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Original Article

Synchronized and integrated prehospital treatment for acute cervical spinal cord injury

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Abstract: Objective: To explore the effect of synchronized and integrated prehospital treatment strategies for on-site first aid, rescue transport and prehospital first aid in patients with acute cervical spinal cord injury. Methods: A prospective non-randomized controlled study was designed to include patients with acute cervical spinal cord injury. A total of 50 patients were included in a Control group (before the implementation of synchronized and integrated prehospital treatment), and 50 patients were included in an Observation Group (after the implementation of synchronized and integrated prehospital treatment). We compared the timeliness of prehospital treatment, the proportion of patients received methylprednisolone treatment within 3 h after injury, the changes in Japanese Orthopaedic Association (JOA) score during transport, the incidence of adverse events, the clinical outcomes, the number of prehospital deaths, the case number of paralysis and the recovery of postoperative neural function between the two groups. Results: Compared with the Control group, the Observation group showed significantly shorter time from injury to admission, from injury to receiving methylprednisolone pulse therapy, as well as from injury to receiving dehydrating agents and diuretics (all $P<0.001$). The proportion of patients received methylprednisolone treatment within 3 h after injury was significantly higher in the Observation group than that in the Control group ($P<0.05$). There was no significant change in the JOA score in the Observation group before and after the transport, while the score was significantly lower in the Control group after the transport ($P<0.001$). The JOA score was higher in the Observation group than that in the Control group at admission ($P<0.001$). The Observation group also showed decreased incidences of adverse events, mortality, and paralysis rate (all $P<0.05$) as well as better recovery of postoperative neural function ($P<0.001$) when compared with the Control group. Conclusion: Synchronized and integrated prehospital treatment has a significant effect in patients with acute cervical spinal cord injury through shortening the admission time, reducing the risk of adverse events, and improving the rescue effect and the prognosis of neural function.

Keywords: Acute cervical spinal cord injury, on-site treatment, prehospital first aid, clinical outcome, neural function

Introduction

Acute cervical spinal cord injury is caused by severe violence from various external factors or forces, resulting in an extremely high mortality and disability rate in patients [1]. The incidence of fatal complications is as high as 25% from the time of accident to admission. Therefore, the survival of most patients with severe trauma depends on whether they can get timely and scientifical treatment [2, 3]. Patients with spinal cord injury are prone to having fatal complications such as shock and asphyxia. So, it is necessary to pay great attention to patients who are suspected to have spinal cord injury, which should be quickly and accurately assessed to implement scientific on-site aid and timely transport patients to hospital for further treatment [4]. In addition, scientific transport methods should be adopted to avoid secondary spinal cord injury.

Among the causes of acute cervical spinal cord injury, traffic accidents rank first, accounting for about 50%, followed by winter sports [5]. Because skiers mostly move fast on an uneven venue and do continuous twisting and tossing movements in the air, they are prone to spinal cord injury, even the deadly cervical spine injury [6, 7]. Establishing a scientific set of safety assurance systems and a multi-mode joint treatment for acute cervical spinal cord injury is of great significance for the safety of patients because the measures can reduce the high paraplegia rate and mortality from sports-lead cervical injuries, and improve the neural function in patients. In this study, we analyzed the effect of the synchronized integrated prehospital treatment for on-site first aid, rescue transport and prehospital first aid in patients with acute cervical spinal cord injury, so as to protect the patients and provide reference for the prehospital first aid.

Materials and methods

Patients

We designed this prospective non-randomized controlled study that included 100 patients with acute cervical spinal cord injury who were admitted to our hospital from January 2017 to December 2020. Patients were eligible if they were diagnosed with acute cervical spinal cord injury, and were treated by our hospital right after the onset [8]. Patients were excluded if they had a history of spinal cord injury, did not have a complete treatment, were lost to follow-up after treatment, or died from other causes during the follow-up.

Ethics statement

This study followed the Declaration of Helsinki and was approved by the ethics committee of our hospital. All patients and their families signed an informed consent form.

