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Original Article

Retrospective analysis of reasons and revision strategy for failed thoracolumbar fracture surgery by posterior approach: a series of 31 cases

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Abstract: Objectives: This study aimed to analyze the reasons for failed thoracolumbar fracture treated with posterior surgical approaches and to discuss the revision strategies for the surgical treatment. Methods: We retrospectively studied the patients that received failed thoracolumbar fracture (T11-L2) treatment with posterior approach and underwent revision surgery in our spine department from March 2010 to December 2020. Results: A total of 31 patients were included in this study. There were 4 (12.9%) cases of A3, 2 (6.5%) cases of B1, 5 (16.1%) cases of B2, 7 (22.6%) cases of B3, and 13 (41.9%) cases of C, according to the AO classification for thoracolumbar injuries. For load sharing classification, 26 (83.9%) cases ≥7, and 5 (16.1%) cases < 7. Regarding to the reasons for surgery failure, 26 cases (83.9%) were due to fracture of the internal fixation (pedicle screw or connecting rod) and kyphosis, 3 cases (9.7%) were due to misplacement of the posterior pedicle screw, 1 case (3.2%) was due to incomplete posterior decompression, and 1 case (3.2%) was due to scoliosis after the removal of the internal fixation. The revision surgery methods included: 2 cases (6.5%) with anterior approach, 17 cases (54.8%) with posterior approach, and 12 cases (38.7%) with posterior and anterior approach. All the patients were followed-up for 12-24 months after the revision surgery, and successful bony fusion with no internal fixation failure was observed. The kyphosis angle improved significantly after the revision surgery in 26 patients at the last follow-up, and the final correction rate was 91.8%. Frankel grading system, visual analog scale (VAS), Oswestry Disability Index (ODI) showed significant improvement at the last follow-up. Conclusions: Types B and C of thoracolumbar fracture, load sharing classification ≥7, and the posterior approach could lead to a high failure rate. Fracture of the internal fixation was the main reason for surgery failure. Performing the posterior approach is inappropriate for every thoracolumbar fracture. Reasonable revision surgery can achieve good results for posterior surgery failure in most cases.

Keywords: Thoracolumbar fracture, posterior approach, revision surgery

Introduction

The thoracolumbar junction (T11-L2) is the transition site from the kyphotic thoracic spine to the more dynamic lordotic lumbar spine, as a result it bears great biomechanical stress; and thus, thoracolumbar junction fracture is the most common fracture of the spinal column [1]. Approximately, half of the thoracolumbar junction fractures are unstable and cause pain, deformity, neurological deficits, and even paralysis [2, 3]. There are several surgical methods for treating thoracolumbar fractures, including posterior short- or long-segment internal fixation, anterior internal fixation, and combined anterior and posterior internal fixation. The posterior approach has a series of advantages, including simple procedure, stable fixation and low operation risk, and it has become the most common surgical method for treating thoracolumbar fracture [4]. However, an inappropriate surgical approach could lead to failure of internal fixation, secondary kyphosis, neurological dysfunction, re-occurrence of back pain, and other serious complications [5-7]. In such cases, additional revision surgery is necessary.

The rate of revision surgery is expected to increase along with the number of patients that undergo spine surgery over the decades [8], and the number of failure cases requiring revision surgery are reported to be up to 10% [9], which means increasing spine surgery cases bring about a substantial number of devastating failures and more complex revision strategies. Revision surgery will not only increase the burden on patients and social medical care, but also lead to potential discord in the doctor-patient relationship. Currently, the success rates for reoperations of the spine are highly variable (ranging from 40 to 94%) and the outcomes can be modest [8, 10].

Surgical revision of a failed thoracolumbar spine surgery is complex. Some authors have reported satisfactory results with stand-alone anterior or posterior techniques in the revision surgery [7], and a combined anterior and posterior procedure is recommended to treat fixed translational deformity after the primary surgery [11]. Meanwhile, a thorough analysis of the reasons of failed primary treatment is required to avoid surgical failure in other cases and choose proper revision strategies. In this study, we retrospectively analyzed the reasons for the primary posterior surgery failure for thoracolumbar fractures and discussed revision surgery strategies, which could help provide references for avoiding surgical failure in treating thoracolumbar fractures.

