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Anterior cervical distraction and screw elevating–pulling reduction for traumatic cervical spine fractures and dislocations

A retrospective analysis of 86 cases

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Abstract

Treatment of cervical fracture and dislocation by improving the anterior cervical technique.

Anterior cervical approach has been extensively used in treating cervical spine fractures and dislocations. However, when this approach is used in the treatment of locked facet joints, an unsatisfactory intraoperative reduction and prying reduction increases the risk of secondary spinal cord injury. Thus, herein, the cervical anterior approach was improved. With distractor and screw elevation therapy during surgery, the restoration rate is increased, and secondary injury to the spinal cord is avoided.

To discuss the feasibility of the surgical method of treating traumatic cervical spine fractures and dislocations and the clinical application.

This retrospective study included the duration of patients' hospitalization from January 2005 to June 2015. The potential risks of surgery (including death and other surgical complications) were explained clearly, and written consents were obtained from all patients before surgery.

The study was conducted on 86 patients (54 males and 32 females, average age of 40.1 ± 5.6 years) with traumatic cervical spine fractures and dislocations, who underwent one-stage anterior approach treatment. The effective methods were evaluated by postoperative follow-up.

The healing of the surgical incision was monitored in 86 patients. The follow-up duration was 18 to 36 (average 26.4 ± 7.1) months. The patients achieved bones grafted fusion and restored spine stability in 3 to 9 (average 6) months after the surgery. Statistically, significant improvement was observed by Frankel score, visual analog scale score, Japanese Orthopedic Association score, and correction rate of the cervical spine dislocation pre- and postoperative ($P < .01$).

The modified anterior cervical approach is simple with a low risk but a good effect in reduction. In addition, it can reduce the risk of iatrogenic secondary spinal cord injury and maintain optimal cervical spine stability as observed during follow-ups. Therefore, it is suitable for clinical promotion and application.

Abbreviations: ACCF = anterior cervical corpectomy and fusion, ACDF = anterior cervical discectomy and fusion, C = cervical, CT = computed tomography, JOA = Japanese Orthopaedic Association, MEPs = motor evoked potentials, MRI = magnetic resonance imaging, SEPs = somatosensory evoked potentials, SPSS = Statistical Program for Social Sciences, T = thoracic, VAS = visual analog scale.

Keywords: cervical spine, dislocation, elevating-pulling reduction, fracture, screw, spinal cord injury

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1. Introduction

Traumatic cervical spine fracture and dislocation are common in clinical practice. Among the major severe spinal injuries, cervical spine fracture and dislocation often cause 3-column structural damage to the cervical spine, injury to the spinal cord, and precipitating alignment of the cervical vertebrae as well as cervical instability, which are detrimental, show poor prognosis, and high rate of mortality rate and disability.[1] To achieve reduction as early as possible, the most effective and direct method is the removal of spinal cord compression, reducing neuronal deaths, and recovering neurological function. Greg-Anderson et al[2,3] retrospectively reviewed 55 cases of unilateral or bilateral locked facet joints and dislocations and followed up for 5 years. The study found that early surgical decompression and reduction exerted a clear effect on the recovery of neurological function in young patients; however, selecting a surgical approach is not significant with respect to the recovery. In the case of patients with multiple injuries, one-stage anterior approach can reduce the risk of secondary spinal cord injury caused by carrying and transporting. On the contrary, for patients with a thoracic or abdominal injury, it could prevent the negative influence on blood pressure, heart rate, and respiration occurring due to the chest and abdominal compression caused by the prone position. The anterior approach can remove the fragmented intervertebral disc completely and directly decompress causing fewer complications; thus, it is popular among many spine surgeons. Therefore, the anterior approach decompression and internal fixation have been recognized as the first choice.[4] However, at our center, the conventional anterior approach reduction for zygopophysis interlocking is challenging as the prying reduction increases the risk of secondary spinal cord injury during the operation; thus, a better anterior approach reduction is essential.

2. Clinical data and methods

2.1. General information

The Ethics Committee of Tongji University Affiliated Oriental Hospital approved the present retrospective study and complete access to the patient's imaging data and medical records. In addition, we also have acquired the patients' informed consent. A cohort of 86 patients with traumatic cervical spine fractures and dislocations, who received one-stage anterior approach treatment between January 2005 and June 2015, were included in the study. The inclusion criteria were as follows: posttraumatic with a backward shift of the bone fracture fragment or spinal cord compression due to posttraumatic disc herniation; Allen-Ferguson classification of distraction–flexion injuries: degree II and III; Cooper classification of bone fractures by morphology: type I. The exclusion criteria were as follows: ankylosing spondylitis; zygapophyseal jointfracture with shifting fragments; severe osteoporosis (T-value <-3.0); previous fracture and dislocation; intolerance to operation due to a poor general condition.

Forty-four patients were injured in a traffic accident, 17 were admitted after fall-related injury, 12 wounded by a falling object, and 13 fell over accidentally. Among these patients, 18 also presented injuries of limb, pelvis, cranium and brain, and chest or abdomen, and 4 had undergone tracheotomy upon admission. Seven patients were sent to the hospital in <8 h after being injured, 47 in 8 to 24 h, 23 in 24 to 48 h, and 9 after >48 h. The cohort comprises 54 males and 32 females, aged 20 to 73 (average, 40.1 ± 5.6) years. Frankel score[5] was A in 11 cases, B in 29 cases, C in 31 cases, D in 13 cases, and E in 2 cases (Table 1).

