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A study of damage control theory in the treatment of multiple trauma mainly represented by emergency abdominal trauma

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Abstract. – OBJECTIVE: This study aimed to explore the measures of damage control theory (DCT) in the treatment of multiple trauma mainly represented by emergency abdominal trauma.

PATIENTS AND METHODS: A total of 76 patients with severe multiple trauma in the Yiwu Central Hospital were selected. Among them, 37 patients with severe multiple trauma were treated with DCT (DCT group), and 39 patients were treated with traditional methods (control group). The prothrombin time (PT), the inflammation index, the duration of mechanical ventilation, the length of stay in the Intensive Care Unit (ICU), and the incidence of sepsis were compared between the two groups.

RESULTS: A total of 60 cases (78.95%) were cured and discharged, and 4 cases (10.81%) died in the DCT group, while 12 cases (30.77%) died in the control group. There were 6 cases (16.22%) of sepsis in the DCT group and 15 cases (38.46%) of sepsis in the control group. This indicates that the mortality and the incidence of sepsis in the DCT group were lower than those in the control group ($p<0.05$ in all comparisons). The PT activated partial thromboplastin time (APTT), the length of stay in the ICU, and mechanical ventilation in the DCT group were notably shorter than those in the control group. The levels of serum tumor necrosis factor-alpha (TNF-α), Interleukin-6 (IL-6), C-reactive protein (CRP), and IL-10 went up remarkably in both groups ($p<0.05$), but the levels of serum TNF-α, IL-6, and CRP in the DCT group were lower than those in the control group, while the IL-10 level in the former was significantly higher than that in the latter ($p<0.05$).

CONCLUSIONS: It is feasible to apply DCT to rescue patients with multiple trauma, which can effectively reduce the mortality and complications, and shorten the length of stay in the ICU.

Key Words:
Damage control theory, Multiple trauma, Treatment.

Introduction

As the economy and society step forward, increasingly more multiple traumas have been caused by accidents, such as car accident and fall accident from a high place. Studies have manifested that multiple trauma is one of the major causes of death in young and middle-aged adults, and it also ranks in the top three among a variety of causes of the total human death[1]. In patients with severe trauma and hemorrhage, especially when the symptoms combined with hypothermia, coagulation dysfunction, and metabolic acidosis, the risk of surgery for patients is remarkably increased. However, patients often have to undergo surgical treatment under certain conditions, so damage control theory (DCT)[2] came into being. The emergent DCT exerts a far-reaching impact on the treatment of severe multiple trauma. How to rationally apply the modern technology to improve the treatment for multiple trauma under the guidance of DCT and increase the survival and recovery rates of patients to the largest extent is a common problem faced by all emergency surgeons. A total of 76 patients with severe multiple trauma were treated with an integrated treatment model under the guidance of DCT in the Yiwu Central Hospital from March 2016 to March 2017 with good therapeutic effects.

Patients and Methods

Patients' Clinical Data

A total of 76 patients with multiple trauma treated in the Emergency Department in the Yiwu Central Hospital from March 2016 to

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March 2017 were selected. There were 50 males and 26 females, from 18 to 78 years old, with a mean age of 39.5. Their injury duration was 25 min to 9 h. Injury severity score (ISS)[3]: ISS ≥16 points in 19 cases (90.5%) and ISS ≥25 points in 2 cases (9.5%). Causes of injury: car accident injury (n=48), injury caused by fall accident from a high place (n=18), fighting injury (n=2), explosion injury (n=1), crush injury (n=3), and other injuries (n=4). Injury sites: multiple trauma mainly represented by abdominal trauma. There were 46 cases complicated with craniocerebral trauma, 8 cases mainly complicated with spine injury, 10 cases complicated with chest injury, 10 cases complicated with pelvic and limb injuries, and 2 cases complicated with crush syndrome. The treatment time after injury was 2.6 h on average. Among them, there were 20 cases complicated with traumatic hemorrhagic shock in 20 cases, 12 cases with coma and 2 cases with breathing difficulties. The following conditions were excluded: patients who died without surgical treatment within 24 h after admission; patients with malignant tumors or other end-stage diseases; patients with basic liver and kidney dysfunction before trauma.

Methods

Firstly, whether the patient's vital signs were normal was checked, and more than two groups of intravenous accesses were quickly established. Secondly, rapid examination was conducted in accordance with the inspection and diagnosis procedures of circulation, respiration, abdomen, spine, head, pelvis, limbs, arteries, and nerves (CRASHPLAN). In combination with X-rays, bedside B-ultrasound, and other methods, the patients were definitely diagnosed in the early stage. Then, the rescue order was arranged according to the severity of each site's injury, and priority is given to dealing with fatal injuries. For patients with severe multiple trauma, the principle of controlled fluid resuscitation should be appropriately implemented. Patients with difficulties in shock correction within a short period were administrated with vasoactive agents to maintain basic blood pressure, thus ensuring the perfusion of vital organs. In patients complicated with pulmonary injury or craniocerebral injury, the input amount of crystal fluid was strictly limited, and the central venous pressure was measured to effectively prevent pulmonary and cerebral edema.