Materials and methods

Patients

This is a retrospective study. Patients with thoracolumbar (T11-L2) fracture that were treated with posterior internal fixation and underwent revision surgery at the spine department of our hospital from March 2010 to December 2020 were included. This study was approved by the Institutional Review Board of our hospital (202205017), and written informed consent was obtained from all patients participating in this study.

The inclusion criteria included: (1) patients who had imaging evidence of thoracolumbar (T11-L2) fracture; (2) patients who were treated by posterior internal fixation with or without decompression; (3) patients who underwent failed primary posterior surgery; (4) patients who received a revision surgery; (5) follow-up for at least 12 months. Exclusion criteria were as follows: (1) patients with thoracolumbar (T11-L2) fracture who underwent conservative treatment or anterior approach surgery; (2) patients who underwent failed primary posterior surgery without a revision surgery; (3) patients who failed the follow-up assessment.

General data included gender, age, fracture segment distribution, AO classification of thoracolumbar fracture, load sharing classification of thoracolumbar fracture, interval between the initial surgery and the revision surgery, the revision surgery time, intraoperative blood loss, and out-of-bed time. Preoperative and follow-up imaging data were routinely prescribed.

Observation indicators

Primary indicators included complications, fusion status, and Cobb angle of kyphotic deformity. According to the criteria proposed by Lee et al. [12], successful fusion was defined as: a) the contour of the implanted bone was not clear, and there was obvious trabecular bone at the interface; b) activity less than 3° on the dynamic plane; and c) there was no transparent zone in the clearance around the fusion area. Computed tomography (CT) scanning was performed when the X-ray was in doubt or the patient's local pain worsened. Measurement of the Cobb angle was as follows: the angle between the adjacent upper endplate of the vertebral body and the perpendicular line of the parallel adjacent lower endplate of the vertebral body at the cephalic side of the injured vertebra. The correction rate was calculated as follows: (preoperative kyphosis Cobb angle - postoperative kyphosis Cobb angle)/preoperative kyphosis Cobb angle × 100%.

Other indicators including Frankel grading system, visual analog scale (VAS) and Oswestry Disability Index (ODI) were recorded preoperatively and at each follow-up. The Frankel grading system was used for assessing neurological function, VAS was used for assessing thoracolumbar back pain or pain in the anterior approach site, and ODI was used for assessing the impact of pain on daily life.

Statistical methods

Statistical software (SPSS 19.0, SPSS Inc., USA) was used for data analysis. The paired t-test was used to compare the Cobb angle,

Table 1. Patients' demographic data

	No. of patients (%)
Sex	
Male	19 (61.3)
Female	12 (38.7)
AO type of fracture	
Type A3	4 (12.9)
Type B1	2 (6.5)
Type B2	5 (16.1)
Type B3	7 (22.6)
Type C	13 (41.9)
Load sharing classification	
≥7	26 (83.9)
< 7	5 (16.1)
Fracture segment	
T11	3 (9.7)
T12	9 (29)
L1	12 (38.7)
L2	7 (22.6)

VAS score, and ODI before and after surgery. The rank-sum test was used to compare changes in Frankel grading before and after surgery. Statistical significance was set as $P < 0.05$.

Results

General data

There were 31 patients included in this study. Among them, 28 were transferred from local hospitals and three were from our hospital. There were 19 males and 12 females, with an average age of 35.4±3.6 (range 19-57). The information of the AO classification of thoracolumbar fracture [13], the load-sharing classification system [14], and the primary fracture site were listed in **Table 1**. The average interval between the initial operation and the revision operation was 11.2 (0.5-27) months. The operation time, intraoperative blood loss, and out-of-bed time of the revision surgery were listed in **Table 2**.

Reasons for revision surgery

Three (9.7%) patients presented with pedicle screw misplacements. Twenty-six (83.9%) cases presented with internal fixation instrument fracture with kyphosis. One patient experienced screw fracture 9 months after the primary posterior short segment fixation, and a second connecting rod fracture 1.5 years after the long segment fixation, and this revision was the third operation. One (3.2%) patient presented with an incomplete decompression. One (3.2%) patient presented with scoliosis after the removal of the internal fixation instrument.

