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Original Article

Impact of surgical timing on the outcomes of traumatic cervical spinal cord injury

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Abstract: Objective: To investigate the association between surgical timing and treatment efficacy in patients with traumatic cervical spinal cord injury. Methods: A total of 78 patients with traumatic cervical spinal cord injury were enrolled in Nantong Haimen People's Hospital from January 2019 to June 2022. Of these, 40 patients who received anterior decompression and fixation surgery with bone graft and steel plate within 2-7 days post-injury were assigned to the control group, while 38 patients who received the treatment within 24 h after injury were assigned to the study group. The recovery outcomes, visual analog score (VAS), anxiety score (Self-Rating Anxiety Scale, SAS), depression score (Self-Rating Depression Scale, SAS), and adverse events were compared between the two groups. Results: The study group demonstrated a significantly higher recovery rate compared to the control group ($P < 0.05$). Additionally, the VAS, SAS, and SDS scores were markedly lower in the study group than those in the control group (all $P < 0.05$), indicating reduced pain and psychological distress. The incidence of adverse events was also significantly lower in the study group compared to the control group ($P < 0.05$), underscoring the safety and efficacy of early surgical intervention. Conclusions: Early surgical intervention not only alleviates physical pain but also effectively reduces psychological stress, thereby promoting overall recovery.

Keywords: Different, surgical methods, treatment timing, traumatic cervical spinal cord injury, therapeutic efficacy, effect

Introduction

Traumatic cervical spinal cord injury is a common type of fracture, with high-altitude falls and traffic accidents being the leading causes [1, 2]. If not promptly treated, such injuries can impair joint function and potentially lead to paralysis [3]. Recent investigations show that the incidence of traumatic cervical spinal cord injury is on the rise, posing a significant threat to both physical and mental health [4]. Currently, decompression surgery is the standard approach for this type of fracture, and the recovery outcomes have been promising. However, follow-up data reveals a risk of spinal instability due to complications such as plate fractures or loosening [5]. To address this, decompression surgery combined with bone grafting and internal fixation is performed to enhance overall spinal stability and improve prognosis and recovery. This fixation technique also directly improves neurological function recovery. Surgical decompression combined with internal fixation has become the primary surgical approach for traumatic cervical spinal cord injury [6, 7]. Ongoing discussions among scholars focus on the timing of treatment. Some studies suggest that hematoma and edema formation following injury can negatively affect neurological function, while spinal instability can further exacerbate nerve damage [8]. Early surgical decompression and fixation of the fracture site have been shown to benefit patient recovery. However, long-term follow-up analysis of neurological function has indicated that the choice of surgical timing may not significantly impact outcomes [9]. Some even suggest that early surgery may cause more severe neurological damage or iatrogenic spinal cord injury [10]. Therefore, the association between different surgical timing, and the efficacy of treatment in patients with traumatic cervical

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spinal cord injury warrants further investigation.

Materials and methods

Baseline information

A total of 78 patients with traumatic spinal cord injury treated at Nantong Haimen People's Hospital between January 2019 and June 2022 were retrospectively selected for this study. These patients were divided into two groups based on different treatment timing: a control group (n=40) and a study group (n=38). Inclusion criteria: (1) patients aged 25-60 years, of either gender, who met the diagnostic criteria for traumatic spinal cord injury [11]; (2) patients with sensory dysfunction in the affected area; and (3) patients or their relatives who voluntarily agreed to participate after understanding the study's purpose. Exclusion criteria: (1) patients with severe organ diseases such as heart and lung conditions; (2) patients with mental or intellectual abnormalities that hindered normal communication; and (3) patients unable to cooperate with observations due to physical reasons, dropouts, or participation in other studies. The study was approved by the ethics committee of Nantong Haimen People's Hospital.

