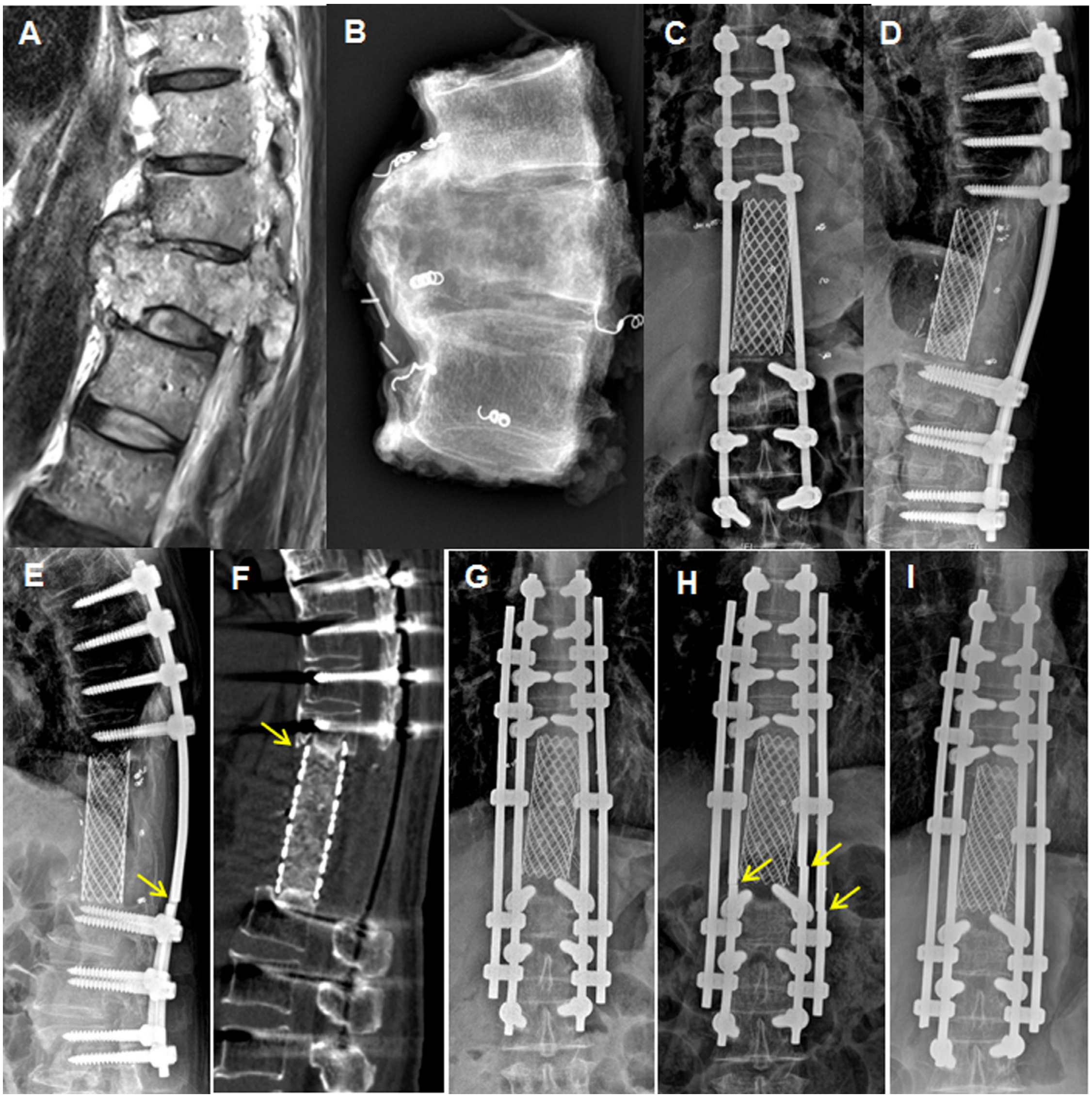

Figure 2. A 63-year-old man with chondrosarcoma at T10 to T12 (case number 2). (A) Sagittal T2 MR image showing tumor involvement at T10, T11, and T12. (B) Radiograph showing the resected specimen including T10, T11, and T12 vertebral bodies. (C), (D) Postoperative anteroposterior and lateral radiographs showing a mesh cage filled with autograft placed between T9 and L1 vertebral bodies. (E) Radiograph obtained 8.6 months after surgery showing 1-side rod fracture (arrow). (F) Computed tomography image showing pseudoarthrosis at the upper cage-bone interface (arrow). (G) Radiograph after revision surgery of dual cobalt-chrome rod fixation. (H) Radiograph showing refracture of 3 rods at 20 months after revision surgery (arrows). (I) Radiograph after the 2nd revision surgery.