Revision surgical methods

In the three cases of pedicle screw misplacement, the misplaced screws were removed and replaced with ilium bone graft fusion (**Figure 1**). In one case of incomplete decompression, anterior decompression was performed, and the posterior internal fixation instrument was retained. In one case (type C) of scoliosis after removal of the internal fixation instrument, posterior transpedicular osteotomy with intervertebral fusion and internal fixation was performed (**Figure 2**). Twelve patients (type C) had pedicle screw fractures. One patient underwent posterior surgery twice in a local hospital. The back muscle of the patient showed severe fibrosis, and the internal fixation instrument was palpable under the skin, restricting his supine position. In this case, anterior reconstruction was performed after the removal of the internal fixation instrument (**Figure 3**). The remaining 11 patients underwent posterior internal fixation instrument removal, followed by posterior long-segment internal fixation and fusion, anterior fracture vertebral resection, and ilium or titanium mesh reconstruction. Fourteen patients (type B) with pedicle fractures underwent posterior long-segment internal fixation and intervertebral bone grafting after removal of the internal fixation instrument.

Observation indicators

All the 31 patients were followed up for 12-24 months, with an average of 17.1±4.5 months. There were no case of failed internal fixation, and all the patients achieved bony fusion 10-12 months after the revision operation. In the 26 patients with kyphosis, the preoperative kyphosis angle was 10°-58°, with an average of 40.5°±15.3°, which was corrected to -3°-7°, with an average of 2.3°±3.7°, There was a statistically significant difference in kyphosis between the preoperative and postoperative last follow-up ($P < 0.05$), and the final kyphosis correction rate was 91.8%.

Table 2. Operation time, blood loss, and out-of-bed time of revision surgery

	Operation time (min)	blood loss (mL)	Out-of-bed time (d)
Anterior (n=2)	147±42	492±103	4±1.5
Posterior (n=17)	112±35.4	317±162	2.1±0.5
Anterior and posterior (n=12)	186±91.5	1092±318	4.6±0.8

According to the Frankel classification for neurological functional assess [15], there were 6 cases of grade A, 12 cases of grade B, 7 cases of grade C, and 6 cases of grade D before revision surgery. After the revision surgery, patients with preoperative complete spinal cord injury (grade A) did not change. The remaining 25 patients with neurological deficits recovered to varying extents. In terms of the Frankel grade at the last follow-up, there were 6 cases of grade C, 4 cases of grade D, and the remaining cases were restored to grade E. The difference in the Frankel grade between the last follow-up and before surgery was statistically significant ($P < 0.05$). At the last follow-up, the VAS decreased from 6.9±0.7 to 2.4±1.3 points ($P < 0.05$), and the ODI decreased from 46.3±5.2% to 12.4±1.7% ($P < 0.05$) (**Table 3**).

Discussion

In 2013, the AO Spinal Internal Fixation Society proposed a new classification of thoracolumbar fractures [13], which simplifies the classification of thoracolumbar fractures and facilitates its clinical application. According to the statistics, type B fracture in the thoracolumbar segment with nerve injury accounts for 32% of all thoracolumbar fractures [16]. C-type fracture is relatively rare, accounting for 19.3%, with a 55% incidence of nerve injury; whereas the incidence of nerve injury in C-type nerve injury with complete fracture dislocation is almost 100% [17]. Owing to the particularity of its anatomical structure and biomechanics, the treatment principle of thoracolumbar fractures remains controversial [4, 18, 19]. Surgical approaches include anterior, posterior, and combined anterior and posterior surgery; and posterior short segments or long segments are common for fixation. In our study, according to the AO classification of thoracolumbar fractures, for type B and type C fractures, the failure rates of posterior fixation alone were comparatively high, up to 45.2% and 41.9%, respectively. A three-column injury of the spine is unstable, and it is difficult to stabilize the spine with a single fixation approach, regardless of the anterior or posterior approach. Biomechanical data indicate that the anterior middle column accounts for 80% of the stability of the spine, while the posterior column accounts for only approximately 20% [20], which may be the main reason for the failure of the initial surgery. As 28 patients underwent primary surgery in local hospitals, the recognition of three-column injury of thoracolumbar fractures could be insufficient.

