

Original Article

Effects of multidisciplinary model of damage control on acute cervical spinal cord injury in winter Olympic sports

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Received December 31, 2020; Accepted February 2, 2021; Epub May 15, 2021; Published May 30, 2021

Abstract: Purpose: To investigate the feasibility of multidisciplinary model of damage control (MMDC) in patients with acute cervical spinal cord injury (ACSCI) in winter Olympic sports. Methods: A total of 110 patients with ACSCI who participated in winter Olympic sports were selected as the study subjects, and were divided into the study group (SG, n=60, MMDC) and the control group (CG, n=50, conventional intervention) according to the intervention mode. The clinical effects of intervention, changes in neurological function and muscle tone before and after intervention, the changes in motor function and activity of daily living during intervention, and patient satisfaction towards intervention were compared between the two groups. Results: The effective rate of intervention in the SG was 98.33%, higher than 88.00% in the CG ($P < 0.05$), and the percentage of patients with Grade E injuries in the SG after intervention was 30.00%, significantly higher than 12.00% in the CG ($P < 0.05$). The scores of all dimensions of Ashworth scale in the SG were lower than those in the CG ($P < 0.05$). The patients in the SG exhibited higher FMA scale and modified Barthel index (MBI) scores than the CG from 1 to 6 months of intervention ($P < 0.05$). Conclusion: MMDC showed better efficacy, the patients' neurological function, muscle tone and motor function could be better restored, and patients' abilities of daily activities were improved after intervention.

Keywords: Winter Olympic games, winter sports, acute cervical spinal cord injury, injury control, multidisciplinary collaborative model, application analysis

Introduction

Winter sports (WSs) have diverse types, with both recreational and athletic features, particularly popular in Northern Europe and North America [1]. With the continuous growth of China's national economy and the steady improvement of residents' living standards, the people's view of sports has changed considerably, and their interest in various types of WSs has been rising, coinciding with Beijing's success in winning the bid to host the 2022 Winter Olympics, which has played a huge role in promoting the development of WSs in China [2, 3]. However, clinical practice found that any sports have certain risks, and improper exercise is very likely to lead to physical injury. WSs are characterized by high speed and high risk, and common WSs injuries include sprains, strains, dislocations, and fractures [4, 5]. Cervical spinal cord injury is also a common type of injury in WSs, and the results of a study

showed that the prevalence of cervical spondylosis among athletes in figure skating, free skiing, and speed skating was as high as 48.3%, significantly higher than that of athletes in other sports. The injury is closely related to the characteristics of these types of sports and prolonged overload training [6].

Acute cervical spinal cord injury is a more serious injury that can lead to death or disability if not treated properly. Generally, patients with upper cervical spinal cord injury are prone to tetraplegia. If accompanied by paralysis of the diaphragm or intercostal muscles, patients may die of respiratory distress. Patients with lower cervical spinal cord injury tend to have limb paralysis below the level of injury, segmental sensory or motor deficits in the upper extremities. If the spinal cord is completely injured, patients will have delayed complete paralysis, the loss of all types of sensation and reflexes below the level of injury, which is generally diffi-

cult to recover [7, 8]. At present, the clinical interventions for acute cervical spinal cord injury still tend to symptom control and symptomatic treatment, which can alleviate the clinical symptoms of patients, but are less effective in improving the prognosis of patients, so it is urgent to seek a more efficient therapy to improve the prognosis of such patients [9].

Damage control surgery was proposed by Rotondo et al. in the 1990s, who concluded that rapid control of body cavity bleeding and physiological resuscitation had positive implications for reducing mortality in critically ill patients [10]. Damage control surgery has also been applied to a variety of acute injuries, and a clinical study on patients with acute craniocerebral injury has found that damage control surgery can significantly improve clinical symptoms and neurological damage of patients, and has positive significance in improving the quality of life of patients [11]. The multidisciplinary model is a clinical intervention model developed from the traditional monodisciplinary treatment model, which is patient-centered and disease-specific. A standardized, individualized, and continuous comprehensive treatment plan was developed with efforts of a multidisciplinary team [12]. It has been shown that the multidisciplinary model can significantly improve effects of clinical interventions and has good therapeutic efficacy for patients with thyroid, diabetes, and hypertension [13]. The purpose of this study was to investigate the feasibility of implementing multidisciplinary model of damage control (MMDC) for patients with acute cervical spinal cord injury (ACSCI) who competed in winter Olympic sports, thereby providing a clinical reference for improving the prognosis of such patients.

