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Effectiveness of different surgical methods in the treatment of acute central cord syndrome without fractures and dislocations of the cervical spine

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Abstract.
BACKGROUND: Acute central cord syndrome (ACCS) without fractures or dislocations is the most common form of incomplete spinal cord injury.
OBJECTIVE: To evaluate the effectiveness of different surgical methods in the treatment of acute central cord syndrome without fractures or dislocations of the cervical spine.
METHODS: A total of 164 patients with ACCS without fracture or dislocation of the cervical spine treated in our hospital from May 2012 to October 2019 were recruited and assigned to study group A and study group B according to different treatment modalities, with 82 cases in each group. Study group A underwent anterior cervical discectomy and fusion, and study group B was treated with posterior cervical laminectomy. The American Spinal Injury Association (ASIA) classification and motor scores of all cases at admission and at discharge were recorded, and the treatment outcomes of the two groups were compared.
RESULTS: No significant differences were found in the ASIA classification and ASIA motor scores between the two groups at admission ($P > 0.05$). One year after surgery, the ASIA motor scores and sensory scores were not statistically significant between the two groups ($P > 0.05$) but showed significant improvement compared to the preoperative scores ($P < 0.05$).
CONCLUSION: Both anterior cervical discectomy and fusion and posterior cervical laminectomy can improve the ASIA classification, ASIA motor scores, and sensory scores of ACCS patients without fractures or dislocations of the cervical spine. Therefore, surgical methods should be adopted based on the patients' conditions.

Keywords: ACCS, cervical spine, anterior cervical discectomy, posterior cervical laminectomy, ASIA

1. Introduction

Cervical spinal injury (CSI) without fractures or dislocations is a condition usually seen in the young and middle-aged population, accounting for about 45% of all cases [1], in which fractures or dislocations of the cervical spine are absent under computed tomography (CT), X-ray, or magnetic resonance imaging (MRI). However, it demonstrates acute CSI symptoms that are detectable by MRI. Patients mainly present with a more pronounced motor nerve impairment in the upper extremity than the lower extremity, loss of sensation, and sphincter dysfunction below the plane of injury, with the central cord syndrome (CCS) being more common.

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Clinically, CSI with fractures or dislocations can be detected by conventional imaging, and the efficiency of surgical treatment for it is considered favorable. Nevertheless, consensus on the treatment for CCS without fractures or dislocations has not yet been developed [1–9]. CSI can be treated with anterior cervical discectomy and fusion or posterior cervical laminectomy. Anterior cervical discectomy and fusion features complex anatomical structures at the surgical site, a small surgical field of view, difficult surgery, and high early complication rates (2.4%–36.6%) [1]. In posterior cervical laminectomy, the cervical spinal cord is indirectly decompressed ventrally by enlarging the cervical spinal canal and moving the spinal cord posteriorly through the "bowstring effect" [2], but patients may experience postoperative axial symptoms [2,3]. The choice of surgical approach (anterior, posterior, or combined anterior-posterior approach) depends mainly on the imaging of the cervical spine in the sagittal plane, the extent of the lesion, the site of compression, the degree of preoperative neck pain, and the surgical history of patients [1–3]. Treatment of non-fractured dislocated cervical spinal cord injuries decompresses the compressed spinal cord, reconstructs the spine, and ensures the stability of the cervical spine, so the determination of spinal cord compression and cervical spine stability is a key reference factor in the evaluation of surgical indications. The selection of a reasonable surgical approach to achieve complete decompression of the spinal canal contributes to a favorable treatment outcome [6]. The choice of the anterior and posterior approaches for surgery should be based on the principle of accurate and effective decompression of the spinal cord with compression, and anterior surgery is more appropriate in most cases because of the presence of cervical disc compression [4,7]. Anterior surgery can be adopted for those with cervical disc herniation compressing the spinal cord or the dural sac leading to spinal stenosis, without continuous posterior longitudinal ligament ossification and hypertrophy of the ligamentum flavum. In the case of mild disc bulge, good spinal canal volume, and no significant interference with cerebrospinal fluid imaging between the disc and the spinal cord, the bulging disc can be considered not to constitute a spinal cord compressor. Hypertrophy of the ligamentum flavum and narrowing of the cervical spinal canal constituting a spinal cord compressor require posterior surgical canal enlargement for treatment, and posterior decompression can be used in the case of continuous posterior longitudinal ligament ossification that precludes anterior surgery. The ASIA issued the neurological classification of spinal cord injuries (ASIA criteria) in 1982, and its fourth edition (1992) was adopted by the International Spinal Cord Society (ISCS) and was recognized by the International Spinal Cord Society (ISCoS) as the international standard for neurological classification of spinal cord in-jury (ISNCSCI) [2]. The sixth edition of the ASIA criteria (2000) included basic concepts, neurological scores, ASIA impairment scale (AIS), and clinical syndromes, and introduced quantitative indicators [3,4], and are widely used worldwide [5].

