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Research Paper

Efficacy of damage control orthopedics strategy in the management of lower limb trauma

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ABSTRACT

Background: Little is known about the efficacy of damage control (DC) surgery in the management of lower limb trauma. Here we compared the clinical parameters and complication rates of such patients received either DC or emergency comprehensive (EC) surgery treatment.

Methods: This study is a retrospective study on patients with lower limb trauma that received surgical treatment. Data of 120 patients were divided into DC and EC surgery groups. Clinical parameters obtained at hospital admission and complications during follow-up were analyzed. Injury Severity Score (ISS), Gustilo classification and Mangled Extremity Severity Score (MESS) were used to assess trauma severity, open fractures and viability of injured limb, respectively.

Results: Age, sex, ISS, fracture type, injury site, MESS, operation time, blood loss, pulmonary and cranial injuries were compared. We found that patients in the DC group had more severe injury as reflected by the higher injury severity score (ISS) (28.1 ± 10.9 vs 21.3 ± 7.4, $P < 0.001$). ISS was also identified as a significant influencer for the treatment selection ($P < 0.001$). In addition, patients treated with DC surgery demonstrated less complications (7 cases vs 27 cases), which was supported by the propensity score logistic regression analysis (Odd ratio 4.667).

Conclusions: DC surgery is more often selected to treat patients with more severe lower limb injuries, which leads to lower complication rates.

Introduction

Damage control was first proposed by the U.S. Navy [1] and was later used by emergency medicine to guide the treatment of patients with multiple injuries. It employs simple, feasible, effective and less traumatic emergency surgery to deal with hypothermia, coagulopathy and acidosis caused by fatal trauma [2]. For non-fatal trauma, further resuscitation and planned staging surgery are used. Thanks to these strategies, the survival rate of treated patients has improved dramatically [3,4]. In orthopedics trauma, fixing fracture in advance is a widely accepted concept. However, for some patients with multiple injuries, especially those with severe chest injury, rupture of the pelvic ring or brain injury; simple hemostasis to stabilize blood volume, active resuscitation and planned reoperation to fix the fracture are the most effective options in the emergency department [5].

Based on previous lessons, Giannoudis and colleagues proposed the essential steps for Damage Control Orthopedics (DCO) [6]. First step is to control bleeding, perform complete debridement and carry out temporary fixation of unstable fractures. Second step is to send the patients to the intensive care unit (ICU) to achieve a stable state by correcting hypothermia, hypovolemia, and coagulation. Once the patient's condition is stable, the final fixation of the fracture, such as bone plate and intramedullary nail, is performed.

Despite of the wide application of DCO around the world, the concept of "doing as little as possible" behind DCO remains controversial. On one hand, one previous retrospective study on femur fracture suggests that external fixation is a viable alternative strategy to achieve temporary rigid stabilization [7]. In addition, a systemic review on the effect of DCO on the German population shows that DCO treatment can dramatically reduce the rate of multiple organ failure in patients with multiple injuries [8]. On the other hand, DCO implementation rate in multiple reputed institutions in the U.S. only ranges from 12 % to 57 % [9–11] and no generalized management strategy was found in 63 controlled trials of DCO reviewed by The Polytrauma Study Group of the

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German Trauma Society [12]. Also, DCO has been suggested not to be considered as an element of golden hour planning for fracture fixation within the military context [13]. In addition to the inconsistencies among different studies, limited knowledge on the underlying molecular mechanisms of trauma-induced injury [14] and the role of genetics in the trauma-induced inflammatory response [15] also challenges the clinical application of DCO.

The present retrospective study aims to compare the clinical parameters and complication rates of patients that suffered from lower limb trauma and received either DC or EC treatment in a Chinese population, so as to gain more insight on the efficacy of DCO.

