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Surgical Treatment for Subaxial Cervical Facet Dislocations with Incomplete or without Neurological Deficit: A Prospective Study of 52 Cases

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Background: This study aimed to treat patients with subaxial cervical facet dislocations with incomplete or without neurological deficit by a prospectively designed surgical protocol and observe the short-term clinical outcomes.

Material/Methods: Fifty-two consecutive subaxial cervical dislocation patients with incomplete or without neurological deficit were enrolled. The surgical strategy was determined based on whether or not the initial anterior closed reduction was successful and whether or not the patients were simultaneously combined with traumatic disc herniation (TDH). Postoperative radiographs were used to assess the reduction and fusion, and kyphosis and lordosis of cervical spines were calculated. The neck pain was assessed by visual analog scale. Body function and neurologic status was evaluated according to the Neck Disability Index and classification of American Spinal Injury Association. Clinical and radiologic outcomes were compared before and after the surgery and during the follow-up. The average follow-up period was 23 months.

Results: Five patients with TDH and 17 with non-TDH were successfully treated by a single anterior approach, 22 non-TDH patients by a posterior-anterior approach, and another eight TDH patients by an anterior-posterior-anterior approach. No neurologic deterioration or other severe adverse events occurred postoperatively. The kyphosis angle of the dislocated levels was well restored after surgery, and the neck pain was significantly relieved as well. The neurologic status was obviously improved, and bony fusion was obtained in all patients within one-year follow-up.

Conclusions: Our prospectively designed surgical strategy is effective for the treatment of patients with subaxial cervical dislocation with incomplete or without neurological deficit.

MeSH Keywords: **Anesthesia, Spinal • Orthopedics • Spine**

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Background

Traumatic subaxial cervical dislocations are severe spinal injuries. Most of such cases present with unilateral or bilateral locked facets. Moreover, a clinical investigation demonstrated that more than 20% of patients with subaxial cervical dislocations were combined with traumatic disc herniation (TDH) [1].

A surgical realignment, decompression, and reconstruction is usually needed for the instable cervical spine due to disc disruption, facet locking, etc. [2,3]. There are several surgical management strategies, including one-stage anterior, posterior, and combined approaches for subaxial cervical facet dislocation, but the optimal surgical approach is still controversial [4,5–9]. For examples, it was preliminarily shown that anterior and posterior surgical approaches for patients with subaxial cervical spine facet dislocations exhibited little difference with regard to long-term neurologic status, quality-of-life, medical adverse events, and rates of instrumentation failure and infection, except that anterior approach might bring about better sagittal alignment [10]. On the other hand, it was reported that the anterior approach was effective and safe for the treatment of subaxial cervical facet dislocation with mild or without spinal cord injury, and after the surgery the cervical spines were well recovered, with intervertebral fusion, but without redislocation or symptoms of spinal cord injury [11]. Generally it is recommended that an initial closed reduction should be conducted, followed by next step, which is based on whether or not the closed reduction succeeded. However, since a considerable proportion of patients simultaneously suffered from incomplete neurological deficit, initially manual closed reduction may not be the best option for the potential impairment of spinal cord or nerve root [4,16]. In this study, we reported our surgical treatment experience for a series of 52 cases of subaxial cervical facet dislocation patients with incomplete or without neurological deficit. This study will provide a rational alternative to select surgical strategy for the treatment of subaxial cervical facet dislocations with incomplete or without neurological deficit.