2.2. Imaging data

All the patients underwent conventional preoperative radiographical examinations, as well as visual analog scale (VAS) and Japanese Orthopedic Association (JOA) score evaluation. The severity of dislocation, based on the Allen–Ferguson classification, was degree II in 54 cases and degree III in 32 cases.[6] The fracture and dislocation were related to C (cervical) 3 to 4 in 6 cases, C4 to C5 in 19 cases, C5 to C6 in 34 cases, and C6 to C7 in 27 cases. The discontinuity or disappearance of physiological curvature of the cervical spine was found in all cases and associated with vertebral adnexa (spinous process) fracture in 47 cases, bilateral locked facet joints in 22 cases, unilateral locked facet joints in 54 cases, and no locked facet joints in 10 cases. An x-ray revealed a kyphosis angle of 20° to 37° (average $24 \pm 4.3°$), and cervical vertebra displacement by 5 to 20 mm (average 13 ± 3.7 mm). Magnetic resonance imaging (MRI) indicated 71 cases of annulus fibrosis ruptures and nucleus pulposus herniations, 19 cases of spinal cord contusions, and 4 cases of spinal cord signal interruptions.

2.3. Operation method

After successful anesthesia and preoperative preparation, all patients were placed in a supine position, with the shoulders and back elevated and the neck slightly extended. The injured vertebra was positioned with the help of G-arm fluoroscopy. A transverse incision was made on the right side of the neck (Smith–Robinson approach). Blunt dissection was performed from the space between cervical vessel sheath and tracheoesophageal sheath to the prevertebral fascia. The G-arm fluoroscopy was used to confirm the injured segment, displacement, and the midline of the vertebral body. The adjacent vertebral body higher to the injured vertebral disc or the 2 adjacent vertebral bodies lower than the injured disc were drilled (Fig. 1B). A Caspar pin was driven into the drilled hole. The Caspar vertebral body retractor was installed and used for longitudinal distraction until a particular tension similar to the surrounding soft tissues was achieved. An anterior cervical titanium plate with a length equivalent to the distance of distraction by the retractor was placed between the 2 Caspar pins. The distraction force of the retractor was reduced appropriately to allow the anterior cervical titanium plate to be securely squeezed between the 2 Caspar pins. Then, the dislocated vertebra described above was drilled through the hole in the middle of the plate (Fig. 1C). A half-thread cancellous bone screw with a 3.5-mm diameter and 18- to 22-mm length (depending on the sagittal diameter of the vertebra and dislocation distance) was driven into the drilled hole by a constant force and elevated and pulled until it was pressed against the titanium plate (Fig. 1B, G). In the event that the reduction was unsatisfactory due to decrease in the holding strength caused by facet interlocking or osteoporosis, a same lag screw could be driven to the 1st adjacent vertebral body higher to the vertebral body where the first screw was placed until complete vertebral reduction was achieved (Fig. 1D, H). The position of the screw

Table 1

Frankel grades of neurological functions in patients with cervical spine fractures and dislocations before surgery and during the last follow-up visit (cases).

Grade before surgery	No. of cases	Grade 7 days after surgery					Last follow-up visit
		A	B	C	D	E	
A	11	6	4	1	0	0	4
B	29	2	10	14	3	0	6
C	31	0	0	5	22	4	12
D	13	0	0	0	1	12	30
E	2	0	0	0	0	2	32
Total	86	8	14	20	26	18	84