The stress load is mainly borne by internal fixation, which can easily lead to failure of internal fixation and kyphosis [21, 22]. McCormack et al. [14] proposed that a load sharing score ≥7 points could be an indication for anterior surgery, and found that all nine of the 28 patients with a score ≥7 points without anterior vertebral body weight construction experienced screw fracture in the posterior approach. In this study, 26 patients had a score ≥7 points, followed by 19 patients with short segment fixation and seven patients with long segment fixation, which also showed internal fixation fracture. Restoration of the normal spine sequence by anterior vertebral body reconstruction plays an important role in enhancing the stability of the spine and preventing internal fixation failure. Cho et al. [23] and Marco et al. [24] further improved the posterior technique on the basis of pedicle internal fixation by strengthening the fractured vertebral body with bone cement and injecting polymethyl methacrylate or calcium phosphate, respectively, which also achieved good results in the short term with no failure of internal fixation. Hao et al. [25] suggested a one-stage posterior approach plus interbody fusion surgery for unstable thoracolumbar fractures, which showed merits compared with posterior and anterior internal fixation in terms of operation time, blood loss, and related complications. Therefore, we believe that regardless of the anterior or posterior approach, it is essential to prevent internal fixation failure and reconstruct the stability of the anterior middle column of the fractured vertebra. In addition, the academic communication among hospitals should be strengthened so that the surgeons in the local

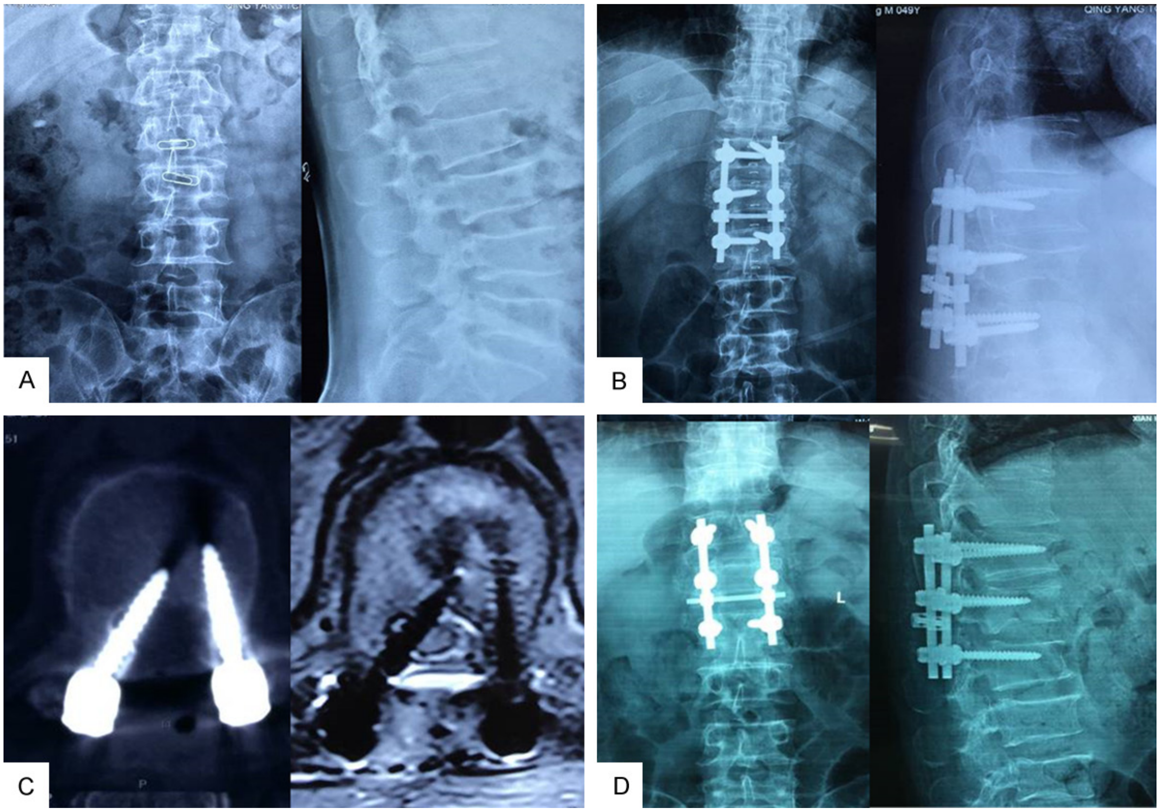

Figure 1. A 49-year-old male with L1 fracture underwent a posterior approach surgery in a local hospital; numbness and dyskinesia were manifested in the right lower limb after the operation. A. Preoperative X-ray showed L1 fracture; B. Posterior open reduction and internal fixation was performed in a local hospital; C. Postoperative computed tomography (CT) and magnetic resonance imaging (MRI) showed that the right pedicle screw completely entered the spinal canal; D. 1 year after surgery, X-ray showed good fracture union.

hospitals can have a better understanding of the classification of thoracolumbar fractures and choose proper treatment methods, reducing the chance of secondary surgery.