Synchronized and integrated prehospital treatment strategies

Quick evaluation of injury: The traumatic condition was checked by the paramedics right after arrival. First, the patient's position was remained before clarifying the injury [9]. Second, patient's consciousness and vital signs were checked. For those with consciousness impairment, breathing, pulse and blood pressure were checked to determine whether the patient was in shock, then corresponding measures were taken for on-site treatment. Third, the cervical spinal cord injury was clarified according to the tenderness and morphological abnormalities of patient's limbs, muscle and cervical spine [10]. Last, the segments and extent of cervical spinal cord injury was determined by observing patient's paralysis, breathing and incontinence [11]. Professional spine surgeons were on-site to conduct the Japanese Orthopaedic Association (JOA) assessment so as to determine the degree of injury. Based on the results of the examination, timely on-site treatment was carried out and transport tools were prepared for patients who were considered to have cervical spinal cord injury.

On-site first aid: First, the patient's airway was kept unobstructed. Mechanical ventilation was conducted mainly with endotracheal intubation through the nose to avoid repeated intubation. Patients with respiratory disorders were performed with modified percutaneous dilatational tracheostomy (MPDT) when necessary to quickly, safely and effectively open the airway in the immobilized position of the neck, so as to provide adequate ventilation support. Second, venous access was established for patients with unstable hemodynamics by giving fluid infusion in time and vasopressors as appropriate, so as to maintain sufficient circulating blood and prevent ischemic shock or secondary spinal cord injury. Fresh frozen plasma or albumin and other colloids, compound lactated Ringer's solution and other crystalloid solutions, as well as glucose saline were prepared on site, and intravenous pulse treatment at regular doses was given to try to reach a sufficient level within 3 hours. Third, neck immobilization was performed by first using the "five-step" method to immobilize it with bare hands and then using a hard neck collar with a support plate on the back for fixing [12]. Sandbags or tape were used intermittently for fixation as well until the patients were transported to the hospital.

Rescue transport: In terms of transport requirements, at least three people were required to move the patient, so as to maintain the stability of the spine axis and prevent the patient from swinging or twisting of the cervical spine. An inelastic stretcher or spine board was used to keep the head slightly lower to avoid excessive flexion and extension of cervical spine [12]. In terms of catheterization, all patients were given urinary catheterization to assist in the assessment of circulatory disorders. It is also

Table 1. Baseline data (n, %) ($\bar{x}$ ± sd)

Item	Observation group (n=50)	Control group (n=50)	t/χ^2	P
Sex			0.049	0.826
Male	36 (72.00)	35 (70.00)		
Female	14 (30.00)	15 (34.00)		
Age (year)	35.2±5.5	34.8±6.2	0.341	0.733
Cause of injury			1.175	0.556
Fall injury	20 (40.00)	17 (34.00)		
Impact injury	17 (34.00)	15 (30.00)		
Car accident	13 (26.00)	18 (36.00)		

helpful for early use of dehydrating agents and diuretics which could prevent cell edema of spinal cord tissues. Patients were closely monitored for vital signs during transport, with both their respiratory tract and the infusion pipeline unobstructed. Also, patients were given anti-shock treatment and kept warm. To avoid unnecessary bumps, the transport was conducted *via* high-speed rail, high-speed road or helicopter according to the patient's injury and the location of the accident.

Evaluation criteria

Degree of cervical spine injury: The JOA score was used for evaluation, including the motor function of upper limbs (total score: 4 points) and lower limbs (total score: 4 points), the sensation of upper and lower limbs (total score: 6 points) as well as bladder function (total score: 3 points), with a total score of 17 points [13]. The lower the score was, the severer the cervical spine injury.

Recovery of neural function

The neural function scale by American Spinal Injury Association (ASIA) was used to evaluate the postoperative recovery of neural function in patients [14]. The ASIA score included sensory function (total score: 224 points) and motor function (total score: 100 points). The higher the score was, the better the recovery of neural function. In addition, the JOA score was also used to further assess the recovery level of patients' neural function.

Outcome measures

There were three main outcome measures. First, the timeliness of prehospital treatment, including the time from injury to admission, the time from injury to methylprednisolone pulse therapy, the time from injury to receiving dehydrating agents and the time from injury to receiving diuretic. Second, the number of patients that received methylprednisolone pulse therapy within 3 hours after injury. Third, the changes in JOA score during transport.

The secondary outcome measures included the incidence of adverse events during the transport (dropping or blockage of the infusion tube, failure of oxygen supply equipment, sudden asphyxia or dyspnea, sudden drop in blood pressure or ischemic shock, etc.), the success rate of rescue, the mortality and the postoperative recovery of neural function.

