

# The efficacy of single-segment anterior decompression, fixation and fusion in the treatment of traumatic spondylolisthesis of the axis

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## Research article

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# Abstract

## Background

This study evaluated the clinical efficacy of single-segment anterior decompression, fixation and fusion in patients with traumatic spondylolisthesis of the axis.

## Methods

From January 2008 to January 2017, 49 patients with traumatic spondylolisthesis of the axis were treated in our centre using single-segment anterior decompression, fixation and fusion. Clinical and radiographic results were analysed. Clinical efficacy was evaluated according to the operative time and blood loss. The Frankel scale was used to evaluate neurological function. A visual analogue scale was used to assess neck pain. Bone graft fusion, instrumentation failure and cervical curvature were monitored via radiography.

## Results

The operative time and intraoperative blood loss of the 49 patients averaged  $90.5 \pm 4.6$  min and  $118.5 \pm 38.12$  ml, respectively. Intervertebral bone grafts were fused in patients with an average fusion time of  $6.7 \pm 1.0$  months (range, 5–8). Cervical curvature was significantly higher at 3 months and 1 year after surgery than before surgery, and the American Spinal Cord Injury Association score at 12 months after surgery was significantly higher than that before surgery.

## Conclusion

Single-segment anterior decompression, fixation and fusion can achieve remarkable curative effects in patients with traumatic spondylolisthesis of the axis including satisfactory anatomical reduction, and this strategy promotes the recovery of spinal cord nerve function.

## Background

Traumatic spondylolisthesis of the axis is a common blunt trauma that manifests as abnormal cervical spine alignment and decreased stability, and it is often accompanied by spinal cord injury, which may lead to pulmonary infection, vascular embolism or respiratory failure and may endanger patient survival in serious cases<sup>[1, 2]</sup>. The treatment of traumatic spondylolisthesis of the axis is generally dominated by surgical procedures. Reduction, decompression, bone grafting, internal fixation and other measures are often used to restore the normal alignment and physiological curvature of the cervical spine, relieve

compression of the spinal cord, re-establish cervical stability and promote the recovery of nerve function<sup>[3-5]</sup>.

The optimal surgical approach to traumatic spondylolisthesis of the axis has not reached a consensus. The compression in front of the spinal cord can be directly removed via single-segment anterior surgery, but resetting the facet dislocation presents certain difficulties<sup>[6]</sup>. Traumatic spondylolisthesis can be reset via single-segment posterior surgery, but this cannot remove the traumatic intervertebral disc herniation in the front<sup>[7]</sup>. Front and rear decompression, fixation and fusion can be applied simultaneously via combined anterior and posterior approach surgery. This strategy is more conducive to spinal cord decompression and facet dislocation reset, but it is associated with substantial trauma<sup>[8]</sup>.

We retrospectively analysed the case data of traumatic spondylolisthesis of the axis treated using single-segment anterior surgery to clarify its clinical impact.

## **Patients And Methods**

### **Patient population**

This retrospective analysis included 49 patients with traumatic spondylolisthesis of the axis who were treated between January 2008 and January 2017. The diagnosis of traumatic spondylolisthesis of the axis was based on clinical symptoms and radiographic findings [X-ray, computed tomography (CT), and magnetic resonance imaging (MRI)]. All patients had single-segment traumatic spondylolisthesis of the axis, and all areas of compression were located in front of the spinal cord and accompanied by neurological dysfunction. The exclusion criteria were as follows: 1) vertebral height loss exceeding 20% or burst fracture of a vertebra; 2) developmental cervical spinal stenosis, ossification of the posterior longitudinal ligament or ossification of the yellow ligament; 3) ankylosing spondylitis, rheumatoid arthritis and other autoimmune diseases; 4) fractures in other parts of the spine that affected neurological function; 5) severe compression of the cervical spinal cord before injury; 6) severe heart, liver, kidney or lung disease or haematopoietic and endocrine diseases; 7) severe infection, tuberculosis or metabolic bone disease; mental disorder or long-term coma combined with severe craniocerebral injury; 8) refusal or inability to undergo surgical treatment; 9) injury lasting for more than 3 weeks; 10) more than one segment of fracture dislocation; and 11) osteoporosis, vertebral disease or pre-existing spinal deformity. The study protocol was approved by the ethics review committee of our hospital, and all patients provided written informed consent.