Material and Methods

Patients

This study was approved by the Ethical Committee of the Affiliated Hospital of Nantong University (Nantong, China). From September 2009 to August 2014, 77 consecutive acute subaxial cervical dislocations with locked facets were admitted to the Department of Spinal Surgery, Affiliated Hospital of Nantong University. Patients with acute subaxial cervical dislocations with locked facets, aged 18–75 years, with incomplete or without spinal cord injury (American Spinal Injury Association,

ASIA Grade B-E) were included. Patients with complete spinal cord injury (ASIA Grade A), multiple injuries, or without consciousness were excluded. Fifty-two patients with incomplete or without spinal cord injury were eventually enrolled. All the patients underwent anterior-posterior and middle-lateral view computed tomography (CT) and magnetic resonance image (MRI) examinations of the cervical spine. Traumatic disc herniation (TDH) was determined by MRI examination, which was defined as the presence of an extruded disc pressing the thecal sac or the nerve root, and being behind the line between the postero-inferior corner of cranial vertebrae and the postero-superior corner of caudal vertebrae [7].

Preoperative preparation

On admission, patients received Gardner-Wells tong skull traction for cervical spine with a force of one-tenth of patient's body weight. Mannitol (250 mL) and small doses (40 mg) of methylprednisolone were administered to patients except those with high neurological intact (ASIA Grade E). Patients underwent trachea traction exercise twice daily after the hospitalization and before the surgery. A preventative antibiotic cefazolin (5 g) was administrated 30 minutes before the surgery and within 72 hours following the surgery.

Surgical procedures

All the surgical procedures were supervised by two senior spinal surgeons (YC and FZ). Patients received general anesthesia and tracheal intubation. The closed and open reductions were performed under the control of an x-ray image intensifier and a spinal cord monitoring device. The selection of surgical plans and approaches were determined based on whether or not the patients with subaxial cervical facet dislocations were simultaneously combined with TDH and whether or not the initial anterior closed reduction was successful.

For subaxial cervical facet dislocations without TDH, closed reduction was manually performed using skull traction before the operation, starting in a flexion supine position and turning to a slight extension position once a satisfactory reduction was achieved. If closed reduction was successful, anterior cervical discectomy and fusion (ACDF) was then carried out (single anterior approach). If it failed, a posterior open reduction and fixation and subsequent ACDF procedure (posterior-anterior approach, P-A approach) was performed instead. In brief, between the first and second turn over of the body, the patients were in a prone position and posterior open reduction was obtained by distracting the two dislocated spinous processes with two bone-holding forceps, and if necessary, facets was simultaneously poked with a narrow osteotome. For some difficult cases, a partial facetectomy was performed prior to realignment. When the reduction was satisfactorily achieved,

the cervical spine was moved into a slight extension position, and the dislocated spinous process was then fastened by a titanium cable.

For subaxial cervical facet dislocations with TDH, patients received anterior discectomy and decompression first. After the herniated disc was certainly moved out, an anterior closed reduction was manually performed by an assistant staff when the patients were in a supine position. The successful cases continued treatment with an ACDF surgery, which is also called single anterior approach, while the failed cases received a posterior open reduction in a prone position and cable fixation between the first and second turn over of the body, followed by anterior fusion (anterior-posterior-anterior approach, A-P-A approach).

Finally, an autogenous bone graft was used in all of the anterior fusions. Drainage was inserted in all incisions and removed within 72 hours after surgery. A neck brace was routinely used for three months after surgery in all cases.

Measurement and follow-up

The kyphosis of the dislocated segments was measured from the angles between the superior endplate of the upper vertebra and the inferior endplate of the inferior vertebra in the middle-lateral view radiographs (Supplementary Figure 1). The blood loss, prone position time, and total operation time were recorded. The neck pain was assessed by visual analog scale (VAS). Body function and neurologic status, reflecting the neurologic function, were measured according to the Neck Disability Index (NDI) and ASIA classification, respectively. Fusion was defined as one of the following three situations: (1) the formation of the bridging trabecular bone at the interface of graft-vertebral body, (2) less than 50% radiolucency around the border of the bone graft, and (3) no implant failure signs [12,13]. Patients were followed-up by regular outpatient visits. At 12, 26, and 52 weeks after the surgery, patients were asked to respond to the VAS and NDI-related questionnaires at the outpatient service center of the Department of Spine Surgery of our hospital, and also to undergo special physical examination and receive anterior-posterior and lateral x-ray checks.