Statistical methods

SPSS 23.0 software (SPSS, Inc., Chicago, IL, USA) was used for statistical analyses. The count data were expressed as number of cases and percentage (n, %) and processed by chi-square test. The measurement data in this study conformed to the normal distribution, expressed as mean ± standard deviation ($\bar{x}$ ± sd), compared between the groups by the independent sample t test, and compared between before and after the intervention within the same group by paired t test. The test level was two-sided with α=0.05, and P<0.05 indicated that the difference was statistically significant.

Results

Baseline data

We included 100 patients with acute cervical spinal cord injury in the present study. Control group included 50 patients from January 2017 to December 2018, when the synchronized and integrated prehospital treatment was not yet implemented. Observation Group included 50 patients from January 2019 to December 2020 with the implementation of synchronized and integrated prehospital treatment. There were over 70% male patients in both groups, and the differences in gender, age and cause of injury were insignificant between the two groups (all P>0.05), so the two groups were comparable. See **Table 1**.

Table 2. Comparison of timeliness of prehospital treatment ($\bar{x}$ ± sd)

Item	Observation group (n=50)	Control group (n=50)	t	P
Injury - admission (h)	3.98±1.26	6.23±2.83	5.136	<0.001
Injury - methylprednisolone pulse therapy (h)	2.95±0.29	5.84±1.03	19.098	<0.001
Injury - receiving dehydrating agents (h)	10.32±2.05	15.93±3.62	9.535	<0.001
Injury - receiving diuretic (h)	8.97±2.23	13.55±2.88	8.891	<0.001

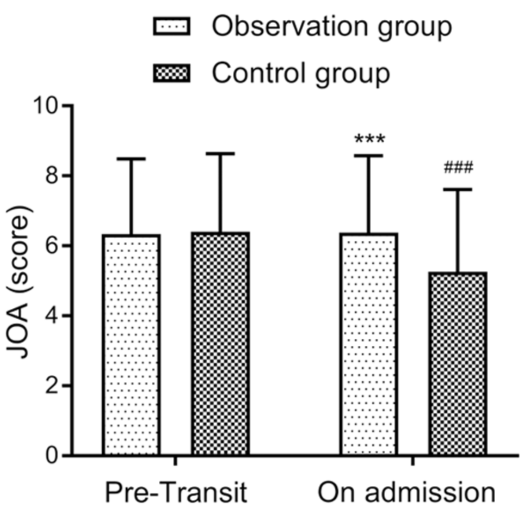

Figure 1. Changes in JOA score during transport. JOA: Japanese Orthopaedic Association. Compared with Control group, ***P<0.001; compared with before transport, ###P<0.001.

Comparison of the timeliness of prehospital treatment

Compared with the Control group, the Observation group had significantly shorter time from injury to admission, from injury to receiving methylprednisolone pulse therapy, as well as from injury to receiving dehydrating agents and diuretic (all P<0.001), especially the time from injury to receiving methylprednisolone pulse therapy which was almost cut in half. See **Table 2**. Thirty-eight patients (76.00%) in the Observation group received methylprednisolone pulse therapy within 3 h after injury, while only 12 patients (24.00%) in the Control group received the therapy within 3 h. Compared with the Control group, the Observation group had a higher proportion of patients who received the methylprednisolone pulse therapy within 3 h after injury (χ^2=27.040, P<0.001).

Changes in JOA score during transport

There was no significant difference in JOA scores between the two groups before transport (P>0.05). After the transport, no significant change was observed in the Observation group (P>0.05), while the JOA score was significantly lower than before in the Control group (P<0.001). Compared with the Control group, the Observation group had a higher JOA score at admission (P<0.001). See **Figure 1**.

Comparison of the incidence of adverse events during transport

Common adverse events in the two groups during transport were dropping, including blockage of the infusion tube, failure of oxygen supply equipment, sudden asphyxia or dyspnea, sudden drop in blood pressure or ischemic shock. There were 2 cases of dyspnea and 1 case of sudden drop in blood pressure in the Observation group, with a total incidence of adverse events of 6.00%. There were 12 adverse events in the Control group, including 5 cases of asphyxia or dyspnea, 4 cases of sudden drop in blood pressure or shock, 1 case of infusion tube shedding and 2 cases of hematoma, with a total incidence of 24.00%. The Observation group had a lower overall incidence of adverse events than the Control group (P<0.05). See **Table 3**.