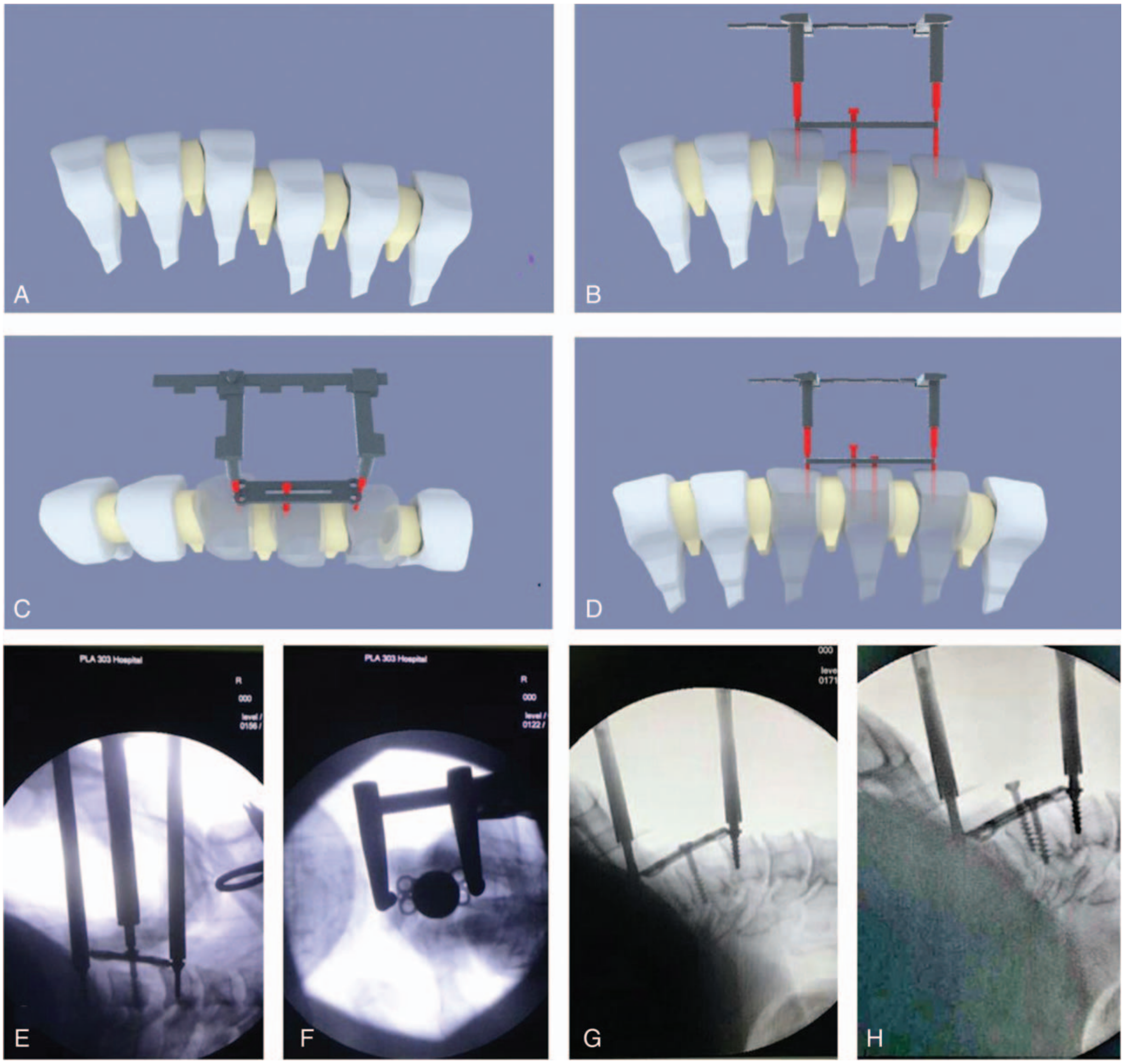

Figure 1. The illustration of operation is as described: (A–D) three-dimensional simulation operation figures; (E–H) images of the operation guided by intraoperative X-ray examination with G-arm fluoroscopy. (A) A cervical fracture and dislocation model. (B) The confirmation of zygopophysis interlocking based on the preoperative image. We installed the Caspar vertebral retractor in the upper and lower vertebral body than the injured vertebral body. Then, the zygopophysis joint was restored to the neutral position by gradual distraction. We installed the measured anterior titanium plate between the retractor fixation needles, followed by loosening the retractor slightly to tighten the fixation screw; then, the titanium plate was firmly fixed. Next, we put a half thread cancellous bone screw with a 3.5-mm diameter and 18- to 22-mm length that gradually pulled up the dislocated vertebral body (G-arm fluoroscopy; E, G). (C) The overhead view of the operation area (G-arm fluoroscopy; F) in which, the screw entering the central hole of titanium plate is apparent, and the vertebral body is restored with assistance of the pulling force of both the thread of the screw and the margin of the central hole of titanium plate. To avoid the screw going extremely deep into the vertebral body, it is placed into a maximum 3/4th of the horizontal length of the vertebral body. Commonly, most of the dislocated vertebral bodies could be completely restored. (D) The situation when the first screw could not be completely restored or the patient had mild-to-moderate osteoporosis ($T < -3.0$); in this case, we placed an extra screw in front of the previous screw. The distance between the 2 screws was 0.5 to 1 cm (G-arm fluoroscopy; H).

varied with different conditions of the locked facet joints. In the case of unilateral locked facet joints, the screw was placed on the side of the locked facet joints, near the midline; if it is presented as bilateral locked facet joints, the screw was placed at the midline. This method was also utilized for coronal dislocation; however, the angle of the screw was not completely vertical to the anterior side of the vertebral body. In this case, we would tilt the screw 10° to 15° to the dislocated side. A complete reduction could not be achieved in some patients mainly because of osteophyte obstruction after cervical spine degeneration as assessed by the computed tomography (CT) images. Here, the complete reduction is unnecessary. Nevertheless, we need to expand the decompression area appropriately in a subsequent decompression process. Consequently, the injured vertebral disc was removed and the bone grafting was performed with an interbody fusion cage. In the case of severe degenerative change and obvious osteoproliferation on the posterior edge of the vertebra, a corpectomy was performed on the affected cervical vertebral segment with injured spinal cord for a systematic decompression, followed by bone graft with titanium mesh; an appropriate anterior cervical locking titanium plate was selected. The screws were fixed and tightened. The G-arm fluoroscopy was used for an X-ray examination, which, if satisfactory, led to the cleaning and closure of with a drainage tube placed inside the incision.

The choice of anterior cervical corpectomy and fusion (ACCF) or anterior cervical discectomy and fusion (ACDF) depends on the evaluation based on the preoperative function-related scores. ACDF applies to patients with mild nerve injury symptoms and does not have spinal cord injury, cervical spinal canal stenosis, or ossification of the posterior longitudinal ligament. On the contrary, ACCF is suitable to those with cervical spinal canal osseous stenosis, severe cervical degeneration, or spinal cord compression by the fracture fragment after cervical reduction, or complete paraplegia where MRI shows spinal cord with high signal intensity. If we select ACDF as the method of operation, the autogenous bone fragments are adopted as a bone graft, which were removed from the rear side of the vertebrae and the vicinity of the intervertebral space during decompression procedure.[7]

During the operation, we continuously monitored the somatosensory evoked potentials (SEPs) and motor evoked potentials (MEPs) using Nicolet Viking VI evoked potentials. The recording electrodes were placed on the contralateral scalp C3’ or C4’ according to the system standard developed by the International Electrographic Society, and the reference electrode was placed at the FPz point. For the diseased segment above C6/C7, the stimulus electrode was placed on the wrist to stimulate the median nerve for the C7 vertebral body, and for the C7/T1 injury, the electrode was placed on the wrist to stimulate the ulnar nerve. For the transcranial electrical stimulation of the MEPs at the location, the Nicolet special disc stimulation electrode placed in the cortical movement area, which is 1 to 2 cm anterior to the C3 and C4 points of the International Conference proposing 10/20 system. The number of stimulating pulses is 4, the pulse interval is 2 ms, the stimulus intensity is 0 to 400 V, the recording time is 10 ms, and the bandwidth is 20 to 3000 Hz. The recording electrodes use needle electrodes with left and right limb symmetry. To monitor the upper limbs, the electrodes were placed in the abductor pollicis muscle and abductor digiti minimi muscle; the electrodes were placed in the anterior tibialis and gastrocnemius muscle for monitoring the lower limbs. SEPs and MEPs are repeated 1 to 2 times during each operation to ensure the stability of the waveform of the MEPs.