Surgical methods

Patients in the control group underwent anterior decompression and fixation with bone graft and steel plate within 2-7 days post-injury. The patients were assisted into a supine position, with the shoulder elevated and the neck tilted to the left. General anesthesia was administered. An oblique incision was made on the right side of the affected intervertebral disc to allow complete separation of the cervical extensor muscles and fascia. A fusion device was then implanted in front of the vertebral body, between the visceral and vascular sheaths. An X-ray was used to examine the internal wound. The thyroid gland, trachea, and esophagus were manipulated to locate the arterial sheath. Traction parameters were adjusted to ensure smooth removal of the protruding intervertebral disc. Special care was given to older patients requiring excision or ossification of hypertrophied ligaments. In younger patients, the posterior ligament could be preserved. For patients with multiple cervical spine conditions, the entire vertebral body was removed, and an appropriate bone block was selected to replace the central cartilage. The anterior cervical approach was stabilized with a steel plate. The positions of the traction, vertebral body, and steel plate were checked using X-ray. If no abnormalities were detected, the wound was cleaned, drained, and sutured. The patient was immobilized with a neck brace and instructed to report any abnormal or uncomfortable sensations upon awakening. Post-surgery, interventions for de-swelling, dehydration, and inflammation were administered, and the patient was placed on a respirator for continuous oxygen administration. The patient was advised not to remove the neck brace and to wear it for at least three months. The drainage tube was removed 1-2 days after surgery, and the cervical area was checked. If no issues were found, stitches were removed around 7 days post-surgery. Patients were advised to attend medical follow-up after discharge. The patients in the study group underwent the same surgery within 24 hours of the injury.

Ethics statement

This study was conducted in accordance with the principles outlined in the Declaration of Helsinki and approved by the Ethics Committee of Nantong Haimen People's Hospital. Patients' consent was waived due to the retrospective nature of the study.

Observational indicators

Evaluation of patient recovery: Postoperatively, the sensory and residual motor function of patients were assessed based on the severity of spinal cord injury (Frankel classification) [12]. Functional status was evaluated using the following criteria.

Grade A: complete loss of motor and sensory function at the injury site.

Grade B: total loss of motor and sensory function at the injury site.

Grade C: complete loss of sensory function and partial non-functional residual motor function at the injury site.

Grade D: presence of incomplete useful motor function at the injury site.

Grade E: complete recovery of motor and sensory function at the injury site.

The recovery rate of spinal cord injury = cases of grades C - E/total cases × 100%.

Evaluation of psychological state and pain level of patients: The psychological status of patients was evaluated using the Self-Rating Anxiety Scale (SAS) and Self-Rating Depression Scale (SDS) after operation [7]. The SAS scale measures anxiety levels, with scores of 50 or lower indicating no anxiety and scores of 51 or higher indicating anxiety. The SDS scale measures depression levels, with scores of 53 or lower indicating no depression and scores of 54 or higher indicating depression. Higher scores on both scales indicate more severe anxiety or depression. Pain level was evaluated using the Visual Analog Scale (VAS), with scores ranging from 0-10, where 0 indicates no pain, 1-3 indicates mild pain, 4-6 indicates moderate pain, 7-9 indicates severe pain, and 10 indicates unbearable pain.

Evaluation of physical status of patients: The American Society of Anesthesiologists (ASA) classification was used to assess the physical status of patients. The ASA scores were assigned based on the patient's medical history and physical examination, categorizing patients into four levels.

ASA 1: A healthy patient with no systemic disease.

ASA 2: A patient with mild systemic disease that does not limit daily activities.

ASA 3: A patient with severe systemic disease that limits daily activities but is not life-threatening.

ASA 4: A patient with a severe systemic disease that is life-threatening and poses a risk to life.

Evaluation of adverse events: Patients were followed up 3 months after surgery to record any adverse events such as plate loosening, plate fracture, and bone graft non-fusion.

Statistical analysis

The statistical software SPSS 20.0 was used for data analysis. Continuous data were presented as mean ± standard deviation, and between-group comparisons were conducted using the t-test. Categorical data were presented as proportions and analyzed using chi-square test. For the comparison of continuous data at different time points between groups, a repeated measures analysis of variance was performed. Statistical significance was defined as $P < 0.05$.