2. Material and methods

2.1. Baseline data

The medical data of 164 patients with ACCS without fracture or dislocation of the cervical spine treated in our hospital from May 2012 to October 2019 were retrospectively analyzed. Study group A had 56 cases of males and 28 cases of females, aged 22–46 years, with a mean age of (33.24 $\pm$ 4.71) years; there were 34 cases of a cervical herniated disc, 27 cases of cervical degenerative disc disease, and 23 cases of spinal stenosis. Study group B had 53 cases of males and 31 cases of females, aged 23–40 years, with a mean age of (32.19 $\pm$ 3.95) years; there were 36 cases of a cervical herniated disc, 24 cases of cervical degenerative disc disease, and 24 cases of spinal stenosis. The two groups showed no significant differences in terms of baseline data ($P > 0.05$). The study protocol was approved by the ethics committee of the First Affiliated Hospital, Hebei North Academy, and the study was conducted as per the Declaration of Helsinki of 1964. The patients and their families provided written informed consent after being fully informed of the process and purpose of the study (Table 1).

2.2. Inclusion criteria and exclusion criteria

Inclusion criteria [7]: Patients with obvious symptoms of CSI confirmed by clinical and imaging examinations, but no fractures and dislocations; with cervical herniated disc compressed the spinal cord or MRI showed abnormal signal length in the cervical spinal cord greater than one vertebral body height; with complete follow-up data; and with reduced or absent physiological cervical curvature or mild kyphosis before surgery were included.

Exclusion criteria [7]: Patients with cervical spine

Table 1
Comparison of baseline data ($\bar{x}s$, n)

Groups	Study group A ($n = 84$)	Study group B ($n = 84$)	x^2/t	P
Gender (male/female)	56/28	53/31	0.235	0.628
Age				
Range	22–46	23–40		
Mean age	33.24 ± 4.71	32.19 ± 3.95	1.562	0.120
Cervical herniated disc	34	36	0.098	0.754
Cervical degenerative disc disease	27	24	0.253	0.615
Spinal stenosis	23	24	0.03	0.864

fractures or dislocations; with severe major organ damages or dysfunctions; with cognitive impairment or impaired consciousness; with severe and uncontrolled chronic medical diseases; and during pregnancy and lactation were excluded.

2.3. Methods

After confirmed diagnosis, all patients were given conservative treatment, including absolute bed rest, prone occipito-mandibular traction, methylprednisolone or dexamethasone shock therapy, and dehydration. On top of the conservative treatment, study group A underwent anterior cervical discectomy and fusion (anterior cervical discectomy and fusion was adopted for those with cervical disc herniation, cervical disc rupture, rupture of the anterior longitudinal ligament, ossification of the discontinuous posterior longitudinal ligament and hypertrophy of the ligamentum flavum), and study group B was treated with posterior cervical laminectomy (posterior cervical laminectomy was adopted for those with continuous posterior longitudinal ligament ossification and cervical stenosis with hypertrophy of the ligamentum flavum) [10–12]. Appropriate medications such as hemostatic and dehydrating agents were given to the patients according to their actual condition. This study did not set up a control group for conservative treatment.

Surgical treatment: ① Anterior cervical discectomy and fusion: after general anesthesia, a transverse incision was made at the lower anterior cervical approach, the vertebral body was subtotaled and decompressed anteriorly, the bone was removed and added to the titanium mesh and then implanted in the bone socket. If the lesion involved 3 segments, segmental decompression, intervertebral decompression, titanium mesh implant, and internal fixation of the anterior cervical plate were performed. ② Posterior cervical laminectomy: After general anesthesia, a longitudinal incision was made at the posterior lower cervical approach, and the stenotic segment and the upper and lower segments were enlarged by single-opening the spinal canal, with internal fixation of the lateral plate.