2.4. Observation indexes

All patients were assigned a JOA[8] score for the cervical spinal cord injury according to the JOA scoring system. The VAS score[9] and Frankel score were evaluated before the operation, 7 days, 3, 6, and 12 months after the surgery as well as the final follow-up visit. Furthermore, these data were compared for analysis.

2.5. Statistical analysis

Statistical Program for Social Sciences (SPSS 17.0) was used for all the statistical analyses. The measurement data were expressed as mean ± SD ($x \pm s$). Two independent samples t test was utilized for data comparison. $P < .05$ indicated a statistically significant difference.

3. Results

The operations were completed successfully in 86 patients, and primary healing was achieved. The rate of total reduction was 90.69% (78/86), and 97.6% (83/86) of the cases demonstrated a minimum of 85% reduction. An intraoperative vessel injury was not found in any of the patients. Four patients presented cerebrospinal fluid leak, who achieved a delayed incision primary healing after elevating the head of the bed that alleviated the swelling of the tissue and prevented the infection (dressing was changed and kept dry in the case of contamination and postoperative infection). One patient had postoperative hoarseness, which might have been caused by intraoperative laryngeal nerve traction; however, it was relieved 2 weeks after receiving postoperative medications for nourishing the nerves (the medicines that revitalize and repair the nerves). One patient had postoperative C5 nerve root palsy that was cured within 6 months after therapy for nourishing the nerves. We used ganglioside as the medication for repairing the neurons (ganglioside serves as only one part of the routine treatment regime in our department). Currently, it lacks sufficient SCI evidence to prove the efficiency in the treatment of spinal injury; thus, it should be cautiously applied. In the acute stage of the disease (especially acute trauma), 100 mg/day was administered by an intravenous drip. After 2 to 3 weeks, the dosage was altered to 20 to 40 mg/day as a maintenance dosage. The medication is administered to patients over a duration of 6 weeks. If the neural function classification is below class C, or accompanied by a peripheral nerve defect, the treatment would be prolonged to 18 to 20 weeks. Six patients had postoperative lung infection that was cured after aerosol inhalation and antibiotic treatment. Five patients had central hyperpyrexia and 7 presented central hyponatremia, which were cured 3 weeks after the surgery by symptomatic treatment. One patient died of myocardial infarction 1 year after the operation, and 1 immigrated to another country; the remaining patients were followed up until the end of the final follow-up visit. The follow-up time was 18 to 36 (average, 26.4 ± 7.1) months. The fusion of grafted bones was achieved, and spinal stability restored 3 to 9 (average, 6) months after the surgery. A statistically significant difference was observed using the Frankel score, VAS score, and JOA score before and after the operation ($P < .01$) (Tables 1 and 2).

4. Discussion

With a booming economy, the pace of life is incredibly rapid. In addition, the incidences of traumatic cervical spine fractures and dislocations have been increasing annually. However, poor prognosis, as well as high rates of mortality and disability arising from such injuries, is under intense focus in the field of spine and spinal cord injury. There is a relatively strong disagreement on the

Table 2

Comparison of JOA scores and VAS sores ($x \pm s$).

Score	No. of cases	Before surgery	1 week after surgery	3 months after surgery	6 months after surgery	12 months after surgery	Last follow-up visit (84 subjects)	F	P
VAS	86	6.58 ± 3.41	3.85 ± 2.17	2.33 ± 3.21	1.74 ± 2.26	1.44 ± 2.63	1.53 ± 2.72	10.237	.028
JOA	86	7.81 ± 3.26	9.25 ± 4.47	11.36 ± 4.63	13.34 ± 4.52	12.83 ± 2.25	14.80 ± 2.84	9.879	.035

$P < .05$ was statistically significant.
JOA = Japanese Orthopaedic Association, VAS = visual analog scale.

therapies for different types of such injuries. The simple cervical anterior approach has been widely recognized and applied. However, the conventional anterior approach has several disadvantages,[10] and thus it is a hot research topic seeking a modified approach.

In this study, we focus on the distraction–flexion injury based on Allen–Ferguson classification. Here, the spinous processes at the level of the injury are typically presented as open fracture; on the contrary, when unilateral or bilateral facet joint dislocation or subluxation is present, fractures are noticed on the vertebrae, vertebral arches, and spinous processes. Furthermore, the dislocated vertebra is mostly complicated with the intervertebral disc injury or herniation, leading to spinal cord compression and injury.[11,12] The treatment comprises the reestablishment of the anatomical morphology and available space of the spinal canal to relieve the compression on the spinal cord and nerve root, as well as to recover the physiological curvature, intervertebral height, and stability of the cervical spine.[13–15] In that case, the advantages of complete anterior reduction, decompression, and fixation are more distinct than those of the simple posterior reduction, fixation, and indirect decompression. In addition, the cases included in this study were primarily classified as degree II and III distraction–flexion injuries, wherein the injuries of the posterior column structure and ligament complex were incomplete, and the stability of the posterior column had not been absolutely lost; also, the injury was less severe than that of the anterior and middle column. Furthermore, the forced posterior elevating–pulling reduction would potentially lead to anterior compression on the spinal cord and aggravate the injury and indirectly damage the stabilizing effect of the posterior cervical muscles and adhering fascia on the posterior column.[16] Several admitted patients also presented chest or abdomen, cranium, and brain injuries. For such patients, surgery in a prone position would render difficulty in administering anesthesia and maintaining a safe, vital sign; importantly, it would impose risk and cause unexpected complications. In addition, turning over the patients during the operation may also cause secondary spinal cord injury.[17,18] The anterior approach benefited these patients.[19–26]