Statistical analysis

Data were expressed as mean $\pm$ standard derivation, and analyzed using GraphPad Prism software (version 5.01; GraphPad, San Diego, CA, USA). Clinical and radiographic characteristics immediately after, and at 12 and 52 weeks, respectively after the surgery were compared with those before the surgery by using a *t*-test. A value of $p < 0.05$ was considered statistical significance.

Table 1. Patients' basic characteristics.

Item	Value
Age (years)	44.7 $\pm$ 29.0 (range 31–72)
Gender	
Male (n)	37
Female (n)	15
Injury mechanism	
Falling from height (n)	20
Motor-vehicle accident (n)	16
Sport activity (n)	9
Head hitting (n)	7
Involved spine levels	
C3/4 (n)	2
C4/5 (n)	6
C5/6 (n)	20
C6/7 (n)	21
C7/T1 (n)	3
Unilateral/bilateral facets dislocation	
Unilateral (n)	17
Bilateral (n)	35
ASIA grade	
B (n)	5
C (n)	19
D (n)	19
E (n)	9
Combination of TDH	
TDH (n)	13
Non-TDH (n)	39

TDH – traumatic disc herniation; ASIA – American Spinal Injury Association.

Results

Patient characteristics are shown in Table 1. Fifty-two patients with subaxial cervical facet dislocation with incomplete deficit or without neurological deficit were enrolled in this study, including 37 males and 15 females. The mean age was 44.7 $\pm$ 29.0 (range, 31–72) years. The injury mechanisms included falling from height (20 cases), motor-vehicle accident (16 cases), sport activity (nine cases) and head hitting (seven cases). Spines were

Figure 1. The detailed treatment strategies for patients with subaxial cervical facet dislocations with incomplete or without neurological deficit.

affected at C3/4 (two cases), C4/5 (six cases), C5/6 (20 cases), C6/7 (21 cases), and C7/T1 (three cases). There were 17 cases with unilateral facets dislocation and 35 cases with bilateral facets dislocation. Particularly, there were 13 cases with TDH, and the other 39 without TDH. There were five patients with ASIA Grade B, 19 Grade C, 19 Grade D, and nine Grade E.

Five patients with TDH and 17 with non-TDH were successfully treated by closed reduction and fusion (single anterior approach). Twenty-two non-TDH patients were considered failed in closed reduction and were then treated by a P-A approach. Another eight TDH patients received anterior decompression and releasing but failed to achieve manual closed reduction; they were finally treated with an A-P-A approach. The detailed treatment strategies are shown in Figure 1. A representative case of a 62-year-old male patient with TDH (ASIA Grade E) who received single anterior approach treatment is shown in Figure 2; a case of a 38-year-old male patient without TDH (ASIA Grade B) who received posterior-anterior approach treatment is shown in Figure 3; and a case of a 50-year-old female patient with TDH (ASIA Grade D) who received anterior-posterior-anterior approach treatment is shown in Figure 4.

Herniated discs in all the TDH patients were completely resected. The mean blood loss for single anterior, P-A, and A-P-A approaches was 78 ± 30 mL, 142 ± 53 mL, and 189 ± 44 mL, respectively. The mean prone position time was 0, 42 ± 15 minutes and 39 ± 18 minutes, respectively. The mean total operation time was 66 ± 19 minutes, 112 ± 44 minutes, and 136 ± 37 minutes, respectively. The mean hospital stay was 7.1 ± 2.3 days,

11.2 ± 4.1 days, and 12.7 ± 4.6 days, respectively (Table 2). No severe adverse events occurred during the operations, except one patient presented splitting of posterior incision when taking out the stitches for hypoproteinemia, but was finally healed by suture and supporting therapy. No neurologic deterioration was found after the surgery.