Materials and methods

Baseline data

A total of 110 patients with ACSCI in Ws at the Winter Olympics treated in our department from January 2018 to December 2019 were enrolled in the study, and were divided into a study group (SG, n=60, MMDC) and a control group (CG, n=50, conventional interventions).

Inclusion criteria: (1) patients with acute cervical spinal cord injury [14] during the winter

Olympic sports; (2) patients with good treatment compliance; (3) this study was approved by the ethics committee of The First Affiliated Hospital of Hebei North University; (4) patients with complete clinical data, medical history, and examination records of the subjects; and (5) the subjects signed the informed consent form.

Exclusion criteria: (1) patients with concurrent psychiatric disorders; (2) patients comorbid with severe hepatic, renal or other organ disorders; (3) drug or alcohol dependence; (4) patients comorbid with other types of trauma; (5) pregnant or lactating women.

Elimination criteria: (1) patients who were lost to follow-up during the intervention; and (2) patients who voluntarily requested to withdraw from the study during the intervention.

Methods

Patients in the CG were treated with conventional interventions, including administration of dexamethasone and methylprednisolone, strengthened nutritional interventions, preventing urinary tract infections and pulmonary complications, etc.

Patients in the SG were additionally cared with MMDC, and the specific measures were as follows: (1) MMDC was divided into the following three phases: initial laparotomy, intensive care unit (ICU) resuscitation, and definitive reconstruction. In the first phase, the priority was controlling hemorrhage followed by contamination control, abdominal packing, and placement of a temporary closure device. In the second phase, the key was to reverse the physiologic insult that occurred, including correction of coagulation disorders and acidosis, relieving airway disorders, etc. The third stage was the accurate reduction and internal fixation of the fracture after the patient's physiological state was stable. According to the patient's imaging examination results, further targeted treatment was carried out. (2) Multidisciplinary model. A multidisciplinary team consisting of spine surgeons, spine nurses, rehabilitation physicians, psychologists, nutritionists, acupuncturists, etc. was established to provide patients with collaborative interventions, including psychological and physiological interventions during the treatment and the recovery

of physical functions of patients after surgery, etc. The entire intervention process focused on comprehensive use of resources to ensure that patients received comprehensive care centered on their condition.

Outcome measurement

Clinical intervention: The clinical efficacy was evaluated after 3 months of intervention in the two groups and was categorized as markedly effective, effective and ineffective. Markedly effective means that the patient's muscle strength below the level of injury is II-IV after intervention, and the patient's thigh muscles are basically recovered. Patients can stand, walk, and control bowel movements. Effective means that the patient's sensation in the segment below the level of injury is restored after intervention. The motor performance is partially improved, but it is difficult to walk on crutches, and the condition of incontinence has been improved. Ineffective means that the clinical symptoms or signs have not been significantly improved or even worsened after intervention. The effective rate = (number of markedly effective + number of effective)/total number of cases × 100%.

Evaluation of neurological function before and after intervention: The neurological function of the two groups was assessed before and after intervention using the Frankel grade. Grade A: complete paralysis; Grade B: sensory function only below the injury level; Grade C: incomplete motor function below injury level; Grade D: fair to good motor function below injury level; Grade E: normal function. The neurological function grading was calculated before and after intervention [15] in the two groups, respectively.

Muscle tone, motor function and life ability scores before and after intervention: The muscle tone, motor function and abilities of daily activities were assessed before and after intervention in the two groups, respectively, where muscle tone was assessed by the modified Ashworth scale, which was a 5 point numerical scale that graded spasticity from 0 to 4, with 0 indicating no resistance and 4 indicating a limb rigid in flexion or extension. Patients were assessed before and 3 months after intervention. The assessment tool for motor function

was Fugl-Meyer Assessment (FMA), which includes items assessing movement, coordination, and reflex action of the shoulder, elbow, forearm, wrist, hand, hip, knee, and ankle, with higher total scores representing better motor function. The scale was assessed at pre-intervention (0 month), 1 month, 2 months, 3 months, 4 months, 5 months and 6 months after intervention. The MBI is a measure of activities of daily living, which shows the degree of independence of a patient from any assistance. It covers 10 domains of functioning activities: bowel control, bladder control, as well as help with grooming, toilet use, feeding, transfers, walking, dressing, climbing stairs, and bathing. Each activity is given a score ranging from 0 (unable to perform task) to a maximum of 10 (fully independent) and the exact score depends on the activity being evaluated. A total score was obtained by summing points for each of the items, with higher scores representing better activities of daily living. The patients were also assessed from 0-6 months [16, 17].