Over the past few years, based on the measurement data of human anatomical specimens, the results of statistical imaging analysis, and using the slipped vertebra elevating-pulling technique for posterior spinal operation, we designed the anterior distraction and screw elevating–pulling technique for cervical spine fractures and dislocations. The operation is performed under general anesthesia so that the neck muscles are fully relaxed, thereby making it easy to conduct longitudinal distraction with Caspar vertebral body retractor. In the case of the complication of bilateral locked facet joints, the Caspar pins of the retractor should be installed at the midline of the coronal plane of the vertebra. For unilateral locked facet joints, such Caspar pins should be installed on the side of the locked facet joints, at a location slightly deviating to the midline; however, unnecessary distraction should be avoided in operation to prevent the traction-related spinal cord injury. After placement of the Caspar pins, a 0.5-cm-deep hole is drilled in the center of the dislocated vertebra. An anterior cervical titanium plate with an appropriate length that functions similar to the lifting arm of a crane is placed between the upper and lower Caspar pins. These pins are contracted to securely fix the titanium plate between them. Considering the sagittal displacement between the dislocated vertebra and the 1st adjacent vertebra lower than that affected, a lag screw is gradually driven to elevate and pull the vertebra through the hole in the middle of the titanium plate. A comparative analysis of the various screws demonstrated that the body (other than the tail) of the half-thread cancellous bone screw with a 3.5-mm diameter could passage through the hole in the middle of the titanium plate. For the bone of patients with mild osteoporosis, adequate holding and elevating–pulling strength are ensured. The sagittal diameter of the vertebra and dislocation distance should be measured by the CT scan, before the operation, to determine the length of the required screw. Currently, local microfracture has been found in a maximum number of target vertebrae, and thus the screw with a length equivalent to 3/4th of the vertebral height was selected in this study. The length of the screw is preferred to be 18 to 24 mm as an excessively long screw could squeeze the bone fragment into the posterior edge of the vertebra, thereby penetrating into the spinal canal further causing injury. In the elevating–pulling process, the vertebral reduction can be achieved in a continuous and stable manner, which effectively avoids further spinal cord injury resulting from the inhomogeneous force generated in the process of prying reduction. For the patient with a higher degree of vertebral slippage (III°, IV°) or complete dislocation, accompanied by unsatisfactory reduction, the same lag screw can be driven into the 1st adjacent vertebral body higher than the vertebral body where the first screw was driven until complete vertebral reduction was achieved.

In the current improved anterior cervical technique, the most important step is to accurately and slowly pull up the screw. The process of pulling should be stabilized to avoid the spinal cord concussion or compression when the facets bounce during reduction. In addition, the patient is operated with great caution and efficiently monitored for neural activity. Any drastic operation would be displayed as fluctuation of the wave amplification, which would direct the changes in our strategy of the operation. The dislocation of the cervical spine is caused by a sudden powerful force. Although some of the structure of the skeletal system is damaged, the soft surrounding tissue is complete, thereby maintaining a robust support system. Therefore, the restoration of the location by a tractor is rather challenging, following which a normal anatomical relationship is exhibited in most patients who had dislocations. Although the instability might persist, there was sufficient support for the decompression and bone grafting operation. As we had previously considered the difficulty at the initiation of the design of the operation, we were cautious that no downward force was imposed throughout the whole operation. Even if during the decompression we retain the lifting maneuver, it would not cause secondary dislocation. In the process of grafting the titanium cage, the posterior longitudinal ligament removal hook was used to pull the bone groove on the side of the dislocation for protecting the vertebral body from collapse. However, in our previous operations, although the hooker traction was not used, we did not find a repeated dislocation of any of patients' vertebral bodies.

For the preoperative treatment, we have improved the technique of the anterior surgery. First, excess time was reserved for the decompression of the cervical spinal cord of the patient. The spacious spinal canal is the prerequisite for reducing edema and compression of the local hematoma on the nerve root. Hence, traction before operation would delay the decompression. Simultaneously, the facet joint locking in some patients cannot be restored by the regular skull traction. The traction of heavy weight can lead to several unnecessary complications; for instance, skull traction cannot prevent the secondary injury caused by the compression from the intervertebral disc in the spinal canal and the bounce caused by the immediate restoration.[26] Moreover, heavy-weight traction could cause the soft tissue injury to the neck, avulsion of the scalp, and injury to the other segment of the cervical posterior column. Thus, we speculate that the skull traction is uncontrollable, and the patient merely requires neck immobilization.

Any operation might increase the risk of spinal cord injury, thereby necessitating the neurological monitoring during the procedure. In that case, we can complete the operation efficiently and ensure a better recovery of the patients. The observation criteria were as follows: the spine was exposure, followed by striping the paravertebral muscle and soft tissue, and before the decompression or operation reduction, the SEPs and MEPs were set as a baseline. The SEPs should be deemed as abnormal when the wave amplitude decreases by 50% or the potential wave are prolonged over 10%. For the MEP amplitude, any decrease >80% would be deemed as abnormal. A persistent disappearance of the wave indicates that the spinal cord function is severely disturbed or damaged. When the operation with a high risk disturbs the spinal cord, the affected part is usually the side of the operation, which shows a simultaneous decrease in the SEP and MEP amplitudes, an extension of the latent period, and little change in the waveform of the opposite side. In that case, the MEPs should disappear abruptly because of direct damage to the spinal cord. When the blood supply to the spinal cord decreases, the secondary factors, such as intraoperative spinal cord traction, can also lead to obvious electrophysiological changes, including a simultaneous reduction in the bilateral SEP and MEP amplitudes and extension of the latent period. In this study, we monitored all the patients; however, sharp fluctuation or disappearance of the wave was not found in those displaying spinal cord functions. In conclusion, we speculate that as long as the operation is conducted cautiously, this technique is safe and stable.