Results

Comparison of general data between the two groups

The two groups showed no significant differences in gender distribution, average age, disease severity, or proportions of hypertension and diabetes, indicating comparability between the two groups, as shown in **Table 1**.

Comparison of ASA scores between the two groups

In the control group, the patients stratified according to ASA levels were 7.50% (3 cases) of level 1, 40.00% (16 cases) of level 2, 42.50% (17 cases) of level 3, and ASA 10.00% (4 cases) of level 4. In the study group, the patients of ASA level 1 accounted for 10.53% (4 cases), ASA 2 for 32.50% (13 cases), ASA 3 for 42.11% (16 cases), and ASA 4 for 13.16% (5 cases). There were no significant differences in patient stratification based on ASA (P=0.909) (**Table 2**).

Comparison of spinal cord injury assessment between the two groups

In the control group, the distribution across the Frankel classification was as follows: 6 (15.00%) in Grade A, 7 (17.50%) in Grade B, 10 (25.00%) in Grade C, 10 (25.00%) in Grade D, and 7 (17.50%) in Grade E, with a spinal cord injury recovery rate of 27 (67.50%). In the study group, there were no cases in Grade A (0.00%), 2 (5.26%) in Grade B, 13 (34.21%) in Grade C, 14 (36.84%) in Grade D, and 9 (23.68%) in Grade E, with a significantly higher recovery rate of 36 (94.74%). The study group demonstrated a significantly higher recovery rate than the control group (P=0.002) (**Table 3**).

Comparison of psychological status between the two groups

In terms of psychological status, prior to the intervention, there was no significant difference in the SAS score between the study group and control group (62.78±1.01 vs. 62.02±2.76)

Table 1. Comparison of baseline information between the two groups of patients

Group	n	Gender (n, %)		Average age (year)	Severity (n, %)	
		Male	Female		Mild	Severe
Control group	40	28 (70.00%)	12 (30.00%)	40.87±1.66	31 (77.50%)	9 (22.50%)
Study group	38	30 (78.94%)	8 (21.05%)	40.45±1.11	29 (76.32%)	9 (23.68%)
X^2/T	/	0.818		1.314	0.015	
P	/	0.366		0.193	0.901	
		Hypertension (n, %)		Diabetes (n, %)		
		Male	Female	Male	Female	
Control group	40	10 (25.00%)	6 (15.00%)	5 (12.50%)	3 (7.50%)	
Study group	38	8 (21.05%)	7 (18.42%)	4 (10.53%)	4 (10.53%)	
X^2/T		0.002		0.013		
P		0.962		0.908		

Table 2. Comparison of patient distribution across various ASA levels between the two groups (n, %)

Group	ASA 1	ASA 2	ASA 3	ASA 4
Control group	3 (7.50%)	16 (40.00%)	17 (42.50%)	4 (10.00%)
Study group	4 (10.53%)	13 (32.50%)	16 (42.11%)	5 (13.16%)
X^2				0.544
P				0.909

Note: ASA 1: with no systemic disease. ASA 2: with mild systemic disease that does not limit daily activities (e.g., controlled hypertension or diabetes without complications). ASA 3: with severe systemic disease that limits daily activities but is not incapacitating (e.g., poorly controlled diabetes or cardiovascular diseases). ASA 4: with severe systemic disease that threats life (e.g., recent myocardial infarction or severe sepsis). ASA: American Society of Anesthesiologists.

Table 3. Comparison of spinal cord injury assessment between the two groups (n, %)

Group	n	A	B	C	D	E	Spinal cord injury recovery rate
Control group	40	6 (15.00%)	7 (17.50%)	10 (25.00%)	10 (25.00%)	7 (17.50%)	27 (67.50%)
Study group	38	0 (0.00%)	2 (5.26%)	13 (34.21%)	14 (36.84%)	9 (23.68%)	36 (94.74%)
X^2	/						9.307
P	/						0.002

(t=1.603, P=0.113). Similarly, there was no significant difference in the SDS score between the two groups (62.14±1.31 vs. 62.76±1.61) (t=1.849, P=0.068). However, after the intervention, a remarkable difference was observed between the two groups. The SAS score in the study group was 39.07±1.50, while in the control group it was 56.27±4.26 (t=23.540, P < 0.0001); and for the SDS score, it was 38.73±1.3 in the study group and 55.28±4.33 in the control group (t=22.841, P < 0.0001) (**Table 4**).