The patients were followed for a mean of 23 ± 33 (range 14–61) months. For shoulder obstruction, the data of kyphotic angles were only obtained in 30 cases. Kyphosis with a preoperative $10.7 \pm 5.4^\circ$ disappeared in all the patients after the surgery and did not recur during the follow-up. Lordosis was increased to $5.3 \pm 2.9^\circ$ after the surgery and maintained over 3° during the follow-up. This result showed the deformity of patients was obviously rectified after the surgery and the angle of lordosis was well maintained until fusion. Postoperative pain was significantly decreased immediately after and at 12 and 52 weeks, respectively, after the surgery compared with preoperative pain ($p < 0.05$). NDI was significantly decreased at 12 and 52 weeks, respectively, after the surgery compared with before the surgery ($p < 0.05$, Table 3). The number of patients with higher ASIA grade (B, C) was decreased but that of patients with lower ASIA grade (D, E) was increased (Table 3). This result indicated that the VAS and patients' neurologic function (shown by NDI and ASIA data) were significantly improved, which were better during the follow-up (Table 3). No implant failure was observed and dislocated segments were fused in all patients within one year after the surgery. Particularly, improvement of kyphosis, lordosis, VAS, and NDI between before, immediately after, and at 12 and 52 weeks after the surgery for single anterior, P-A, and A-P-A approaches are shown in Table 4.

Discussion

Treatment choices for subaxial cervical dislocations are still controversial. The decision-making for these patients is mainly affected by patients' neurologic status, presentation, or absence of disc herniation, dislocation of the facet joint, etc. [14]. For subaxial cervical dislocation patients with incomplete or without neurological deficit, the possibility of recovery is relatively higher [15]. In this case, protection of the remaining neurologic functions from further damage appears to be more important, which needs to be considered during the surgery for these patients. In addition, TDH often is accompanied by subaxial cervical dislocations. For example, according to Rizzolo et al., there was a 22% rate of TDH in cases of unilateral subaxial cervical dislocations and 40% TDH in cases of bilateral subaxial cervical dislocations [1]. Nakashima et al. showed 29.2% of patients with subaxial cervical dislocations presented with TDH [7]. Consistently, in our patient cohort, 25% (13/52) presented TDH revealed by preoperative MRI examination. Based on the situation of initial closed reduction and presence/absence of

Figure 2. A 62-year-old male patient with TDH (ASIA Grade E) received single anterior approach treatment. (A, B): Preoperative X photographs of cervical spine; (A) anterior-posterior view and (B) lateral view. (C, D): Preoperative CT imaging showed unilateral facet dislocation at C3; (C) routine CT and (D) routine CT with 2D reconstruction). (E): Preoperative MRI examination of cervical spine revealed a large TDH protruding into spinal canal. (F, G): Postoperative x photographs of cervical spine; (F) anterior-posterior view and (G) lateral view.

TDH, in this study we planned effective surgical strategies, including single anterior, posterior-anterior, and anterior-posterior-anterior approaches, and achieved satisfactory outcomes in patients with subaxial cervical dislocations with incomplete or without neurologic compromise.

Several management strategies have been reported for the treatment of lower cervical dislocations with incomplete neurological deficit. Manually closed reduction is usually initially employed, which is a basis on which the next steps are based. Reindl et al. reported a high success rate 80.5% (33 of 41 cases) of closed reduction and designed an anterior open approach reduction manner for eight patients who failed in closed reduction [4]. Unfortunately, one patient was found to have neurologic deterioration after reduction maneuver [4]. In our study, 22 of 52 patients (42.3%) successfully received closed reduction, and no neurologic deterioration was found. The difference in the success rate of closed reduction between the Reindl et al. study and our study may be related to the affected segments

of cervical spine, the presence of TDH or not, the extent of neurological deficit (ASIA grade), and the presence of unilateral or bilateral facets dislocation in patients.