Comparison of clinical outcomes

There was no death during prehospital treatment transport, and 1 death during treatment in the hospital in the Observation group. There were 3 cases died in the Control group during prehospital treatment transport, and 4 cases died during treatment in the hospital. The Observation group had a significant lower mortality rate than the Control group (14.00% vs. 2.00%, P<0.05). In addition, paralysis rate was also lower in the Observation group than that in the Control group (12.00% vs. 36.00%, P<0.01). See **Table 4**.

Recovery of postoperative neural function

The median follow-up time of the two groups were 13.5 months (6-24 months) and 14.2

Table 3. Comparison of the incidence of adverse events during transport (n, %)

Item	Observation group (n=30)	Control group (n=30)	χ^2	P
Adverse events				
Dropping of infusion tube	0 (0.00)	1 (2.00)		
Hematoma	0 (0.00)	2 (4.00)		
Asphyxia or dyspnea	2 (4.00)	5 (10.00)		
Sudden drop in blood pressure or shock	1 (2.00)	4 (8.00)		
Total incidence	3 (6.00)	12 (24.00)	6.353	0.012

Table 4. Comparison of clinical outcomes (n, %)

Group	Death	Paralysis
Observation group (n=50)	1 (2.00)	6 (12.00)
Control group (n=50)	7 (14.00)	18 (36.00)
χ^2	4.891	7.895
P	0.027	0.005

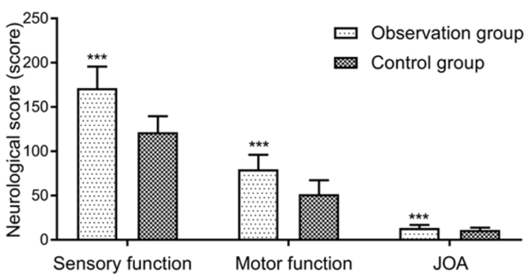

Figure 2. The recovery of neural function. JOA: Japanese Orthopaedic Association. Compared with Control group, ***P<0.001.

months (7-19 months) respectively. The Observation group showed higher scores of sensory functions, motor function and JOA than the Control group at the end of the follow-up (all P<0.001). See **Figure 2**.

Discussion

Among the 4 peak death periods of patients with cervical spinal cord injury, 80% of deaths are attributed to complications that occur in the first and second periods [15, 16]. The first period is post-accident. The patient may die due to fatal complications such as multiple injuries, hemorrhagic shock or high cervical spinal cord injury. Followed by a few hours after the cervical spinal cord injury, during which patients may die from complications such as respiratory dysfunction or asphyxia [4]. Scientific and efficient prehospital treatments in these two periods are the key to reducing mortality and improving prognosis.

At present, the timeliness of prehospital treatment has been seen as the key to reducing the mortality and disability rate of patients with trauma such as spinal cord injury [17]. In this study, we compared the timeliness of prehospital treatment in 100 patients with acute cervical spinal cord injury before and after the implementation of synchronized and integrated prehospital treatment. We found better timeliness in the Observation group as compared with the Control group. The time from injury to admission, from injury to methylprednisolone pulse therapy, and from injury to receiving dehydrating agents and diuretics were significantly shortened in the Observation group. A study showed that the earlier surgical or non-surgical treatments performed within 24 hours after injury were helpful for the prognosis of neural function [18]. The clinical effect of emergency surgery 8-12 hours after injury was significantly better than that of surgery within 12-24 h, and patients treated over 24 hours after injury had the worst recovery of neural function [19]. Therefore, early admission is of great significance for improving patient's neural function recovery. In addition, synchronized and integrated prehospital treatment also particularly emphasized the early methylprednisolone pulse therapy. The effect of methylprednisolone is to increase the blood supply of the spinal cord, reduce edema, inhibit inflammatory reactions, promote energy metabolism, inhibit the peroxidation of oxygen free radicals and lipids and improve nerve excitation [20, 21]. It is recommended to carry out sufficient maintaining pulse intravenous treatment at a conventional dose within 3 hours. Our results showed that the proportion of patients who received the methylprednisolone pulse therapy within 3 hours after injury was higher in the Observation group than that in the Control group (76.00% vs. 24.00%). This may be one of the important reasons why the neural function of Observation group was significantly better than that of Control group after treatment.