bone grafts were placed posteriorly. Revision surgery was not performed in 4 patients because they did not experience back pain aggravation, and the anterior support structures seemed to be fused to the vertebral bodies on CT scan (Table 2). It is also notable that 8 patients experienced rod breakage despite seemingly fused anterior support structures on CT scan (Table 2). In other words, even if the anterior graft seems to be fused on radiographic examination, the fusion mass may be not strong enough to endure long-term repetitive force, causing fatigue fracture of rods. The authors assumed that the cause of back pain aggravation in the presence of rod fracture is caused by mechanical one. Therefore, revision surgery was performed for all patients experiencing back pain aggravation with rod fracture regardless of radiographic findings. Ito et al. reported similar results to our study in their case report of 3 patients undergoing TES [19]. They found that these patients experienced late stress fracture of anterior strut graft after removal of instrumentation despite seeming graft incorporation on plain radiograph and CT scan. Alan et al. found that rod fracture occurred in 9.5% of patients with apparently solid radiographic fusion after adult spinal deformity, although this paper was not aimed at a tumor analysis [13]. These results suggest that patients who undergo TES surgery should be observed carefully for delayed rod fracture, even if apparent fusion was observed in the radiographic examination.

Table 3
Factors related to rod fracture

Parameters		No. of patients	No. of patients with rod breakage	p*
Sex	M	18	7 (38.9%)	.704
	F	14	5 (35.7%)	
Age	<60	21	8 (38.1%)	.590
	≥60	11	4 (36.4%)	
Tumor histology	Primary	19	7 (36.8%)	.670
	Metastatic	13	5 (38.5%)	
Location of resected tumor	Thoracic	23	6 (26.1%)	**.004**
	Thoracolumbar	7	4 (57.1%)	
	Lumbar	2	2 (100%)	
No. of resected vertebrae	1	22	9 (40.9%)	.906
	2	6	2 (33.3%)	
	3	4	1 (25.0%)	
Anterior support method	Expandable cage	13	5 (38.5%)	.790
	Mesh cage	13	6 (46.2%)	
	Strut bone graft	6	1 (16.7%)	
Rod diameter	5.5 mm	5	2 (40.0%)	.370
	6.0 mm	27	10 (37.0%)	
History of radiotherapy†	Yes	24	12 (50.0%)	**.019**
	No	8	0 (0%)	

Bold p values are statistically significant.
* The p values were calculated by log-rank test of Kaplan-Meier survivorship analysis.
† Radiotherapy included preoperative or postoperative radiotherapy.

In terms of risk factors related to rod fracture, we found 2 significant factors, radiotherapy history, and location of resected tumor. In the present study, no patient who did not receive radiotherapy preoperatively or postoperatively experienced rod fracture, whereas rod fracture was observed in half of the patients with a history of radiotherapy. According to the literature, irradiation has a negative impact on bone quality and healing process [20]. To reduce the necessity for radiotherapy after surgery, surgeons should try to minimize tumor contamination during surgery and to get negative resection margin as much as possible. We also found that, for patients who received radiotherapy, there was no difference in total radiation dose between patients who experienced rod fracture and those who did not (46.2 Gy and 42.8 Gy, respectively). Therefore, the negative effect of radiotherapy on the spinal construct does not seem to be proportional to total radiation dose. Further study about the optimal dosage and fractionation strategy of radiotherapy is warranted.

The authors found that tumor location was another significant risk factor of rod breakage. The TES at the lumbar spine had the highest risk of rod fracture, followed by thoracolumbar and thoracic levels. This might be because the lumbar spine has the greatest moment of flexion force and is not supported by adjacent stabilizing structures such as ribs of the thoracic spine. According to Sciubba's study, the rate of rod fracture was as high as 39.1% in 23 patients who underwent lumbar TES [6]. Thus, when TES is planned at the lumbar spine, more attention should be paid to achieve solid graft-bone incorporation.

To avoid rod fracture, several surgical techniques are recommended; meticulous endplate preparation, disc to disc cut (no cut through body), longer posterior fixation point, larger diameter rods, spinal column shortening, and proper anterior support method [14,21,22]. Among these recommendations, the authors think anterior support method is one of the important considerations because only solid osseous fusion between graft and bone is the ultimate solution to prevent the delayed rod fracture. Titanium mesh or expandable cages were most commonly used for anterior support structures after TES. In this study, the failure rate (16.7%) in cases of strut bone graft filled with autograft were lower than those of mesh cages (46.2%) and expandable cages (38.5%), although these results did not reach statistical significance. The authors postulated that the larger contact area between graft and bone may help to obtain solid osseous fusion. The long-term results of strut bone graft after TES should be researched in the future with a larger number of cases.

The present study has several limitations. The retrospective nature of the study carries some risk of information bias. Caused by the multicenter study design, diversity of surgical methods from different hospitals is another weak point of this study. Also, small sample size of lumbar TES and multilevel TES could lower the statistical power. Despite the recognized limitations, this study showed rod fracture and related factors after TES in detail, using a relatively large number of patients with fair follow-up duration. The results obtained from this study will hopefully contribute to reconstruction strategy after TES.

Conclusions

Rod fracture was not a rare complication after TES surgery. History of radiotherapy and TES at the lumbar level were significant risk factors related to rod fracture. Robust strategy to obtain solid osseous fusion should be considered when planning TES.

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