Nakashima et al. reported that using posterior open reduction and posterior spine arthrodesis in a series of 40 patients with cervical dislocations with TDH obtained favorable reduction without neurologic deterioration [7]. However, 62.5% (25 out of 40) patients had complete neurological deficit cases (ASIA Grade A) in their series; in contrast, patients in our study had incomplete or had no spinal cord injury, placing more importance on protecting the remained neurologic functions from further damage. Therefore, this management strategy used by Nakashima et al. [7] may not be suitable for patients with incomplete or without spinal cord injury, such as the patients included in our study.

Park et al. reported a single-stage posterior approach, i.e., open reduction and pedicle screw fixation with the removal

Figure 3. A 38-year-old male patient without TDH (ASIA Grade B) received posterior-anterior approach treatment. Preoperative X photographs of cervical spine; (A) anterior-posterior view and (B) lateral view. (C, D): Preoperative CT imaging showed bilateral facet dislocation at C7; (C) routine CT and (D) routine CT with 2D reconstruction. (E): Preoperative MRI examination of cervical spine excluded the existence of TDH. (F, G): Postoperative X photographs of cervical spine; (F) anterior-posterior view and (G) lateral view.

of herniated disc fragments via a postero-lateral approach, for patients with subaxial cervical facet dislocations with TDH [9]. Although all the patients were improved neurologically and segmental angles were significantly corrected, patients had to suffer a prolonged time in the prone position. Different from these studies [7,9], we initially tried closed reduction so as to decrease the risks of open reduction, followed by the next steps based on whether or not the closed reduction was successful and whether or not TDH was presented.

Moreover, spinal surgeons prefer removing a prolapsed disc via an anterior procedure versus a posterior procedure. Feng et al. treated 21 cases of lower cervical facet dislocations with TDH by combined approaches, i.e., anterior decompression and bone grafting and posterior fixation [8]. Although good kyphosis correction was achieved after surgery and optimal neurologic recovery was observed at least one year later, the long levels of posterior rigid fixation sacrificed the mobility of adjacent normal segments.

Previously, anterior reduction was commonly used for patients, regardless of whether or not TDH was present. For patients with TDH, herniated discs might be displaced backward and even dropped into the spinal canal during the anterior reduction, which may then aggravate the spinal cord injury. Moreover, anterior open reduction usually needs excessive distraction of the dislocated segments, which is technically demanding with a potential risk of iatrogenic neurologic injury [16]. Therefore, in our study, before the anterior closed reduction procedure, the herniated disc was resected by anterior discectomy to decrease the risks of anterior reduction. Our results showed no neurologic deterioration was noted postoperatively in all of the TDH patients.

As to the cases without successful anterior closed reduction in our series, posterior approach had to be used for reduction and temporary stabilization. We used titanium wires, with the advantage of time saving (averaged 45 minutes) and flexibility, for posterior inter-process fixation, which allowed secondary anterior reposition. Postoperative neck pain was significantly

Figure 4. A 50-year-old female patient with TDH (ASIA Grade D) received anterior-posterior-anterior approach treatment. Preoperative X photographs of cervical spine; (A) anterior-posterior view and (B) lateral view. (C, D): Preoperative CT imaging showed bilateral facet dislocation at C6; (C) routine CT and (D) routine CT with 2D reconstruction. (E) Preoperative MRI examination of cervical spine revealed mild TDH. (F, G): Postoperative X photographs of cervical spine; (F) anterior-posterior view and (G) lateral view.

Table 2. Intra-operative data for different surgical approaches.

Approaches	Blood loss (mL)	Prone position time/ total operation time (min)	Hospital stay (d)
Single anterior (n=22)	78±30	—/66±19	7.1±2.3
P-A (n=22)	142±53	42±15/112±44	11.2±4.1
A-P-A (n=8)	189±44	39±18/136±37	12.7±4.6

P-A – posterior-anterior, A-P-A – anterior-posterior-anteri.

relieved due to a satisfactory reduction in our series. In addition, a biomechanical test [17] and our follow-up data indicated that anterior fusion could effectively reconstruct and well maintain the stability of index segments.