Nevertheless, spinal cord injury is yet a global concern based on our clinical observations and experience with the previous literature analysis.[1,2,4,6,17,21] Irrespective of the type of injury, surprisingly, the results of the surgical treatment for cervical fracture dislocation are superior to those of natural recovery therapy. This might be attributed to the following causes: first, the fracture and dislocation are usually caused by high-energy trauma. Second, the patients could have bone structural damage, such as spinal cord shock along with spinal cord injury. Some patients with spinal cord disruption might culminate into with general paralysis. However, spinal cord edema and spinal canal hematoma posttrauma can lead to secondary damage to the spinal cord. The surgical repair of the spine bone structure, improving the physiological sequence of the spine, and proper fixation can achieve immediate physiological stability. In addition, a full decompression of the spinal cord could create a beneficial environment for the neuron repair. Moreover, appropriate spinal canal space and spinal nerve channel would also serve as a prerequisite condition for the nerve cells to regrow. We did not observe any of these advantages in natural recovery therapy, as the unstable cervical spine might aggravate the spinal cord injury during the care delivery. The complications of a prolonged bed-stay might lead to catastrophic consequences in patients. However, after the improved technique of the anterior operation, rapid restoration in early stage and decompression can create the condition for the recovery of the spinal cord. Furthermore, the simplified method of operation, the small area of operation, stable restoration, and shortened duration of operation can reduce the complications of surgery, which cannot be achieved by the routine method.

The lower cervical spine is not stable if injured. According to the literature, necessary preoperative skull traction might increase the stability. We found that 3 patients developed the leakage of the cerebrospinal fluid during the surgeries, and after the surgery, the neurological functions failed to recover, although the dura maters were not injured during the surgery. The review of the preoperative and intraoperative CT images revealed that some bone fragments had moved and damaged the dura mater. In subsequent surgeries, we gave up the preoperative skull traction and immobilized the cervical spine with a cervical brace; finally, the incidence of cerebrospinal fluid leak decreased without the further aggravation of the spinal cord function due to posttraumatic instability. This phenomenon might be ascribed to the slippage of bone fragments during preoperative traction that caused the leak and worsened the spinal cord compression as well as paraplegia.[26,27] The postoperative pharyngeal pain, choking on water, C5 nerve root palsy, lung infection, and other postoperative complications are common manifestations of the anterior approach. According to statistics, the design of the modified operation was similar to the conventional anterior approach in the incidence of complications. Central hyperpyrexia and central hyponatremia are irrelevant to the surgical operation but correlated to the degree and segment of the spinal cord injury.

In this study, the rate of complete vertebral reduction was up to 90.69% (78/86); 90% reduction was achieved in 5 patients with osteoporosis. Also, we measured the dislocation shift height between the dislocated vertebral body and the adjacent normal vertebral body preoperatively using X-ray images. During the operation and after reduction, we again measured the dislocation shift height using the G-arm X-ray machine. Both the groups of data were compared: 78/86 patients gained complete reduction at a rate of 90.69%; 83 patients were found to achieve at least 85% reduction as compared with the initial distance, and thus the rate of 85% reduction was 97.6%. Only 3 cases demonstrated unsatisfactory reduction (reduction rate <85%) mainly due to soft tissue incarceration; the intraoperative X-ray examination with the G-arm fluoroscopy showed 80% reduction. After the decompression through vertebral subtotal resection, the volume of the spinal canal recovered, and the recovery of the spinal cord function was not adversely affected by such unsatisfactory reduction during the postoperative follow-up. The JOA score, Frankel score, and VAS score were found to be significantly improved during the postoperative follow-up, thereby indicating that the change in operation did not adversely affect the postoperative recovery without distinct differences between the recovery achieved by the modified operation and that as shown in previous studies using conventional reduction operation.[28] The high-energy injury of the lower cervical spine often affects the stability of the 3-column structure of the spine. The stability of the anterior and middle column is critical. We found that the injured segments fused 4 months after surgery in a majority of the patients. However, no obvious instability was revealed in the MR and CT images, as well as X-ray slides during the follow-up for 18 to 36 months; the stability of the cervical spine was adequate during the short- and mid-term follow-up (Fig. 2E–H: images during the 2-year follow-up postsurgery); a majority of the symptoms were significantly improved or disappeared after surgery. Therefore, it can be the modified operation, designed in the present study, and might exhibit a similar effect as that of conventional operation.