### **Preoperative preparation**

Prior to surgery, all patients received rehydration, nutritional nerve and other treatments. Patients were administered a standard dose of methylprednisolone within 8 h after injury.

### **Surgical procedure**

The supine position was used to maintain skull traction. A C-arm X-ray was used to identify the injured segment. A right transverse incision was made with the injured vertebra as the centre. The damaged intervertebral disc and part of the posterior longitudinal ligament were removed, and complete decompression was performed. The tension of the retractor was adjusted to restore the height and physiological curvature of the damaged segment vertebral body, and then rotary traction was performed to move the dislocated vertebral body to its proper position. Cervical spine alignment was restored to normal, and an intervertebral cage with bone grafting was imbedded. Then, the titanium plate was fixed (Fig. 1). Somatosensory and motor evoked potentials were continuously monitored using an evoked potential detector during surgery.

## Postoperative management

A tracheotomy bag was prepared beside the bed, and symptomatic treatment including rehydration, nutritional nerve and analgesia was adopted. The drainage tube was removed when the 24-h drainage volume was less than 5 ml. Positive and lateral X-ray images and CT or MRI of the cervical spine were examined 1 week after surgery. Once the patient was ambulatory, a custom orthotic protected the cervical spine for 6 weeks, allowing normal movement of the neck after bone graft fusion.

## Evaluation standard

Operative time, blood loss and complications were recorded. The patients were followed up 1, 6 and 12 months after surgery and then once annually thereafter. The visual analogue scale (VAS) was used to assess the intensity of neck pain, and the American Spinal Cord Injury Association (ASIA) scale was used to assess neurological function. X-ray or CT was used to observe the position of internal fixation, cervical curvature<sup>[9]</sup> and the condition of the intervertebral bone graft fusion<sup>[10]</sup>.

## Statistical analysis

SPSS 19.0 (SPSS, IL, USA) statistical software was used for statistical analysis. VAS and cervical curvature between preoperative and postoperative were compared using a paired-samples *t*-test. The Wilcoxon symbolic rank test was used for ASIA classification comparison. The significance level was set as 0.05 on both sides.

## Results

The 49 included patients consisted of 28 males and 21 females with an average age of  $40 \pm 9.5$  years (range, 22–73). The sites of traumatic spondylolisthesis of the axis were C3–4, C4–5, C5–6 and C6–7 in 10, 14, 13 and 12 patients, respectively. The mean operative time was  $90.5 \pm 4.6$  min, and the mean blood loss was  $118.5 \pm 38.12$  ml. Cervical spine curvature was significantly improved after surgery compared with that before surgery ( $P < 0.05$ ), and no significant loss of curvature occurred during follow-up ( $P > 0.05$ , Table 1). VAS at 3 months after surgery was significantly improved compared with that before surgery, and further improvements were recorded at 12 months after surgery ( $P < 0.05$ , Table 1). Before

surgery, the ASIA scores were A, B, C and D in 0, 10, 20 and 19 patients, respectively. Following surgery, the ASIA scores were C, D and E in 3, 24 and 12 patients, respectively.

The mean follow-up period was  $23.7 \pm 8.2$  months (range, 12–48). All intervertebral bone grafts fused with a mean fusion time of  $6.7 \pm 1.0$  months (range, 5–8). Reduction was not achieved in one case of a dislocated facet. Two cases of postoperative discomfort when swallowing eased within 6 months after surgery. No occurrence of epidural haematoma formation, aggravation of spinal cord injury, laryngeal nerve injury or tracheoesophageal fistula was found in any patients after surgery. No implant-related complications, such as screw loosening, fracture or displacement, were found during follow-up.