Methods

Patients

The present retrospective study was performed on patients with lower limb trauma that received surgical treatment at Cangzhou Hospital of Integrated Traditional and Western Medicine from February 2020 to December 2022. During this time period, the hospital's orthopedic trauma protocol and regulation on routine practice for patients with lower limb trauma remained the same. Injury sites include tibial plateau fracture, middle and distal tibia and fibula fracture, as well as lower femoral fracture. No vascular injury was observed. The study was approved by the ethical committee of Cangzhou Hospital of Integrated Traditional and Western Medicine (2020115). All included patients were between the age of 18 and 60. All included patients signed a consent form at the time of hospital admission for using their medical records for future research studies. All methods were carried out in accordance with relevant guidelines and regulations. Inclusion criteria include lower limb trauma with surgical treatment indications, surgically treated and complete 1-year follow-up. Exclusion criteria include patients undergoing a single operation for lower limb and other fractures at the same time, patients with a history of autoimmune diseases, malignant tumors, communication disorders and mental disorders, pathological fracture caused by tumor or infection and patients who refused to participate or did not have a complete follow-up record. Fractures with minor soft tissue injury were not included in this study, because DC is not needed in this situation according to our hospital's policy. All patients were followed up for 1 year at a 3-month interval. The follow-up lasts for 30 to 60 min. A medical review was performed to assess the patients' current status, including incision healing, mobility, limb strength, gait evaluation, potential complications, pain management and physical therapy frequency. At the 6-month follow-up time point, the presence of severe complications was specifically assessed, including infections that require additional surgery; delayed union characterized by absence of bony structure at the fracture site; material failure, including pin loosening or misposition and breakdown of the osteosynthetic material; refracture of the injury bone and the need of amputation.

Assessment

Patients were separated into damage control (DC) surgery and emergency comprehensive (EC) treatment surgery groups. Selection of DC surgery was based on the judgement of the on-scene paramedics and doctors of the emergency department. Patients in the DC group were treated by soft tissue debridement and fracture stabilization before sending into ICU. Final fracture fixation was performed when the patients reached a stable state. Patients in the EC group were treated with intramedullary nail as the first procedure of fixation. Clinical, functional and demographic data were retrospectively extracted from patients' medical record database. Injury Severity Score (ISS) was used to assess trauma severity. Gustilo classification was used to classify open fractures [16]. Mangled Extremity Severity Score (MESS) was used to estimate the viability of injured limb. Pulmonary injury was detected by radiological examinations, including CT-scan and magnetic resonance imaging (MRI). Cranial injury was detected by CT-scans. All results were assessed by experienced traumatic surgeons and radiologists. Operation time and blood loss during surgery were recorded.

Statistical analysis

Statistical analysis was performed using the SPSS software 18.0 (IBM, Armonk, NY). Statistical significance was determined using the student *t*-test for continuous data and the Mann-Whitney-*U* test for categorical data.

Since randomization of patient allocation into the two treatment groups in not feasible in the present study due to its retrospective nature, we employed a generalized propensity score adjusted for ISS, fracture type and blood loss to assess the complication rates of the DC and EC groups. The propensity score represents the probability to receive a treatment based on the clinical characteristics. It was calculated using a multinomial logistic regression model that considers ISS, fracture type and blood loss as previously described [17], with a value ranging from 0 to 1. A value of 0 indicates 0 % probability of using a given treatment in a situation defined by the pre-treatment factors, while a value of 1 indicates 100 % probability. Logistic regression was then used to model the association between the complication rate and the log odds of the propensity score for the two groups. After that, the model parameters were applied to estimate the risk of complications in all patients. Adjusted complication rate was an average of all patients in one group. 95 % confidence intervals for adjusted complication rate and OR were calculated using bootstrap with 10,000 replications. Multinomial logistic regression analysis was used to investigate the correlation between clinical characteristics and treatment option. Both multinomial regression models had an area under curve/c-statistic value over 0.9. $P < 0.05$ was considered as statistical significance.

Results

A total of 120 patients were included in the present study, where 80 were in the EC group and 40 were in the DC group. Most of the trauma was caused by traffic accident and others were caused by fall from height. Overall, 65 % of the patients were male with an average age of 37.8. No significant difference was observed in age or sex distribution between the two groups (Table 1). The injured sites were relatively evenly distributed among the 4 skeletal elements in both groups (Table 1). A significant difference was observed in term of ISS, where patients in the DC group had more severe injury compared with the patients in the EC groups (Table 1). In addition, more patients in the DC

Table 1
Clinical characteristics of patients from the DC and EC groups. DC, damage control; EC, emergency comprehensive; ISS, Injury Severity Score; MESS, Mangled Extremity Severity Score.