Comparison of pain levels between the two groups

Before the intervention, there was no significant difference in pain levels between the study group and the control group as indicated by the VAS scores (7.16±0.40 vs. 6.99±0.49, P=0.101). However, after the intervention, a significant difference was observed. The pain level in the study group (4.62±1.29) was significantly lower than that in the control group (5.68±0.71) (P < 0.0001) (**Figure 1**), suggesting that early intervention had a more favorable effect on reducing pain.

Comparison of adverse events between the two groups

In the control group, there were 3 cases (7.50%) of loose steel plates, 2 cases (5.00%) of steel plate fractures, and 2 cases (5.00%) of non-union of bone graft, resulting in an adverse reaction rate of 17.50%. While in the study

Table 4. Comparison of psychological status between the two groups

	Time	Study group (n=38)	Control group (n=40)	*t*	*P*
SAS	Before intervention	62.78±1.01	62.02±2.76	1.603	0.113
	After intervention	39.07±1.50	56.27±4.26	23.540	0.000
SDS	Before intervention	62.14±1.31	62.76±1.61	1.849	0.068
	After intervention	38.73±1.3	55.28±4.33	22.841	0.000

Note: SAS: Self-Rating Anxiety Scale, SDS: Self-Rating Depression Scale.

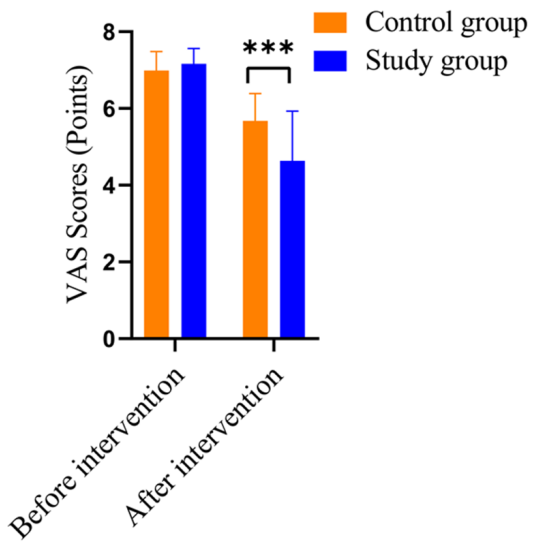

Figure 1. Comparison of pain levels between the two groups. Note: VAS: Visual Analogue Scale; ****P < 0.001*.

group, there was only 1 case (2.63%) of loose steel plate, with an adverse reaction rate of 2.63%, significantly lower than that in the control group (P=0.031) (**Table 5**).

Discussion

Traumatic cervical spinal cord injury significantly impairs both motor and sensory function at the site of the injury. Patients may experience symptoms such as neck pain, limb numbness, restricted joint movement, sensory disorders, and in severe cases, paralysis, progressive sensory function loss, and other complications that significantly impact their physical and mental well-being [13-15]. Surgery is the primary clinical treatment for this condition. While anterior surgical decompression can improve spinal cord injury, it often results in poor postoperative spinal stability and a high rate of adverse reactions [16-18]. Therefore, the current focus of treatment for this condition is on reducing spinal cord compression, enhancing spinal stability, and minimizing adverse reaction rates.

Our study investigated the efficacy of different treatment timing (≤ 24 hours vs. 2-7 days) on patients with traumatic cervical spinal cord injury. Our findings indicate that early anterior decompression combined with bone grafting and plate fixation significantly improved patient recovery, including reductions in pain, anxiety, and depression, as well as a lower incidence of adverse events. These results provide important insights for clinicians and emphasize the importance of timely surgical intervention.