Grouping

Patients were divided into the observation group (DCT group, n=37) and the control group (stage I definitive surgery, n=39), according to different treatment plans for patients. Gender, age, acute physiology, and chronic health evaluation II (APACHE II) score, ISS score, etc., were compared between the two groups. The difference was not statistically significant, and the data were comparable (p>0.05) (Table I).

Treatment Methods

The operation plan was selected for the patients in the control group, according to the specific conditions of trauma, and they were treated with stage I definitive surgery. The observation group underwent staged surgery according to DCT. To be more specific, (1) damage control: for patients definitely complicated with vascular, hepatosplenic, and other substantial visceral injuries; if these symptoms were repaired within a short period of time, they could be repaired by surgery; otherwise temporary intubation and tamping for rapidly control active bleeding, temporary closure of body cavity, and prevention of body cavity pollution and other rapid simplified initial surgeries were performed, without consideration of repair, anastomosis or other progressive surgeries[4]. (2) After the damage control treatment, dilatation, hypoxemia correction, rewarming, acidosis correction, coagulation function correction, etc. were carried out, and after the vital signs were stable, the definitive surgery was generally conducted at 3-5 d after damage control. There were statistically significant differences in gender, age, injury causes, and other general data between the two groups of patients (p>0.05), and these data were comparable. All patients and their families were

Table I. Comparisons of clinical data between the two groups of patients

Group	No.	Age (years old, x±s)	Male [n (%)]	APACHE II score	ISS score
DCT group	37	51.01±11.10	23 (62.16)	21.04±4.23	22.14±5.03
Control group	39	50.23±12.08	24 (61.53)	20.20±3.14	21.21±4.12
t/χ^2		0.29	0.00	0.98	0.88
p		>0.05	>0.05	>0.05	>0.05

Table II. Comparisons of clinical outcomes between the two groups of patients.

Group	No.	Death [n (%)]	Duration of mechanical ventilation (d, $\bar{x}$±s)	Length of stay in ICU (d, $\bar{x}$±s)	Sepsis [n (%)]
DCT group	37	4 (10.81%)	10.60±5.20	4.30±1.70	6 (16.22)
Control group	39	12 (30.77%)	15.31±6.31	8.60±2.80	15 (38.46)
t/χ^2		4.30	3.55	8.14	4.70
p		<0.05	<0.05	<0.01	<0.05

informed of the purpose of this study, agreed to participate in the experiment and signed the informed consent. This study was approved by the Medical Ethics Committee of the Yiwu Central Hospital.

Monitoring Indexes

The venous blood was collected from the two groups of patients at 24 h after definitive surgery. The following indexes were detected *via* enzyme-linked immunosorbent assay (ELISA): interleukin 6 (IL-6), tumor necrosis factor-alpha (TNF-α), C-reactive protein (CRP), IL-10, and coagulation function, including prothrombin time (PT), activated partial thromboplastin time (APTT), D-dimer (DD), fibrin degradation products (FDP), and blood platelet count (PLT).

Observational Indexes

The duration of mechanical ventilation, the length of stay in the Intensive Care Unit (ICU), the incidence rate of sepsis, and the 28-d mortality rate were observed in the two groups of patients.

Statistical Analysis

Statistical Product and Service Solutions (SPSS) 19.0 software (IBM, Armonk, NY, USA) was used for statistical analysis. Count data were compared using χ^2-test. The measurement data were expressed as ($\bar{x}$±s), and the *t*-test was adopted for the comparison between the groups. $p<0.05$ represented that the difference was statistically significant.

Results

Comparisons of Clinical Outcomes Between the Two Groups of Patients

The duration of mechanical ventilation and the length of stay in the ICU in the DCT group were shorter than those in the control group, displaying statistically significant differences (t=3.55 and 8.14, $p<0.05$). The mortality and the incidence of sepsis in the DCT group were lower than those in the control group, with statistically significant differences (χ^2=4.30 and 4.70, $p<0.05$) (Table II).

Comparisons of Serum Inflammatory Indexes Between the Two Groups of Patients

In the DCT group, serum TNF-α, IL-6, and CRP levels were lower than those in the control group at 24 h after admission (t=3.06, 3.90 and 4.18, $p<0.05$). The serum IL-10 level in the corresponding period was higher in DCT group than that in the control group (t=3.70, $p<0.05$) (Table III).

Comparison of Coagulation Function at 24 h After Admission Between the Two Groups of Patients

At 24 h after admission, the levels of PT, APTT, FDP, and DD in the DCT group were significantly lower than those in the control group (t=6.65, 9.02 and 6.96), while the levels of PLT and FDP in the DCT group were significantly higher than those in the control group (t=4.65 and 7.08), showing statistically significant differences between the two groups ($p<0.05$) (Table IV).

Table III. Comparisons of serum inflammatory indexes at 24 h after admission between the two groups of patients ($\bar{x}$±s).