2.4. Efficacy evaluation

Patients were followed up after admission, two weeks, and one year after surgery and were graded by ASIA classification: Grade A (complete injury): There is no preservation of any motor and sensory function below the neural plane of spinal cord injury, including the sacral segment S4 to S5 (saddle area). Grade B (incomplete injury): There is preserved sensory function below the spinal cord injury nerve level, including the S4 to S5 region of the sacral segment, without any preservation of motor function. Grade C (incomplete injury): There is preserved motor function below the neural plane of spinal cord injury, but more than half of the key muscles below the neural plane of spinal cord injury have muscle strength less than grade 3. Grade D (incomplete injury): there is preserved motor function below the neural plane of spinal cord injury, and at least half of the key muscles below the neural plane of spinal cord injury have muscle strength equal to or greater than grade 3. Grade E (normal): normal sensory and motor functions. ASIA motor scores: motor scores were clinically graded on a scale of 1–5 points, with grade 1 muscle strength being 1 point and grade 5 muscle strength being 5 points. The higher the scores, the better the recovery of motor function. Sensory score: 0 indicates sensory loss, 1 indicates sensory impairment; 2 indicates normal sensation [13–18].

The cervical curvature and Japanese Orthopedic Association (JOA) [4] scores were recorded for 1 year before and after surgery, and the improvement rate of JOA scores was calculated. Improvement rate of JOA score (%) = (JOA score at the last follow-up − preoperative JOA score)/(17 − preoperative JOA score) $\times$ 100%.

2.5. Statistical analyses

All data was statistically analyzed using SPSS 24.0. The measurement data was expressed as ($\bar{x} \pm s$) and

Table 2
Comparison of ASIA classification between the two groups (n)

Groups	n	At admission						Two weeks after surgery						One year after surgery					
		A	B	C	D	E	D ~ E	A	B	C	D	E	D ~ E	A	B	C	D	E	D ~ E
Study group A	84	14	22	35	13	0	13	3	8	22	33	18	51*	0	1	7	28	48	76*
Study group B	84	13	24	34	12	0	12	4	6	24	30	20	50*	0	1	6	31	46	77*
x^2							0.047						0.025						0.073
P							0.828						0.875						0.787

Note: *indicates $P < 0.001$ in the comparison between postoperative and at admission.

Table 3
Comparison of ASIA motor scores between the two groups ($\bar{x} \pm s$)

Groups	n	At admission	Two weeks after surgery	One year after surgery
Study group A	84	41.92 ± 16.73	66.78 ± 17.08*	69.22 ± 17.81*
Study group B	84	42.48 ± 17.26	65.14 ± 16.12*	69.17 ± 16.35*
t		0.214	0.643	0.016
P		0.831	0.521	0.987

Note: *indicates $P < 0.001$ in the comparison between postoperative and at admission.

Table 4
Comparison of sensory scores between the two groups ($\bar{x} \pm s$)

Groups	n	At admission	Two weeks after surgery	One year after surgery
Study group A	84	72.73 ± 27.74	147.54 ± 36.70*	148.69 ± 37.28*
Study group B	84	73.41 ± 26.63	143.13 ± 37.52*	146.82 ± 36.23*
t		0.162	0.770	0.331
P		0.871	0.442	0.741

Note: *indicates $P < 0.001$ in the comparison between postoperative and at admission.

Table 5
Comparison of treatment satisfaction two weeks after surgery in the two groups (n)

Groups	n	Highly satisfied	Satisfied	Dissatisfied	Total satisfaction rate
Study group A	84	24	47	13	71 (84.52%)
Study group B	84	21	53	11	73 (86.90%)
x^2					0.194
P					0.659

processed using the t-test, and the count data was expressed as percentages (%) and analyzed using the chi-square test. $P < 0.05$ indicates that the difference is statistically significant.

3. Results

3.1. Comparison of ASIA classification and ASIA motor and sensory scores

No significant differences were found in the ASIA classification and ASIA motor scores between the two groups at admission ($P > 0.05$) (Tables 2–4).

3.2. Comparison of satisfaction

Two weeks after surgery, the total satisfaction rate of study group A was 84.52% (71/84), and that of study group B was 86.90% (73/84), and the differences in satisfaction rate between the two groups were not significant ($P > 0.05$) (Table 5).

3.3. Comparison of JOA score and JOA score improvement rates

One year after surgery, the JOA scores of the two groups were significantly increased versus before treatment ($P < 0.05$). One year after surgery, there were no significant differences in the improvement rate of JOA scores between the two groups ($P > 0.05$) (Table 6).