A study on patients with traumatic cervical spinal cord injury featuring intramedullary hemorrhage and edema, implied that those who underwent early anterior surgery exhibited lower SAS, SDS, and VAS scores compared to individuals who underwent decompressive surgery ≥ 2 days after the injury [19]. Previous study focusing on patients with acute traumatic cervical spinal cord injury classified as Abbreviated Injury Scale (AIS) grade C and grade D, demonstrated that the incidence of adverse reactions was significantly lower in patients who received early anterior surgical decompression combined with bone graft and plate fixation in contrast to those who underwent delayed anterior surgery [20-22], and the results of this study are consistent with our study.

In our study, early anterior surgical decompression combined with bone grafting and plate fixation within 24 hours after traumatic cervical spinal cord injury appears to be a promising treatment option for improving recovery rate, reducing negative emotions, alleviating pain, and minimizing adverse reactions. Our results imply that this surgical procedure is effective in improving neurological function and relieving spinal cord pressure in the cervical region. However, postoperative spinal stability is gen-

Table 5. Comparison of adverse events between the two groups

Group	n	Loose steel plate	Steel plate fracture	Nonunion of bone graft	Adverse reaction rate
Control group	40	3 (7.50%)	2 (5.00%)	2 (5.00%)	7 (17.50%)
Study group	38	1 (2.63%)	0	0	1 (2.63%)
X^2	/				4.680
P	/				0.031

erally compromised, leading to potential adverse reactions that can affect motor and sensory function, increase pain and negative emotions, and prolong the recovery process [23]. Nevertheless, internal fixation with bone graft and plate fixation treatment can enhance spinal stability using the compressive and locking effects of the plate, thus reducing the incidence of plate loosening, displacement, and non-union of the bone graft [24, 25]. Anterior surgical decompression effectively reduces spinal cord compression caused by trauma, facilitating bone graft fusion. The herniated disc is removed to relieve spinal cord compression. By combining bone grafting with plate fixation, spinal stability is enhanced, maintaining a normal structure. This approach accelerates bone fusion, reduces adverse reactions, alleviates postoperative pain during healing, and promotes good recovery of the spinal cord [26]. Consequently, it effectively alleviates negative emotions and provides substantial comfort for patients [27, 28].

In addition, a combined surgical treatment within 24 hours after the injury can promptly alleviate spinal cord compression, reducing the risk of spinal cord necrosis and secondary damage caused by compression. This approach promotes the recovery of spinal stability, effectively avoiding secondary injuries related to trauma [29]. Open surgical reduction, compared to closed surgical reduction, reduces the incidence of nerve damage, facilitates nursing operations, and can mitigate complications associated with prolonged bed rest, such as hypostatic pneumonia, deep vein thrombosis, and bedsores [30]. Moreover, this approach can shorten the patient's intubation duration, hospital stay, and intraoperative blood transfusion [31]. However, combined operation within 24 h after injury also has adverse factors such as operation risk, anesthesia risk and increased cost. Thus, treatment plans must consider the patient's condition and weigh the benefits and drawbacks of each factor. Ultimately, patients and their relatives' informed choices should be respected and considered when creating and selecting clinical treatment plans [32].

Despite the valuable insights gained from this study, several limitations should be acknowledged. Firstly, while 78 cases were included, the sample size is relatively small compared to large multicenter studies, which may limit the generalizability of the conclusions. Secondly, the current data primarily focus on short-term outcomes, and there is a lack of long-term follow-up data to assess long-term complications or neurological recovery. Therefore, future work should include extended follow-up periods to evaluate these aspects.

In conclusion, compared with delayed surgical decompression, early anterior decompression surgery combined with bone graft and plate internal fixation within 24 h after injury can alleviate negative emotions and reduce surgical pain for patients with traumatic cervical spinal cord injury. It also helps in reducing adverse events and promotes the recovery of spinal cord injuries.

Disclosure of conflict of interest

None.

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