In addition to timeliness, the survival rate and long-term neurological prognosis of patients with spinal cord injury are also closely related to the correct on-site treatment, movement, and rescue transport [22, 23]. Our results showed that the JOA score of Observation group had no significant change during transport. While in the Control group, the JOA score was significantly reduced with 3 patients died, and the incidence of adverse events (6.00% vs. 24.00%), mortality (2.00% vs. 14.00%) and paralysis rate (12.00% vs. 36.00%) were increased. These data showed that synchronized and integrated prehospital treatment can effectively improve the safety of prehospital transport and the clinical outcomes. We believe that these benefits may be due to the following 3 factors. First, the degree of cervical spine injury in patients was quickly and accurately evaluated during synchronized and integrated prehospital treatment, which, combined with on-site JOA assessment, provides scientific guidance for first aid. Second, we were equipped with endotracheal intubation and oxygen inhalation devices as well as professional medical personnel so as to perform MPDT for asphyxiated patients who may have life-threatening bleeding or airway obstruction to prevent death. In this study, there were 2 patients who had dyspnea in the Observation group. The condition of 1 patient could not be improved by increased oxygen inhalation, so MPDT was performed immediately which effectively avoided death from asphyxia. Third, the intermittent use of neck collar and sandbags or tape reduced the pressure from neck collar, which could press the trachea, affect breathing and blood circulation, and cover the hematoma and subcutaneous emphysema formed after hemorrhage and tracheal rupture [24].

We followed up the two groups of patients for 6-24 months and assessed the patients' recovery of neural function at the end of the follow-up. The results of the study showed that the Observation group had higher sensory functions, motor function and JOA score as compared with the Control group, indicating that synchronized and integrated prehospital treatment can effectively improve the prognosis of neural function. However, we did not evaluate the impact of surgical time and surgical methods after admission, so the difference in neural function between the two groups needs to be further verified.

There are some limitations in our research. We included more patients who were injured in skiing in the Observation group, but the injury type in the Control group was not specifically managed, which may cause bias in the baseline characteristics of the two groups of patients. In addition, we did not evaluate the differences in treatments after admission (as mentioned above), so there might be some bias in the data about clinical outcomes and neural function. Therefore, a prospective randomized controlled study still needs to be conducted for further verification.

In conclusion, synchronized and integrated prehospital treatment has a significant effect in patients with acute cervical spinal cord injury, through effectively improving the timeliness and the safety of treatment, the success rate of rescue and the prognosis of neural function.

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Disclosure of conflict of interest

None.

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References

[1] Bezdudnaya T, Marchenko V, Zholudeva LV, Spruance VM and Lane MA. Supraspinal respiratory plasticity following acute cervical spinal cord injury. Exp Neurol 2017; 293: 181-189.
[2] Farhadi HF, Kukreja S, Minnema A, Vatti L, Gopinath M, Prevedello L, Chen C, Xiang H and Schwab JM. Impact of admission imaging findings on neurological outcomes in acute cervical traumatic spinal cord injury. J Neurotrauma 2018; 35: 1398-1406.
[3] Wilson M, Nickels M, Wadsworth B, Kruger P and Semciw A. Acute cervical spinal cord injury and extubation failure: a systematic review and meta-analysis. Aust Crit Care 2020; 33: 97-105.
[4] Savic G, DeVivo MJ, Frankel HL, Jamous MA, Soni BM and Charlifue S. Causes of death af-