Although different surgical approaches have been previously reported for patients with subaxial cervical dislocation with incomplete neurologic defect [4,7–11], how to select an optimal treatment strategy for a specific individual has not been

clear. To try to utilize the advantages of anterior closed reduction and simultaneously avoid its potential risk as well as ensure the efficacy of reduction, we prospectively designed an effective surgical treatment strategy to gain satisfactory outcomes. This strategy was basis of the observation of the situation of the initial anterior closed reduction and determination of the presence/absence of TDH. This approach has not been previously reported. An important limitation of this study was that the follow-up period was not long enough. Future

Table 3. Data and functional results in perioperative and follow-up.

Time Points	Kyphosis/Lordosis (°, n=30)	VAS (n=52)	NDI (%, n=52)	ASIA grade				
				A	B	C	D	E
Preoperative	10.7±5.4/–	6.7±2.9	56±25	–	5	19	19	9
Postoperative	–/5.3±2.9	3.3±2.1*	–	–	4	14	23	11
12-week FU	–/3.1±1.7	1.7±1.4*	26±11*	–	2	12	20	18
52-week FU	–/3.5±1.9	1.6±0.9*	19±12*	–	0	3	26	23
P	–	<0.01	<0.01					

* P<0.05 compared with preoperative data. FU – follow-up; VAS – visual analog scale; NDI – Neck Disability Index; ASIA – American Spinal Injury Association.

Table 4. Data and functional results in perioperative and follow-up.

Approaches	Kyphosis/lordosis (°, n=30)	VAS (n=52)	NDI (%, n=52)	ASIA				
				A	B	C	D	E
Single anterior (n=22)	(n=16)	(n=22)	(%, n=22)					
Preoperative	9.9±5.6/–	7.1±2.0	59±23	0	3	6	9	4
Postoperative	–/5.1±2.1	3.1±2.2*	–	0	2	6	9	5
12-week FU	–/2.9±1.4	1.9±1.2	22±14*	0	1	5	8	8
52-week FU	–/3.1±1.5	1.8±0.8	18±11	0	0	0	13	9
P-A (n=22)	(n=9)	(n=22)	(%, n=22)					
Preoperative	11.7±4.5/–	6.4±2.4	67±25	0	2	9	8	3
Postoperative	–/6.3±3.8	3.5±2.0*	–	0	2	6	10	4
12-week FU	–/4.3±1.6	1.9±1.5	29±17*	0	1	5	8	8
52-week FU	–/3.8±1.4	1.9±1.0	21±15	0	0	2	12	8
A-P-A (n=8)	(n=5)	(n=8)	(%, n=8)					
Preoperative	10.2±6.2/–	6.9±2.9	56±25	0	0	4	2	2
Postoperative	–/3.7±1.9	4.6±2.2*	–	0	0	2	4	2
12-week FU	–/3.8±1.2	2.7±1.4	25±13*	0	0	2	4	2
52-week FU	–/2.5±2.1	1.9±1.7	23±10	0	0	1	1	6

* P<0.05 compared with preoperative data. FU – follow-up; P-A – posterior-anterior; A-P-A – anterior-posterior-anterior; VAS – visual analog scale; NDI – Neck Disability Index; ASIA – American Spinal Injury Association.

studies with more related cases that are treated and analyzed during a longer follow-up period need to be carried out to verify these results.

Conclusions

For subaxial cervical dislocation with incomplete or without neurological deficit, a prospectively designed surgical treatment strategy based on the situation of initial anterior closed reduction and presence/absence of TDH is effective, with satisfactory short-term clinical outcomes.

Conflict of interest

The authors declare that they have no conflict of interest.

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Supplementary Figure

Supplementary Figure 1. Measurement of cervical vertebral kyphosis. Cervical vertebral kyphosis of the dislocated segments was measured from the angle between the superior endplate of the upper vertebra and the inferior endplate of the inferior vertebra in the middle-lateral view radiographs.

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