Despite the increase in the success rate of C-arm and navigation technology applied to pedicle screw placement, injury to the spinal cord and nerve caused by pedicle screw penetration into the spinal canal is still of concern. Technical error is one reason for the misplacement of internal fixations. The misplacement rate of pedicle screws is approximately 14% [26, 27]. In this study, three cases of spinal cord injury after screw placement were transferred from local hospitals to our hospital. The screw was removed and re-inserted and decompression was performed, and the postoperative pain at the lower back was slightly improved without recovery of neurological function.

Proper distraction of the fractured vertebral body can not only restore the height of the vertebral body, but also restore the volume of the vertebral canal with the tension of the anterior and posterior longitudinal ligaments and the fibrous ring of the intervertebral disc. For an extreme pursuit of fracture reduction, over-distraction of the vertebra will lead to the separation of the injured vertebral fracture, formation of vertebral cavity, overload of pedicle screw, and a notable increase in screw breakage and bone nonunion rate. In this study, overdistraction was observed in five patients, which was another cause of failed thoracolumbar fracture surgery, accounting for 16.13% (5/31) of the revision cases.

Intervertebral disc injury adjacent to thoracolumbar fracture (usually upper intervertebral disc injury) is also an important cause of chronic instability of the anterior and middle columns of the spine, which often leads to the failure of