ter traumatic spinal cord injury-a 70-year British study. Spinal Cord 2017; 55: 891-897.
[5] Hayashi T, Fujiwara Y, Sakai H, Maeda T, Ueta T and Shiba K. Risk factors for severe dysphagia in acute cervical spinal cord injury. Spinal Cord 2017; 55: 940-943.
[6] Dalkilic T, Fallah N, Noonan VK, Salimi Elizei S, Dong K, Belanger L, Ritchie L, Tsang A, Bourassa-Moreau E, Heran MKS, Paquette SJ, Ailon T, Dea N, Street J, Fisher CG, Dvorak MF and Kwon BK. Predicting injury severity and neurological recovery after acute cervical spinal cord injury: a comparison of cerebrospinal fluid and magnetic resonance imaging biomarkers. J Neurotrauma 2018; 35: 435-445.
[7] Furlan JC, Craven BC and Fehlings MG. Is there any gender or age-related discrepancy in the waiting time for each step in the surgical management of acute traumatic cervical spinal cord injury? J Spinal Cord Med 2019; 42: 233-241.
[8] Streeter KA, Sunshine MD, Patel SR, Gonzalez-Rothi EJ, Reier PJ, Baekey DM and Fuller DD. Mid-cervical interneuron networks following high cervical spinal cord injury. Respir Physiol Neurobiol 2020; 271: 103305.
[9] Zou ZM, Li J, Cao QY, Lian HX, He CN and Wang B. Clinical value of diffusion tensor imaging parameter value in evaluating the prognosis of spinal cord injury in acute cervical spinal cord injury. Zhonghua Yi Xue Za Zhi 2017; 97: 17-21.
[10] Jiang H, Wang J, Xu B, Yang H and Zhu Q. A model of acute central cervical spinal cord injury syndrome combined with chronic injury in goats. Eur Spine J 2017; 26: 56-63.
[11] Ihalainen T, Rinta-Kiikka I, Luoto TM, Thesleff T, Helminen M, Korpijaakko-Huuhka AM and Ronkainen A. Risk factors for laryngeal penetration-aspiration in patients with acute traumatic cervical spinal cord injury. Spine J 2018; 18: 81-87.
[12] Karsy M and Hawryluk G. Modern medical management of spinal cord injury. Curr Neurol Neurosci Rep 2019; 19: 65.
[13] Ishibashi Y, Adachi N, Koga H, Kondo E, Kuroda R, Mae T and Uchio Y. Japanese orthopaedic association (JOA) clinical practice guidelines on the management of anterior cruciate ligament injury-secondary publication. J Orthop Sci 2020; 25: 6-45.
[14] Aarabi B, Olexa J, Chryssikos T, Galvagno SM, Hersh DS, Wessell A, Sansur C, Schwartzbauer G, Crandall K, Shanmuganathan K, Simard JM, Mushlin H, Kole M, Le E, Pratt N, Cannarsa G, Lomangino CD, Scarboro M, Aresco C and Curry B. Extent of spinal cord decompression in motor complete (American spinal injury association impairment scale grades A and B) traumatic spinal cord injury patients: post-operative magnetic resonance imaging analysis of standard operative approaches. J Neurotrauma 2019; 36: 862-876.
[15] Ahuja CS, Nori S, Tetreault L, Wilson J, Kwon B, Harrop J, Choi D and Fehlings MG. Traumatic spinal cord injury-repair and regeneration. Neurosurgery 2017; 80: S9-S22.
[16] Mortezaee K, Khanlarkhani N, Beyer C and Zendedel A. Inflammasome: its role in traumatic brain and spinal cord injury. J Cell Physiol 2018; 233: 5160-5169.
[17] Cao Y, DiPiro N and Krause JS. Health factors and spinal cord injury: a prospective study of risk of cause-specific mortality. Spinal Cord 2019; 57: 594-602.
[18] Fehlings MG, Vaccaro A, Wilson JR, Singh A, W Cadotte D, Harrop JS, Aarabi B, Shaffrey C, Dvorak M, Fisher C, Arnold P, Massicotte EM, Lewis S and Rampersaud R. Early versus delayed decompression for traumatic cervical spinal cord injury: results of the surgical timing in acute spinal cord injury study (STASCIS). PLoS One 2012; 7: e32037.
[19] Zhao WT, Chen GD, Xia DC and Li PP. Effect of surgical intervention time on the recovery of nerve function in acute spinal cord injury: a meta-analysis. Zhongguo Gu Shang 2018; 31: 354-360.
[20] Liu Z, Yang Y, He L, Pang M, Luo C, Liu B and Rong L. High-dose methylprednisolone for acute traumatic spinal cord injury: a meta-analysis. Neurology 2019; 93: e841-e850.
[21] Sámano C and Nistri A. Mechanism of neuroprotection against experimental spinal cord injury by riluzole or methylprednisolone. Neurochem Res 2019; 44: 200-213.
[22] Kreinest M, Scholz M and Trafford P. On-scene treatment of spinal injuries in motor sports. Eur J Trauma Emerg Surg 2017; 43: 191-200.
[23] Markenson D, Ferguson JD, Chameides L, Cassan P, Chung KL, Epstein J, Gonzales L, Herrington RA, Pellegrino JL, Ratcliff N and Singer A. Part 17: first aid: 2010 American heart association and American red cross guidelines for first aid. Circulation 2010; 122: S934-S946.
[24] Qi L, Li M, Zhang S, Si H and Xue J. C1-c2 pedicle screw fixation for treatment of old odontoid fractures. Orthopedics 2015; 38: 94-100.