## Discussion

Traumatic spondylolisthesis of the lower cervical spine is a serious injury that affects spinal cord function and even endangers the lives of patients. Its characteristics are as follows: 1) abnormal cervical spine alignment affects stability; 2) most vertebral segments with spondylolisthesis also exhibit disc injury or herniation, resulting in spinal cord compression or injury; and 3) varying losses of cervical intervertebral height and physiological curvature [11, 12]. The basic principles of treatment are restoration of the normal cervical alignment, complete decompression, restoration of intervertebral height and physiological curvature and reconstruction of immediate stability of the cervical spine [13]. Operation is the gold standard to cure traumatic spondylolisthesis of the axis. It is crucial to reduce pressure and restore the normal sequence of spinal stability to create conditions facilitating the recovery of neural function [14]. Traumatic spondylolisthesis of the axis can be caused by anterior cervical discectomy and distraction between vertebral bodies [15, 16]. Anterior surgery with less trauma, less bleeding and simple exposure can restore the normal cervical spine sequence, intervertebral height and physiological curvature, and it is characterised by high fusion rates, few fusion segments and guaranteed spinal activities [17, 18]. At the same time, it avoids secondary spinal cord injury that may be caused by postural changes during anterior and posterior surgeries [17, 18]. According to the study results after surgery, all cases of spondylolisthesis were completely reset, intervertebral bone grafts were fused and no loss of cervical intervertebral height and physiological curvature with good stability of the cervical spine was observed, consistent with previous results.

It would be combined with intervertebral disc injuries or herniations when Traumatic spondylolisthesis of the lower cervical spine occurred with compression mainly in the front of the spinal cord. Therefore, the surgery successfully accomplished direct decompression of the spinal cord, fully relieving the compression of the spinal cord, restoring the effective capacity of the cervical spinal canal and providing conditions for the recovery of neurological function [19]. In prior research, all patients had a better ASIA score after surgery, which is consistent with our results. This indicates that single anterior decompression, fixation and fusion can provide conditions for spinal cord functional recovery and a curative effect.

Anterior surgery is highly effective for correcting spinal cord decompression and facilitating the immediate recovery of cervical curvature. In addition, anterior intervertebral bone graft fusion can avoid

the dysplasia of cervical curvature caused by secondary collapse of the injured intervertebral disc [6]. This study indicated that the recovery of the cervical sequence and physiological curvature is achieved through anterior surgery, but it is difficult to reset the rear facet fracture dislocation using this strategy. This surgery is also prone to aggravate the spinal cord damage caused by excessive intervertebral distraction, especially in cases of severe damage joint disorder. The anterior-posterior approach failed to reset one facet dislocation in this study, and thus, anterior surgery had a certain failure rate (2.04%). However, there were no secondary complications of spinal cord injury. We might add posterior surgery to reset facet fracture dislocation for normal articular process correspondence when anterior surgery fails.

However, there was less impact on the clinical curative effect if the dislocation was not reset. Two patients experienced postoperative discomfort when swallowing eased, but both cases were resolved within 6 months after surgery. It has been reported that bone graft displacement, prosthesis formation, hoarseness, cerebrospinal fluid leakage and other complications are common after anterior cervical surgery, and adjacent segment degeneration is accelerated [19]. However, in this study, there were no cases of epidural haematoma, aggravation of spinal cord injury, recurrent laryngeal nerve injury and tracheoesophageal fistula. During the follow-up period, there were no implant-related complications, such as loosening, fracture and internal fixation displacement.

This study had a few limitations. First, this was a retrospective study with a small sample size. Large-sample, multi-centre and randomised prospective studies are needed to verify its conclusions. This study lacked an evaluation of quality of life. The follow-up time was relatively short, and the long-term effects were not discussed.

## Conclusions

Single-segment anterior decompression, fixation and fusion in the treatment of traumatic spondylolisthesis of the axis can obtain satisfactory anatomical repositioning, provide a distinct curative effect and promote the recovery of spinal cord function.

## Abbreviations

VAS: Visual analog scale; CT: Computed tomography; MRI: Magnetic resonance imaging; Pre-op: pre-operation; Post-op: post-operation; ASIA: American Spinal Injury Association; SEPs: Somatosensory evoked potentials; MEPs: motor evoked potentials.

## Declarations

Ethics approval and consent to participate

Ethical approval from the Ethics Committee of the Shaanxi Provincial People's Hospital was obtained for this study. Each author certifies that all investigations were conducted in conformity with ethical principles. Written informed consent was obtained from all patients included in the study.