Statistical analysis

Data were analyzed using statistical software, and the normal distribution test was carried out on the collected data. If the data conformed to normal distribution, the count data were expressed as [n (%)], and the *Chi-square* test was selected for the analysis of variance between groups. The measurement data were expressed as mean ± standard deviation, and the *t*-test was used for the analysis of variance between groups. For the comparison of continuous variables within groups, *t* test was also selected. Statistical graphs were drawn by GraphPad Prism 8. $P < 0.05$ indicated a significant difference [18].

Results

Comparison of baseline data

In this study, 110 patients were included, including 60 cases in the SG and 50 cases in the CG. The intergroup comparison of the above indicators showed no significant difference between the two groups in terms of baseline data ($P > 0.05$), suggesting that the two groups were comparable (Table 1).

Table 1. Comparison of general data ($\bar{x} \pm sd$)/[n (%)]

Baseline data		Study group (n=60)	Control group (n=50)	t/ χ^2	P
Gender	Male	37	28	0.547	0.362
	Female	23	22		
Average age (years)		25.98±4.33	26.01±4.29	0.036	0.987
Average weight (kg)		64.29±3.91	64.34±3.89	0.066	0.917
Average BMI (kg/m ²)		21.29±1.22	21.31±1.21	0.086	0.932
Preoperative MMSE score		12.81±2.11	12.78±2.21	0.073	0.942
The degree of damage	Complete injury	23	20	0.032	0.858
	Incomplete damage	37	30		
Injury reason	Fall injury	41	40	1.912	0.167
	Injured by a crashing object	19	10		

Table 2. Comparison of clinical efficacy

Grouping	Number of cases	Markedly effective	Effective	Ineffective	Effective rate
Study group	60	50 (83.33)	9 (15.00)	1 (1.67)	59 (98.33)
Control group	50	34 (64.00)	10 (20.00)	6 (12.00)	44 (88.00)
χ^2	-	-	-	-	4.887
P	-	-	-	-	0.027

tion ($P > 0.05$). The percentage of patients with grade E in the SG was significantly higher than that in the CG after intervention ($P < 0.05$) (**Table 3**).

Muscle tone, motor function and life ability scores before

Comparison of clinical efficacy

After 3 months of intervention, the efficacy of the intervention was evaluated. The results showed that the SG had 50 cases of markedly effective and 9 cases of effective, with the total effective rate of 98.33%. While the CG had 34 cases of markedly effective and 10 cases of effective, with the total effective rate of 88.00%, and the difference between the effective rates of the two groups of intervention was statistically significant ($P < 0.05$) (**Table 2**).

Comparison of Frankel's grade before and after intervention

Neurological function was assessed in both groups before and 3 months after intervention using Frankel grade. The pre-intervention Frankel A-E grade percentages were 20.00%, 31.67%, 25.00%, 23.33% and 0.00% in the SG, and 26.00%, 36.00%, 22.00%, 14.00% and 2.00% in the CG. The percentage of patients in the SG with grade E increased from 0.00% before intervention to 30.00% after intervention ($P < 0.05$), and the percentage of patients in the CG increased from 2.00% before intervention to 12.00% after interven-

and after intervention

There was no significant difference in the scores of the modified Ashworth scale before intervention between the two groups ($P > 0.05$). After intervention, both groups of patients showed a reduction in the scores of the above dimensions ($P < 0.05$), and the scores of all dimensions in the SG were lower than those in the CG ($P < 0.05$) (**Figure 1**).

Dynamic assessment of motor function and activity of daily living

FMA scale scores did not differ between the two groups at 0 month ($P > 0.05$), but were significantly higher in the SG than in the CG ($P < 0.05$) from 1 month to 6 months of intervention (**Figure 2**). The difference between the groups in MBI scale scores before intervention was not statistically significant ($P > 0.05$), but MBI scores in the SG were significantly higher than those in the CG at 1-6 months of intervention ($P < 0.05$) (**Figure 3**).