Characteristics	DC (n = 40)	EC (n = 80)	P value
Age (mean ± SD)	38.4 ± 12.4	37.5 ± 13.5	0.710
Sex (male:female)	26:14	52:28	1
ISS (mean ± SD)	28.1 ± 10.9	21.3 ± 7.4	<0.001
Fracture type (n, % of total)			0.116
Type I	14 (35 %)	34 (42.5 %)	
Type II	11 (27.5 %)	30 (37.5 %)	
Type III	15 (37.5 %)	16 (20 %)	
Injury site (n, % of total)			0.966
left femur	9 (22.5 %)	20 (25 %)	
right femur	10 (25 %)	18 (22.5 %)	
left tibia	12 (30 %)	22 (27.5 %)	
right tibia	9 (22.5 %)	20 (25 %)	
MESS (mean ± SD)	3.5 ± 1.1	3.4 ± 1.2	0.613
Operation time (min) (mean ± SD)	175.5 ± 32.2	183.0 ± 33.4	0.242
Blood loss (ml) (mean ± SD)	989.6 ± 243.6	1067.2 ± 270.0	0.125
Pulmonary injury (yes:no)	23:17	35:45	0.155
Cranial injury (yes:no)	20:20	36:44	0.605

group suffered from type III fracture than the EC group (37.5 % versus 20 %), although the overall distribution of the fracture types was not statistically significant (P = 0.116) (Table 1). No significant difference was observed in MESS, operation time or blood loss between the two groups (Table 1). Presence of pulmonary and cranial injury was also found to be similar between the two groups (Table 1). No vascular injury was observed in any of the patients.

Next, we investigated the impact of the above-mentioned characteristics on treatment selection using the multinomial logistic regression analysis. We assigned the EC group as the reference group. We found that ISS was a significant influencer for treatment selection with an odd ratio of 1.536 (Table 2), indicating that the tendency towards DC treatment increases with higher injury severity. In addition, fracture type was found to be a marginally significant influencer (Table 2).

Overall, infections and delayed union were the two most common complications, affecting 10 % (12 out of 120) and 12.5 % (15 out of 120) of all patients, respectively. Percentages of patients with both complications were found to be higher in the EC group. Besides, material failure and refracture were also observed. More complications were found in the patients of the EC group (33.75 %, 27 out of 80) compared with the DC groups (17.5 %, 7 out of 40) during the follow-up period (Table 3). Then, we adjusted the treatment differences using the propensity score logistic regression method and revealed similar difference in complication rates between the two groups (Table 4). Based on the odd ratio (OR), patients treated with EC had a higher odd of complications compared with patients treated with DC (Table 4).

Discussion

DC concept has become a popular treatment option for severely injured patients. It can be applied in orthopedics, injury assessment and staged treatment. In the present study, we compared the clinical characteristics and complication rates between DC and EC treatments on patients with lower limb trauma. We show that patients that were treated with DC had more severe injury, which is in line with the international trend for the treatment of trauma with multiple injuries. We identified ISS as a significant influencer for treatment selection, which also came up in a previous study [17]. In that study, old age, female sex and tibia fracture that were shown to be correlated with external fixation, but not EC or DC [17]. In addition, more type III fracture cases were found in the DC group and fracture type was also identified as a marginally significant influencer for treatment selection. This is in line with the above-mentioned study [17] and a previous retrospective study performed on military ballistic limb trauma in Tunisia, where they found that a type III of Gustilo skin opening was significantly associated with local complications [18]. Given that some inflammatory indices were shown to reach the maximum values at the time of admission before surgery, DC treatment prior to ICU admission may have a positive impact on infections. Less delayed union cases in the DC group suggests that early treatment might be critical for bony healing during the post-operative recovering period. Moreover, more complication cases were found in the EC group and the propensity score logistic regression predicts a higher risk of complication rate in EC treated patients. These findings support our treatment selection of using DC for patients with more severe injury to reduce the risk of complications.