## Consent for publish

All patients signed informed consent to publish their personal details in this article.

## Availability of data and materials

The datasets supporting the conclusions of this article are included within the article. The raw data can be requested from the corresponding author on reasonable request.

## Competing interests

The authors declare that they have no competing interests.

## Funding

N/A

## Authors' contributions

DZ, YZ and JL participated in the recruitment, data collection and analysis. All authors contributed to the study design and drafting of the manuscript. All authors read and approved the final manuscript.

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## Tables

**Table 1.** Patient characteristics and surgical outcomes

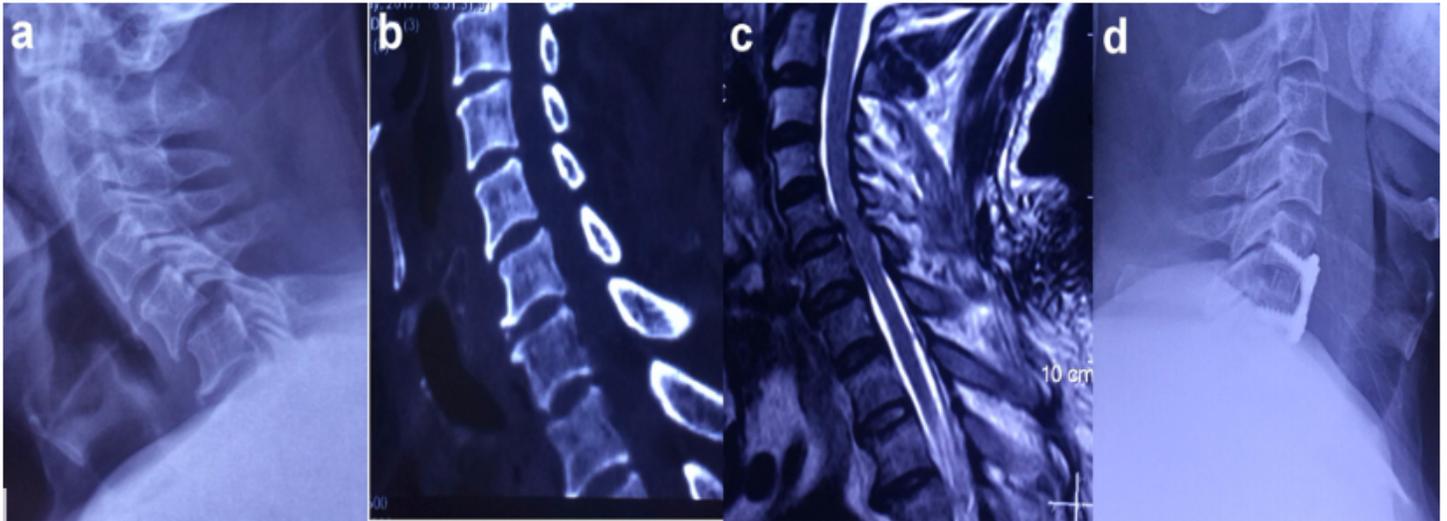
Characteristic	Pre-op	Post-op 3 months	Post-op 12 months
VAS	7.6±0.79	3.3±0.72*	1.3±0.44 <sup>#</sup>
Cervical curve (mm)	5.4±0.85	8.7±0.84*	8.6±0.40

Pre-op, Preoperative; Post-op, Postoperative; VAS, visual analogue scale

\*□ Post-op 3 months vs. Pre-op,  $P < 0.05$

<sup>#</sup>□ Post-op 12 months vs. Post-op 3 months,  $P < 0.05$

## Figures



**Figure 1**

A 58-year-old male with C5–6 spondylolisthesis caused by a fall (ASIA grade C) underwent single-segment anterior decompression, fixation and fusion. (a, b) Preoperative cervical X-ray and computed tomography revealed C5–6 spondylolisthesis. (c) Preoperative cervical magnetic resonance imaging revealed C5–6 segment spinal cord injury. (d) Postoperative X-ray revealed the recovery of the normal cervical spine sequence and curvature.