Group	No.	TNF-α (ng/L)	IL-6 (ng/L)	IL-10 (ng/L)	CRP (ng/L)
DCT group	37	10.42±4.26	173.0±22.89	189.2±82.19	62.21±38.28
Control group	39	14.27±6.54	198.0±32.41	124.2±70.23	110.32±60.21
t/χ^2		3.06	3.90	3.70	4.18
p		<0.05	<0.05	<0.05	<0.05

Table IV. Comparison of coagulation function at 24 h after admission between the two groups of patients ($\bar{x}\pm s$).

Group	No.	TNF-α (ng/L)	IL-6 (ng/L)	IL-10 (ng/L)	CRP (ng/L)
DCT group	37	10.42±4.26	173.0±22.89	189.2±82.19	62.21±38.28
Control group	39	14.27±6.54	198.0±32.41	124.2±70.23	110.32±60.21
t/χ^2		3.06	3.90	3.70	4.18
p		<0.05	<0.05	<0.05	<0.05

Discussion

The emphasis of the traditional concept lies in solving the existing problems of patients by surgery once, but the surgery is often time-consuming and cause trauma itself, which is tantamount to a more severe secondary attack on the injured patients, often resulting in hypothermia, metabolic acidosis, coagulation dysfunction, and pathological and physiological changes in other aspects. The manifestations of the body include difficulty in correction, disseminated intravascular coagulation (DIC), acute respiratory distress syndrome (ARDS), and multiple organ dysfunction syndrome (MODS), which ultimately causes a high mortality[4-7].

DCT initially originated from the United States Navy and was later further developed by Stone and other scholars for the application in medical field. It aims to reduce the extra burden of surgical operations. The emergency surgery applied in the early stage should be simple, fast, minimally invasive, and effective, aiming to preserve life[8] and prevent further aggravation of primary injury. The definitive surgical treatment was selected in light of the patient's general condition, lesion range, follow-up treatments, and other later reassessments[9]. The theory mainly aims to minimize the "continuous strike" after the "first strike" in patients[10].

Multiple trauma indicates the condition that two or more parts of organs are damaged by the same injury factor at the same time or one after the other. In severe cases, there were excessive bleeding and sharply reduced effective circulating blood volume, and their lives were even threatened. After being damaged, the body releases an excess of inflammatory mediators, which activate a variety of physiological, biochemical, and immune pathways, elevate the expression levels of IL-6, TNF-α, and other inflammatory factors, reduce immune function and influence the body's coagulation function at the same time[11], so that the patients suffer from endogenous coagulopathy in the early stage of trauma. Besides, there are significant differences in the expressions of the relevant inflammatory factors and the coagulation function of patients with different prognoses at different lesion levels[12-17], eventually influencing the patient's prognosis. With various functions, IL-6 and TNF-α exert crucial effects on inhibiting and triggering inflammation, and they also play important roles in the process of severe injury and tissue repair. According to the results of this study, after receiving the treatment based on DCT, patients in the DCT group had lower serum levels of IL-6, TNF-α, and CRP, as well as a higher serum level of IL-10 at 24 h after admission than the control group, indicating that the application of DCT to multiple trauma can effectively regulate the expression of inflammatory factors, suppress the body's inflammatory response, enhance coagulation function, reduce the risk of body injury, help patients recover, as soon as possible, improve the clinical prognosis and shorten the length of stay in the ICU and mechanical ventilation time.

In this study, patients were treated with the treatment model integrated with the overall application of emergency treatment, combination with each department, temporary fixation, intensive care, reassessment and surgery determination, and postoperative rehabilitation under the guidance of the core DCT. Sepsis also occurred in 21 patients, but there were 60 cases successfully cured after active rescue. It was found in this study that pulmonary infection was the most common complication, which had close correlations with the combination with craniocerebral injury, rib fractures, the application of ventilators, smoking, malnutrition, and other factors[18].

DCT is currently an effective novel concept for tackling with multiple trauma. However, its promotion is still faced with extensive limitations, such as precise judgement of trauma, prompt grasp of changes in the patient's condition, and the close collaboration with high-quality medical rescue teams.

Conclusions

Applying DCT to the emergency treatment of severe multiple trauma is an especially effective measure, which significantly increases the rescue

success rate and cure rate of critically ill patients. Patients with severe multiple trauma cannot be treated without multidisciplinary collaborative therapy, which can utilize hospital resources to benefit patients to the largest extent, cut down hospital stays, and reduce unnecessary treatment and costs. Nevertheless, the sample size in this study was small, so multiple-center and large-sample studies are still needed to draft a unified standard for clinical diagnosis and treatment.

Conflict of Interests

The Authors declare that they have no conflict of interests.

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Availability of Data and Materials

The datasets used and/or analyzed during the present study are available from the corresponding author on reasonable request.

Authors' Contributions

MJ drafted this manuscript. MC, TC, YJ, JZ, XW, and Xiaoying Huang were mainly devoted on collecting the information. Xiaofei Hong was mainly devoted on collecting and interpreting the data. NZ read and approved the final manuscript.

Ethics Approval and Consent to Participate

The study was approved by the Ethics Committee of the Yiwu Central Hospital. Signed written informed consents were obtained from the patients and/or guardians.

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