Discussion

With the continuous prosperity of China's WSs [19], the training mode of athletes with high

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Table 3. Comparison of Frankel's grade before and after intervention [(%)]

Grouping	n	Time	Grade A	Grade B	Grade C	Grade D	Grade E
Study group	60	Pre-intervention	12 (20.00)	19 (31.67)	15 (25.00)	14 (23.33)	0 (0.00)
		Post-intervention	2 (3.33) [#]	12 (20.00)	10 (16.67)	18 (30.00)	18 (30.00) ^{#,*}
Control group	50	Pre-intervention	13 (26.00)	18 (36.00)	11 (22.00)	7 (14.00)	1 (2.00)
		Post-intervention	7 (14.00)	15 (30.00)	8 (16.00)	14 (28.00)	6 (12.00)

Note: [#] $P < 0.05$ compared with pre-intervention, and ^{*} $P < 0.05$ compared with the control group.

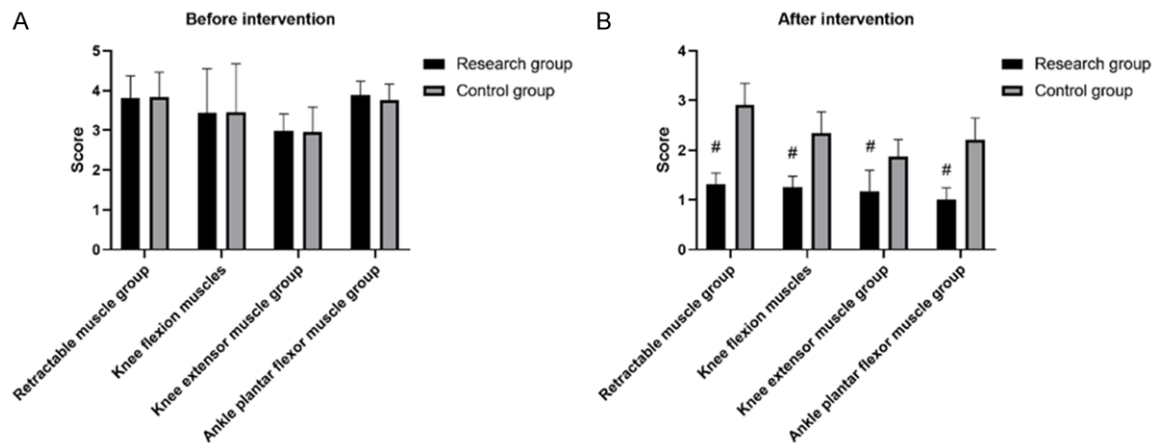


Figure 1. Comparison of changes in dystonia scores. Before intervention, there was no statistically significant difference in the dimensions of dystonia scores between the two groups ($P > 0.05$) (A); after intervention, the scores of each dimension in the study group were significantly lower than those in the control group ($P < 0.05$) (B). Compared with the control group, [#] $P < 0.05$.

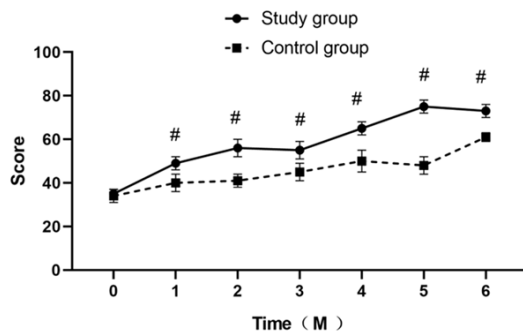


Figure 2. Comparison of motor function. Before intervention (0 month), there was no statistically significant difference in FAM scale scores between the two groups ($P > 0.05$). FAM scale scores in the SG were higher than those in the CG from 1 month to 6 months after intervention ($P < 0.05$). Compared with the control group at the same time point, [#] $P < 0.05$.

intensity and high capacity is becoming more common. In the daily training and competition, injury accidents will not only affect the normal training of athletes in the competition, but also have a serious impact on the physical and mind of athletes, hindering the long-term develop-