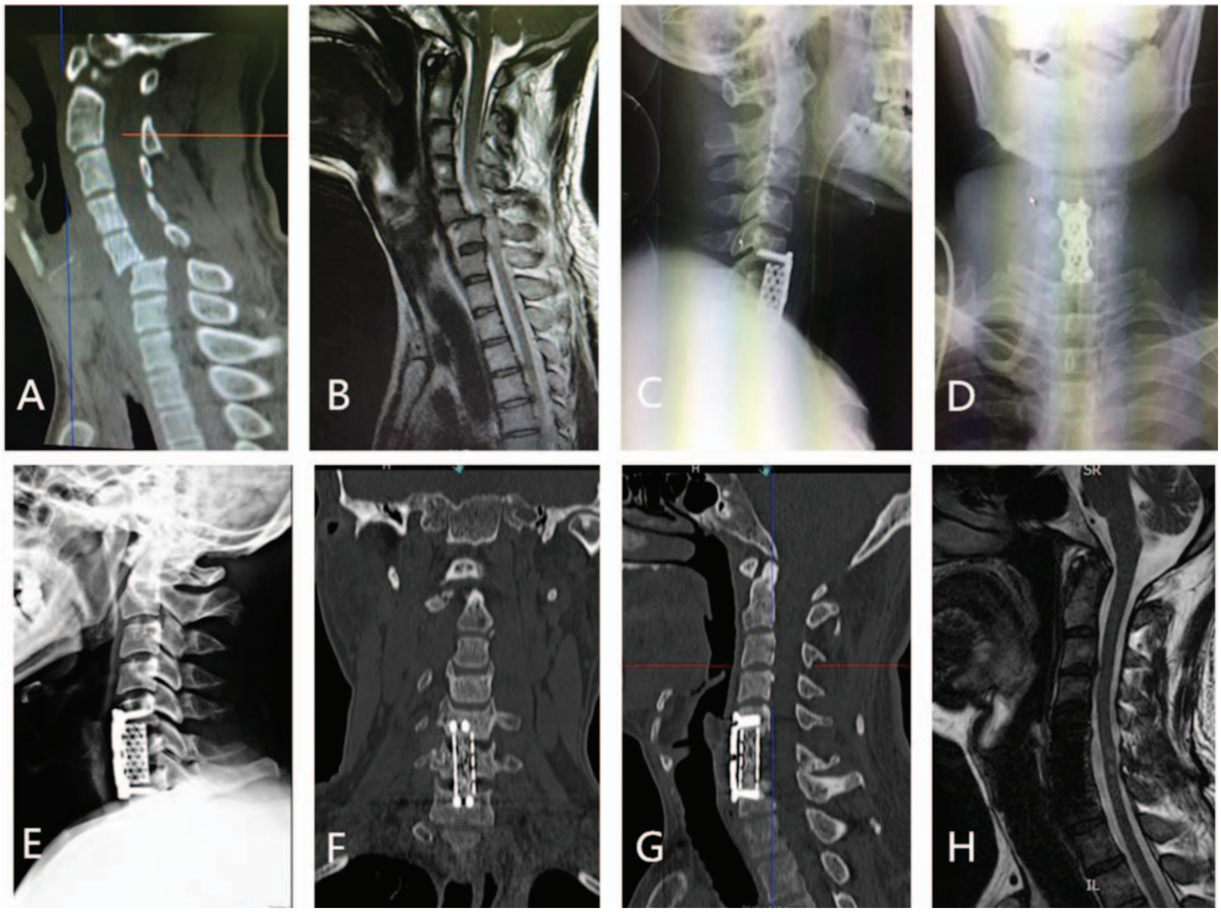

Figure 2. A 51-year-old male with C5-C6 fracture and dislocation caused by a traffic accident; Allen–Ferguson classification of distraction–flexion injury: degree III; preoperative Frankel score: C. ACCF was performed after reduction. (A) Preoperative sagittal CT images show C5 to C6 fracture and dislocation. (B) Preoperative MRI shows spinal cord compression due to C5 to C6 fracture and dislocation and disc herniation. (C, D) Postoperative anteroposterior and lateral radiographs were examined. (E) Lateral radiographs acquired 2 years postsurgery show normal physiocurvature of the cervical spine and disc space height. (F, G) CT reconstruction images obtained 2 years after the surgery show fusion of the grafted bones. (H) MR images were taken 2 years after the surgery show unobstructed spinal canal, good stability of the cervical spine, and fusion of the grafted bones.

To reduce the systematic error produced during operation as a result of the varying surgeons and to verify the reliability and objectivity of this technique, we selected the cases from the 3 surgery groups, and found no remarkable difference in the vertebral reduction rate, postoperative JOA score, Frankel score, and VAS score. Moreover, our technique does not require a specific instrument or material, thereby not imposing any increased financial or social health care burden on the patients. As a simple technique, it does not require excessive experience, and thus new young surgeons can also implement the technique. Although we have stated many benefits of this technique, it has some limitations. For patients with ankylosing spondylitis, the injury of the lower cervical spine is involved with the 3-column structure, and the fusion rate of fixed short segments is low; thus, the anterior approach is not applicable.[29,30] We observed that the scar formation and the obstruction of bone fragments caused an intraoperative reduction to be unsatisfactory in >74% of the patients with old fractures or facet joint fractures. In addition, under the circumstances that preoperative bone density *T*-score was <-3.0,[31,32] we made several attempts to conduct intraoperative screw elevating–pulling reduction; however, the effect was poor, and the incidence of the inoperative screw and of the inability to elevate and pull the screw was >37.5%. In that case, the posterior internal fixation was better than the anterior internal fixation from the aspect of biomechanics.[33] We aspire to further modify the surgery by considering the operating experience of lumbar spondylolisthesis surgery in patients with osteoporosis. Currently, we look forward to a prolonged follow-up to observe the changes in postoperative stability. Nonetheless, the limited possibilities led us to continually attempt to modify the conventional anterior approach.

In summary, after reviewing the treatment and follow-ups of these 86 patients, we considered this type of modified cervical anterior approach surgery. During surgery, no additional specific surgical instruments were needed, the overall operation difficulty of the surgeons was not increased, and there was no additional financial burden on the patients. Moreover, the operation risks were relatively lower, with decreased risk of iatrogenic spine injury. Furthermore, in the process of the surgery, the vertebrae restoration showed satisfactory results, and every patient acquired bone fusion by the last follow-up, achieving short- and mid-term cervical stability. Finally, this type of surgery could accomplish similar postoperative nerve function restoration.