4. Discussion

Acute central cord syndrome is a specific type of spinal cord injury caused by compression of the cen-

Table 6
Comparison of JOA score and JOA score improvement rates ($x \pm s$)

Groups	n	JOA score		Improvement rate of JOA score (%)
		Before surgery	One year after surgery	
Study group A	84	7.1 ± 1.7	14.6 ± 1.3*	56.4 ± 4.9
Study group B	84	6.8 ± 2.1	13.2 ± 2.1*	57.3 ± 5.1
t		0.698	0.865	1.325
P		0.241	0.324	0.412

Note: *indicates a significant difference ($P < 0.05$) in comparison with before surgery.

tral cervical spinal cord from the anterior and posterior cervical spinal canal. The disease is more frequently seen in the young and middle-aged population and is characterized by the typical acute cervical spinal injury without fractured and dislocated cervical vertebrae, with complex specific manifestations. Its etiology is poorly understood. As patients with mild conditions of the disease may recover spontaneously after conservative treatment [19–21], the application of surgical methods for ACSS remains controversial, and conservative treatment has been more frequently adopted in previous practice. However, results of the follow-up statistics by Ratre et al. showed no relief or even worsening of symptoms in some cases [22–24]. With the development of MRI technology, it has been found that most patients with CCS had severe soft tissue injury around the spinal cord and some underlying lesions of spinal canal compression, which necessitates surgical treatment [25,26]. Results of the present study showed significant improvement in the ASIA classification, ASIA motor scores, and sensory scores after surgery ($P < 0.001$), and patients in both groups were satisfied with the surgical methods without significant differences ($P = 0.659$). A possible explanation can be that the surgery reduces the edema of the spinal cord and its internal pressure, improves blood circulation, and lessens or avoids secondary damage to the spinal cord, thereby accelerating early recovery of spinal cord function and increasing patient satisfaction, which is similar to the results by Zhu et al. [27]. After the onset of CSI, tissue hemorrhage, edema, and dural adhesions lead to increased intradural pressure in the spinal canal and spinal cord parenchyma, causing an ischemic and hypoxic pathophysiologic process that accelerates the cascade response of secondary spinal cord injury. Proper timing of surgery and appropriate surgical decompression strategies can reduce the associated secondary injuries. However, there is still debate about the safety and efficacy of decompression surgery. Considering the impact of the degree and severity of nerve injury on the timing of surgery, clinical CSI subgroups may potentially benefit from early surgery. Early decompression should be considered for patients with incomplete cervical CSI, and patient age should be excluded from the criteria for early surgery. The optimal time point for early surgery should not be limited by progression and is encouraged to be determined by a thorough examination of the patient's condition and the shortest time for stabilization of the patient's status. Therefore, a variety of circumstances, such as standardized decompression methods, indications, and timing of surgery, should be considered to ensure the effectiveness and safety of early surgical interventions and to promote functional recovery of residual nerve tissue. No significant differences between the anterior cervical discectomy and fusion and the posterior cervical laminectomy for patients with ACCS in terms of ASIA classification, ASIA motor scores, and sensory scores were found. It was shown that the complication rate of posterior cervical spine surgery is lower than that of anterior surgery in patients with CSI [9]. The limitations of this study include the lack of studies on complications and the small number of patients included. In the future, a multicenter study with a larger number of patients will be conducted to obtain more clinical data. Moreover, elderly patients were not covered in this study. The elderly population is prone to traumatic cervical medullary injuries due to physical deterioration, poor coordination, and poor muscle protection and compensatory capacity, and therefore cervical medullary injuries in the elderly population require increasing attention. ACSS, as one of the most common types of incomplete cervical medullary injury, features an incidence of about 70% [1]. Because elderly patients usually have degenerative cervical spine diseases and different degrees of cervical spinal cord compression and other pathological bases in the spinal canal, they are more susceptible to spinal cord compression after trauma. Elderly patients with ACCS, even without cervical fracture-dislocation, are often associated with injury to the anterior cervical ligament, or the disc-anterior longitudinal ligament complex, leading to potential cervical instability [4–6], which is an absolute indication for surgical treatment. With the development of tissue engineering and medical devices, the self-locking zero-tangential interbody fusion ROI-C was designed to be used in anterior cervical decompression fusion surgery. Currently, the ROI-C fusion device has been widely used in the surgical treatment of cervical degenerative diseases with satisfactory results due to its simple operation, high time efficiency, and good treatment effects.

5. Conclusion

Both anterior cervical discectomy and fusion and posterior cervical laminectomy can improve the ASIA classification, ASIA motor scores, and sensory scores of ACCS patients without fractures or dislocations of the cervical spine. Therefore, surgical methods should be adopted based on the patients' conditions.

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Conflict of interest

The authors declare that they have no conflict of interest.

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