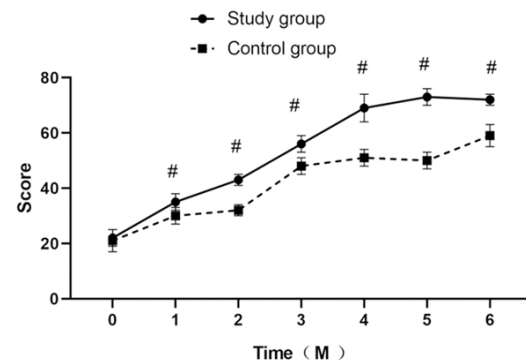


Figure 3. Comparison of daily living ability between the two groups of patients. Before intervention (0 month), there was no statistically significant difference in MBI scale scores between the two groups ($P > 0.05$). MBI scale scores in the SG were higher than those in the CG from 1 month to 6 months after intervention ($P < 0.05$). Compared with the control group at the same time point, [#] $P < 0.05$.

ment of WSs. The results of a retrospective analysis conducted on ice skaters found that ice hockey, freestyle skiing, speed skating, and figure skating are sports with a high incidence

of injuries, and the athletic injury often occurred in knee, ankle, low back, cervical and lumbar spine, etc. The common types of injuries include joint sprains, falls, and bruises, and the causes of injuries are mostly related to intense conflict, fatigue, etc. [20]. In addition, evidence has also been found that cervical spinal cord injuries are also a more common type of injury in WSSs, and these injuries could end careers of athletes. If the athletes do not receive timely and effective treatment, they may even have serious consequences such as paralysis and loss of motor function [21].

In this study, it was found that the effective rate in the SG was significantly higher than that in the CG (98.33% vs. 88.00%), and the post-intervention Frankel scores were higher in the SG. A clinical study conducted on patients with spinal cord injury and paraplegia found that the multidisciplinary model could significantly reduce the preoperative waiting time and postoperative hospital stay in patients with spinal cord injury. It could also help reduce the incidence of complications and improve patient satisfaction with the intervention, and the study concluded that the multidisciplinary model could provide optimal treatment plan by integrating medical resources under the guidance of a multidisciplinary team [22]. Another controlled study of 80 patients with spinal cord injury showed that a multidisciplinary model significantly improved the activities of daily living of patients and also improved their satisfaction with the intervention [23]. This study concluded that the injury control surgery puts emphasis on preventing the “lethal triad”, rather than correcting the anatomy, and it is meant to save lives. The approach would provide a limited surgical intervention to control hemorrhage and contamination. This subsequently allows clinicians to focus on reversing the physiologic insult prior to completing a definitive repair. Multidisciplinary intervention is another treatment model that can integrate physiotherapy resources and maximize the efficiency of intervention, and the combination of the two significantly improves the clinical efficacy as well as the neurological function of patients [24].

This study further assessed the muscle tone and activities of daily living in both groups before and after intervention, and the results

showed that on the one hand, the muscle tone scores of the patients in the SG were significantly better than those of the CG after intervention, and on the other hand, the motor function and activities of daily living scores of the patients in the SG were significantly higher during the intervention, both of which indicate that MMDC is more effective in improving the quality of life and motor function of the patients. A controlled study conducted on 80 patients with spinal cord injury showed that a multidisciplinary model was more effective in improving trunk control, muscle strength and motor function compared to traditional rehabilitation treatment, which is similar to the results of this study [25]. Another study has found that damage control orthopedics has a positive effect on the prognosis of patients with spinal cord injury and can significantly improve their long-term living ability [26]. Based on this study, we believe that multidisciplinary model can, on the one hand, prevent patients from “secondary injury” during the treatment, and on the other hand, can implement comprehensive interventions for patients from multiple perspectives such as psychological and physiological, which can minimize the incidence of medical errors in the intervention process, thus improving the prognosis of patients [27].

In conclusion, MMDC is effective for patients with ACSCI in the winter Olympic sports, the neurological function, muscle tone and motor function of the patients can be better restored, and their activity of daily living is significantly improved after intervention, which is worthy of clinical promotion. The innovation of this study is that the effectiveness of MMDC was demonstrated from the aspects such as activity of daily living, motor ability, and muscle tone, etc., which can provide theoretical reference for follow-up studies. The shortcomings of this study include the neglect of the effect of the subject's underlying disorders on the intervention effect, and a low degree of departmental coordination which may have affected the efficiency of the intervention. It is proposed to be improved in the follow-up study.

Acknowledgements

This work was supported by Scientific and Technological Winter Olympic Games Special

Project of Hebei Provincial Technological Innovation-Guided Plan in 2020 (No. 2047-7707D).

Disclosure of conflict of interest

None.

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