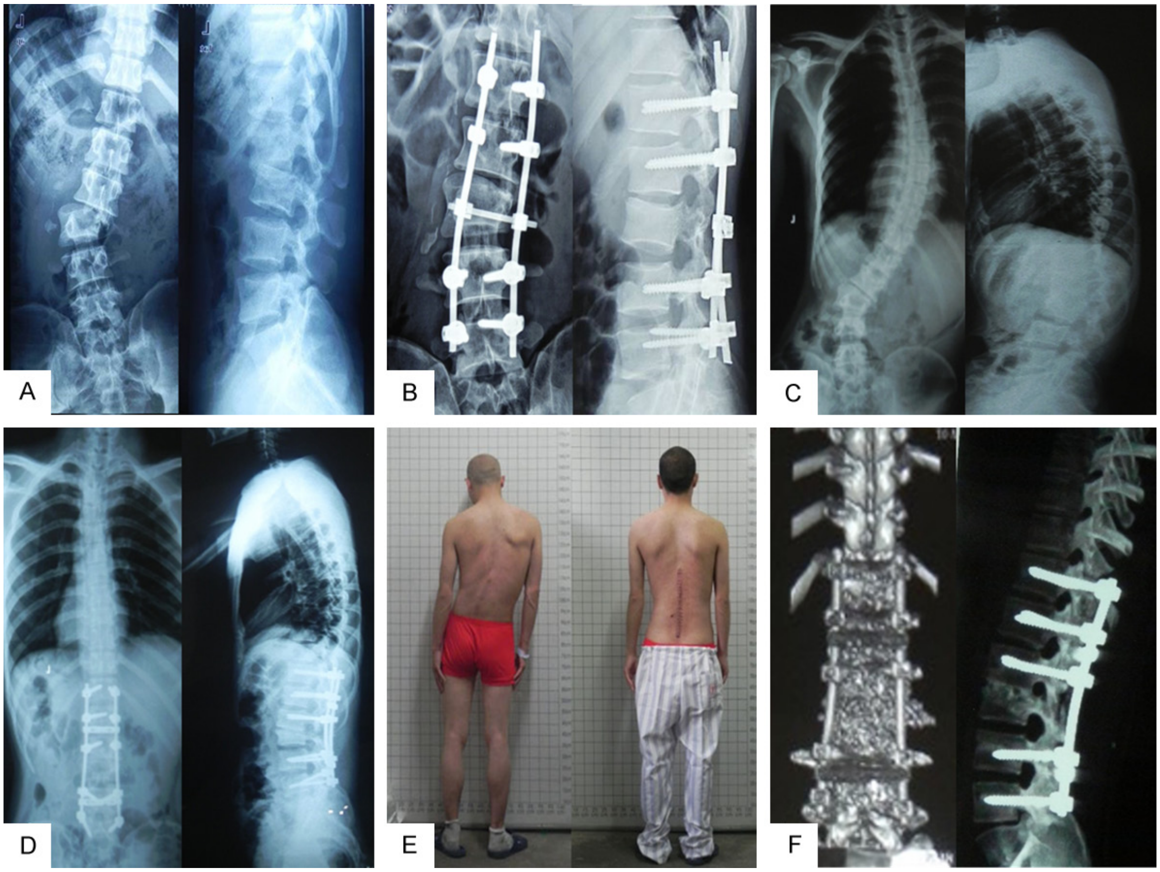

Figure 2. A 35-year-old male with L3 fracture and L2 dislocation underwent a posterior approach surgery in a local hospital. The patient's muscle strength recovered from grade 2 to grade 4 1 year after the operation. A. Preoperative X-ray showed L3 fracture and L2 dislocation; B. X-ray of the lumbar spine 1 year after surgery; C. Scoliosis deformity occurred 6 months after removal of the internal fixation; D. Posterior osteotomy, iliac bone grafting, and internal fixation, and the scoliosis was completely corrected; E. Trunk appearance before and after surgery; F. CT scan of lumbar spine 1 year after surgery.

internal fixation and the occurrence of scoliosis after removal of internal fixation. Some studies have proposed that the integrity of the disc above the fractured vertebral body is an important factor in maintaining the stability of the fracture, and patients with adjacent disc tissue damage are considered unsuitable for posterior fixation surgery [28]. In this study, B3- and C-type fractures were mostly accompanied by disc injury, and fracture healing could not indicate good spinal stability. One patient showed good fracture healing, but after internal fixation removal, scoliosis deformity gradually appeared and worsened. In the review of the primary data, disc injury between L2 and L3 was observed, and lateral dislocation occurred, which was neglected during the first operation, and disc injury did not heal over time. Therefore, another purpose of revision surgery for such patients is to correct the kyphosis deformity, reconstruct the balance of the coronal position, and obtain a strong fusion. Some scholars have included this in the category of traumatic kyphosis and proposed their own treatment methods. Benli et al. [29] suggested anterior surgery for vertebral fixation and reconstruction. The follow-up results of 40 patients with kyphosis for a minimum of 5 years showed that the angle of kyphosis was corrected from 51.4° to 8.4°. Suk et al. [30] compared anterior and posterior combined surgery with posterior closed wedge osteotomy in the treatment of traumatic kyphosis with neurological symptoms and found that despite a more demanding technique of posterior osteotomy, it could shorten the operation time and reduce intraoperative bleeding with better clinical effects. We believe that the early recognition of disc injury is essential. The one-stage anterior-posterior approach may be better as it combines the