In 2000, external fixation prior to intramedullary nail treatment has been proposed to be a viable option to achieve temporary rigid stabilization in patients with femur injuries [7]. Later studies performed on multiple trauma with femur fracture have further verified its usefulness [19–21]. Harwood et al., show that DC surgery treatment was associated with reduced systemic inflammatory response than early total care for femur fractures [22]. In a prospective, randomized, multicenter study, sustained inflammatory response was only observed after primary intramedullary femoral instrumentation, but not after initial external fixation or after secondary conversion to an intramedullary implant [8]. In a retrospective study carried out on patients with gunshot limb trauma treated by DC surgery, DC was shown to be able to accelerate wound healing and protect against infection, which could shorten the delay of conversion from external fixation into an internal osteosynthesis [23]. In term of DC treatment for multiple trauma, it is suggested that DC can effectively reduce the mortality and complication rate, as well as shorten the ICU duration [24]. For floating knee injury, DC poses less mortality rate but poor functional recovery outcome [25]. On the other hand, a recent systemic review on databases from 1950 to 2019 finds few indications for DC as a reliable method and suggests that it should be used only when definitive surgery cannot be performed [26]. To the best of our knowledge, our study is the first one to assess the efficacy of DC surgery in the management of lower limb trauma in a Chinese population. Our findings agree with the above-mentioned studies, although some studies suggest otherwise [13]. In term of population differences, studies on German and Australian population show no differences between DC and EC treatments [19], whereas studies on Spanish population demonstrate lower mortality rate for DC treatment [20], which is in line with our results. Therefore, it seems that the efficacy of DC is much dependent on patient population.

Our study is mainly limited by its retrospective and single-institutional nature, as well as the limited patient number. Future prospective studies at the multi-institutional level are needed to confirm our findings. Increasing the patient number may better reveal the differences between the two groups in terms of clinical variables. In addition, the ISS values are different between the two treatment groups, making it difficult for a side-by-side comparison. Future prospective study should be designed to randomly assign patients with similar ISS values into the DC or EC groups.

Table 2
Multinomial logistic regression identifying the significant influencer for treatment selection. EC was used as the reference group. DC, damage control; EC, emergency comprehensive; ISS, Injury Severity Score.

Characteristics	DC		
	OR	95 % CI	P value
Age	0.852	0.614–1.143	0.456
Sex	0.933	0.902–1.068	0.867
ISS	1.536	1.235–1.966	<0.001
Fracture type	1.152	1.033–1.198	0.045
Injury site	0.921	0.846–1.114	0.354
operation time	1.363	0.766–1.896	0.245
blood loss	1.225	0.796–1.653	0.318
pulmonary injury	1.069	0.826–1.331	0.486
cranial injury	1.395	0.618–1.958	0.354

Table 3
Complication rates.

Complications (n, % of total)	DC (n = 40)	EC (n = 80)
Infections	2 (5 %)	10 (12.5 %)
Delayed union	3 (7.5 %)	12 (15 %)
Material failure	2 (5 %)	3 (3.75 %)
Refracture	0	2 (2.5 %)
Amputation	0	0

Table 4
Propensity score logistic regression. OR, odd ratio.

	DC	EC
Adjusted complication rate (95 % CI)	19.5 % (15 %–21 %)	30.5 % (26.5 %–36 %)
	EC/DC	
OR (95 % CI)	4.667 (1.116–11.598)	

Conclusions

Patients with more severe injuries were more commonly treated with DC surgery, which could lead to lower complication rates compared with the EC surgery.

Funding sources

Not applicable.

Ethics approval

The study was approved by the ethical committee of Cangzhou Hospital of Integrated Traditional and Western Medicine (2020115), who also approved the written informed consent. Written informed consent was obtained from all participated patients. All methods were carried out in accordance with Cangzhou Hospital of Integrated Traditional and Western Medicine's guidelines and regulations.

CRediT authorship contribution statement

Fubin Li: Methodology, Formal analysis, Data curation. **Lecai Gao:** Data curation. **Jiangang Zuo:** Data curation. **Jindong Wei:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no conflict of interest.

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