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References

[1] Mithani SK, St-Hilaire H, Brooke BS, et al. Predictable patterns of intracranial and cervical spine injury in craniomaxillofacial trauma: analysis of 4786 patients. Plast Reconstr Surg 2009;123:1293–301.
[2] Greg-Anderson D, Voets C, Ropiak R, et al. Spine J 2004;4:506–12.
[3] Gelb DE, Aarabi B, Dhall SS, et al. Treatment of subaxial cervical spinal injuries. Neurosurgery 2013;72(suppl 2):187–94.
[4] Toh E, Nomura T, Watanabe M, et al. Surgical treatment for injuries of the middle and lower cervical spine. Int Orthop 2006;30:54–8.
[5] Mc Cormaek R, Taraikovie E, Gaines RW. The load sharing classification of spine fractures. Spine 1994;19:1741–2.
[6] Beml AJ, Ronl F, Thomas RL, et al. A mechanistic classification of closed, indirect fractures and dislocations of the lower cervical spine. Spine 1982;7:1–926.
[7] Ba Z, Zhao W, Wu D, et al. Box cages packed with local decompression bone were efficient in anterior cervical discectomy and fusion: five- to 10-year follow-up. Spine 2012;37:E1260–1263.
[8] Fukui M, Chiba K, Kawakami M, et al. Japanese Orthopaedic Association Back Pain Evaluation Questionnaire. Part2. Verification of its reliability: The Subcommittee on Low Back Pain and Cervical Myelopathy Evaluation of the Clinical Outcome Committee of the Japanese Orthopaedic Association. J Orthop Sci 2007;12:526–32.
[9] Huskisson EC. Measurement of pain. Lancet 1974;2:1127–31.
[10] Dong Jiamao , He Yongxiong , Jia Lianshun , et al. Single-stage anterior prying reduction for fractures and dislocations of the lower cervical spine: A report of 80 cases. J Spinal Surg 2015;13:126–8.
[11] Joaquim AF, Patel AA. Subaxial cervical spine trauma: evaluation and surgical decision-making. Global Spine J 2014;4:63–70.
[12] Rizzolo ST, Piazza MR, Corrl , et al. Intervertebral disc injury complicating cervical trauma. Spine 1991;16:187.
[13] Doran SE, Papadopoulos SM, Ducker TB, et al. Magnetic resonance imaging documentation of coexistent traumatic locked facets of the cervical spine and disc heriniation. J Neurosurg 1993;79:341–5.
[14] Caspar W, Barbier DD, Klara PM. Anterior cervical fusion and caspar plate stabilization for cervical trauma. Neurosurgery 1989;25:491–502.
[15] Aebi M, Zuber K, Marches D. Treatment of cervical spine injuries with anterior plating: indications, techniques and results. Spine 1991;16: 38–45.
[16] Eismont FJ, Arena MJ, Green BA. Extrusion of an intervertebral disc associated with traumatic subluxation or dislocation of cervical facets. J Bone Joint Surg Am 1991;73:1555–60.
[17] Wang Lei , Liu Chao , Tian Jiwei . Selection of the surgical method for fractures and dislocations of the lower cervical spine. Chin J Spine Spinal Cord 2013;23:610–6.
[18] Koivikko MP, Myllynen P, Santavirta S. Fracture dislocations of the cervical spine: a review of 106 conservatively and operatively treated patients. Eur Spine J 2004;13:610–6.
[19] Koller H, Reynolds J, Zenner J, et al. Mid- to long-term outcome of instrumented anterior cervical fusion for subaxial injuries. Eur Spine J 2009;18:630–53.
[20] O'Dowd JK. Basic principles of r11anagement for cervical spine trauma. Eur Spine J 2010;19(Suppl1):S18–22.
[21] Lambiris E, Zouboulis P, TyllianakisM , et al. Anterior surgery for unstable lower cervical spine injuries. Clin Orthop Relat Res 2003;411:61–9.
[22] Samandouras G, Shafafy M, Hamlyn PJ. A new anterior cervical instrumentation system combining an intradiscal cage with all integrated plate: an early technical report. Spine 2001;26:1188–92.
[23] Nishizawa S, Yamaguchi M, Matsuzawa Y. Interlaminar fixation using the atlantoaxial posterior fixation system (3XS system) for aflantoaxial instability: surgical results and biomechanical evaluation. Neurol Med Chir (Tokyo) 2004;44:61–6.
[24] Tannous O, Jazini E, Ludwig SC. Anterior surgical treatment for cervical spondylotic myelopathy. Sem Spine Surg 2014;26:73–80.
[25] Weiss RJ, Karrholm J, Hailer NP, et al. Salvage of failed trochanteric and subtrochanteric fractures using a distally fixed, modular, uncemented hip revision stem. Acta Orthop 2012;83:488–92.
[26] Nakashima H, Yukawa Y, Ito K, et al. Posterior approach for cervical fracture-dislocations with traumatic disc herniation. Eur Spine J 2011;20:387–94.
[27] Yuan Wen , Jia Lianshun , Chen Deyu , et al. Anterior approach for severe fractures and dislocations of the lower cervical spine. Chin J Spine Spinal Cord 2001;11:23–5.
[28] Park HK, Jho HD. The management of vertebral artery injury in anterior cervical spine operation: a systematic review of published eases. Eur Spine J 2012;21:2475–85.
[29] Tico N, Ramon S, Garcia-Ortun F, et al. Traumatic spinal cord injury complicating ankylosing spondylitis. Spinal Cord 1998;36:349–52.
[30] May PJ, Raunest J, Herdmann J, et al. Treatment of spinal fracture in ankylosing spondylitis. Der Unfallchirurg 2002;5:165–9.
[31] Kanis JA, Melton LJIII, Christiansen C, et al. The diagnosis of osteoporosis. J Bone Miner Res 1994;9:1137–41.
[32] Kim YM, Demissie S, Genant HK, et al. Identification of prevalent vertebral fractures using CT lateral scout views: a comparison of semi-automated quantitative vertebral morphometry and radiologist semi-quantitative grading. Osteoporos Int 2012;23:1007–16.
[33] Kwon BK, Beiner J, Grauer JN, et al. Anterior/posterior operative reduction of cervical spine dislocation: techniques and literature review. Cur Opin in Orthop 2003;14:193–9.