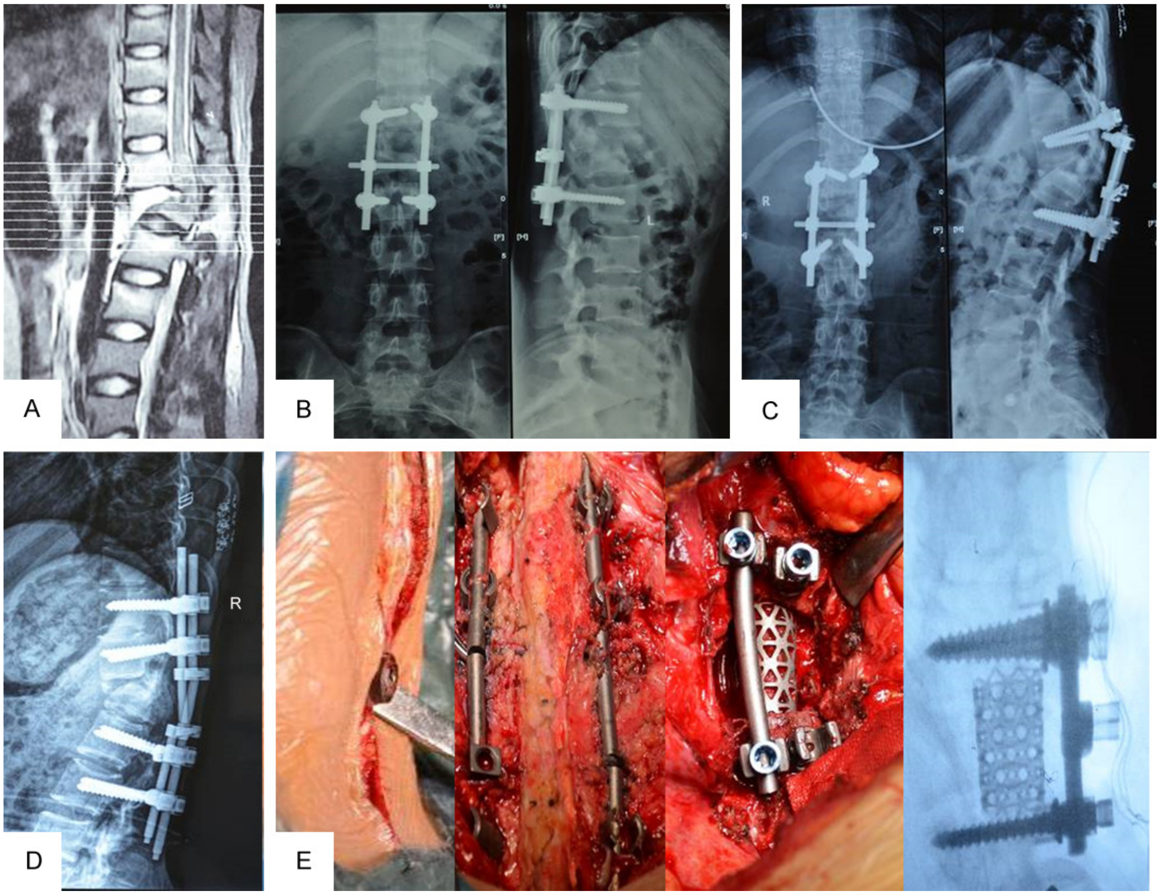

Figure 3. A 27-year-old female with L1 fracture and T12 dislocation underwent a posterior approach surgery in a local hospital. A. MRI showed L1 fracture with T12 dislocation and spinal cord injury; B. posterior short segment fixation was performed in a local hospital, postoperative X-ray showed that L1 had overdistraction; C. 1 year after surgery, X-ray showed screw fracture. D. The connecting rod fracture occurred 1.5 years after the secondary surgery in a local hospital. E. Posterior internal fixation instrument were removed and anterior titanium mesh bone graft fusion was performed in our hospital.

Table 3. The observation indicators before and last follow-up after revision surgery

	Before revision surgery	Last follow-up after revision sugery	P
Kyphosis angle, mean ± SD	40.5±15.3	2.3°±3.7°	< 0.05
Frankel classification, A/B/C/D/E	6/12/7/6/0	6/0/6/4/15	< 0.05
Visual analog scale, mean ± SD	6.9±0.7	2.4±1.3	< 0.05
Oswestry disability index, mean ± SD	46.3±5.2	12.4±1.7	< 0.05

advantages of anterior and posterior surgery in the reconstruction of the spine sequence and mechanical stability, which can provide strong three-column stability and reduce internal fixation failure and deformity. For the reconstruction of thoracolumbar type B and type C fractures with kyphotic deformity and obvious disc damage, if the adjacent vertebral defect is mild, posterior transpedicular wedge osteotomy is preferred to obtain stability and fusion of the anterior, middle, and posterior columns.

This is a single center retrospective study, and given the rarity of failed surgery, small sample size is a limitation inherent to study. Thus, further multi-center, large-sample-size study is recommended.

In conclusion, performing the posterior approach for every thoracolumbar fracture is inappropriate. The failure rate of the posterior approach alone was high for types B and C fractures and load sharing classification ≥7.

The goal of revision surgery is to reconstruct the anterior middle column of the spine and prevent a second internal fixation failure, and revision surgery can achieve good results for failed posterior surgery in most cases.

Disclosure of conflict of interest

None.

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