Submitted: 13 October, 2022 Accepted: 12 December, 2022 Published: 08 May, 2023 DOI:10.22514/sv.2023.031

Open Access
Signa Vitae

ORIGINAL RESEARCH

Application of damage control orthopaedics in treatment of massive hemorrhage in severe traumatic fractures

Haiyang Zhao[1,*], Jingyuan Si[2], Hongmin Guo[3], Xiaoming Li[4], Jinzhu Wang[1]

[1]Department of Severe Trauma Orthopedics, The Affiliated Hospital of Chengde Medical University, 067000 Chengde, Hebei, China
[2]Operating Room, The Affiliated Hospital of Chengde Medical University, 067000 Chengde, Hebei, China
[3]Department of Emergency, Chengde Central Hospital, 067000 Chengde, Hebei, China
[4]Department of Orthopedics, Xinglong Count People's Hospital, 067399 Chengde, Hebei, China

***Correspondence**
zhaohaiyang_vv@163.com
(Haiyang Zhao)

Abstract

This study is designed to investigate the clinical application value of the damage control orthopaedics (DCO) concept in guiding the treatment of severe traumatic fractures with massive hemorrhage. Using the introduction of the DCO concept in the hospital in June 2021 as the cut-off point, patients with severe traumatic fractures and major bleeding admitted in the two periods before the introduction of the DCO concept (January 2021~May 2021) and after the introduction of the DCO concept (June 2021~January 2022) were included as control group (n = 39) and observation group (n = 39), respectively. The control group was given conventional surgery and treatment, whereas the DCO group received treatment and surgery under the guidance of the DCO concept. The results of the intervention were compared between the two groups. The time from admission to definitive surgery was longer in the DCO group than that in the control group. Fewer suspended red blood cells, fresh frozen plasma and platelets were used in the DCO group compared to the control group. The total hospital stay was shorter and the rates of postoperative complications and mortality were lower in the DCO group than those in the control group. Patients were followed up for 6–8 months, with an average of (6.87 $\pm$ 1.15) months, and the results showed that the fracture healing rate in DCO group was higher than that in the control group. The concept of DCO could correctly guide the treatment of severe traumatic fractures complicated by massive hemorrhage, and improve the therapeutic safety, reduce the incidence of postoperative complications and mortality, and enhance the later fracture healing rate of patients.

Keywords

Severe traumatic fractures; Massive hemorrhage; Concept of damage control orthopaedics; Therapeutic effect

1. Instruction

With the continuous development of economy and transportation in China, fractures complicated with multiple injuries caused by falls from heights and traffic accidents are becoming more and more common [1, 2]. Patients with severe traumatic fractures complicated with multiple injuries often have heavy bleeding and are prone to hemorrhagic shock. Early deterministic surgery may disrupt the periosteum during the process of achieving a good fracture reduction, further aggravating physiological exhaustion and predisposing the patient to serious complications such as acute respiratory distress syndrome (ARDS) and multiple organ failure (MOF), leading to a deterioration in prognosis [3–5]. Damage control surgery originated in the United States, and was firstly applied to the treatment of severe abdominal injuries. Later, the concept of damage control orthopedics (DCO) was proposed and applied in clinical practice. When it comes to DCO, it is about controlling the primary injury and providing intensive care unit (ICU) monitoring as well as supportive treatment before performing the final surgery, thus effectively stabilizing the condition, improving the body's tolerance to subsequent surgical treatment and increasing the safety of treatment [6–8]. In order to understand the practical value of DCO concept in guiding the treatment of severe traumatic fractures complicated by massive hemorrhage, the following study was thus performed.

2. Subjects and Methods

2.1 Research subjects

Using June 2021 when the DCO concept was introduced in the hospital as the cut-off point, patients with severe traumatic fractures and major bleeding admitted during the two periods before the introduction of the DCO concept (January 2021~May 2021) and after the introduction of the DCO concept (June 2021~January 2022) were included as the control group (n = 39) and the observation group (n = 39). (1) Inclusion

criteria: the injury severity score (ISS) score was equal to or greater than 17 on admission; patients aged 18–60 years old; fracture of the pelvis, spine, or extremities confirmed by radiographic examination; patient who met the criteria for moderate to severe hemorrhagic shock in the traumatic hemorrhagic shock grading [9], blood loss between 1500–2000 mL on admission, extensive fluid resuscitation and blood transfusion more than 10 L before admission to hospitalization. (2) Exclusion criteria: patients with pathological fracture; pregnant women; patient who was complicated with malignant neoplasms; patient who died within 1 h of admission; patient who was complicated with cardiovascular disease, hypertension and other primary diseases. (3) Case information: The 78 patients with severe traumatic fractures complicated with massive hemorrhage were equally divided into DCO group and control group by a random number table method. In DCO group, there were 22 males and 17 females, aged 23–54 years, with an average age of 37.48 ± 12.02 years. As for fractures: there were 11 cases with open fractures, 28 cases with closed fractures, 3 cases combined with head injury, 12 cases combined with chest and lung injury, 9 cases combined with abdominal organ injury, 4 cases with major vascular injury, 10 cases with skin and soft tissue injury, 7 cases with upper limb fracture, 23 cases with femoral fracture, 8 cases with thoracolumbar vertebral fracture, 7 cases with rib fracture, and 8 cases with pelvic fracture; the ISS score on admission was 17–34 points, with an average score of 22.78 ± 4.15 points; the time from injury to admission was 0.5–3.1 h, with an average of 1.78 ± 0.25 h. In control group, there were 25 males and 14 females, who aged 22–55 years, with an average age of 38.26 ± 11.74 years. As for fractures: there were 15 cases with open femoral fractures combined with pelvic fractures, 15 cases with closed femoral fractures combined with multiple rib fractures, 3 cases with femoral fractures combined with ulnar fractures, 6 cases with multistage open fracture of tibiofibular, 11 cases combined with chest and lung injury, 7 cases combined with abdominal organ injury, and 2 cases combined with head injury; the ISS score at admission was 17–35 points, with an average score of 23.05 ± 4.77 points; the time from injury to admission was 0.5–3.0 h, and an average of 1.69 ± 0.31 h. There were no statistically significant differences regarding the general data between the two groups ($p > 0.05$).

2.2 Methods

2.2.1 Treatment methods in control group

Patients in the control group were examined and treated accordance to an internationally recognized systematic procedure Crash Plan [10], as follows: after the patient was admitted to the hospital, physical conditions and vital signs were actively evaluated by physician from traumatology department; peripheral venous blood was collected for detection; radiographic examinations such as bedside X-ray and B ultrasound were arranged as soon as possible; repeated movement of patients was avoided; electrocardiograph monitoring was performed and intravenous channel was established; resuscitation treatment was started as soon as possible; effective hemostasis was performed; and the corresponding treatments were carried out by physicians from relevant departments if patient had abdominal organ injury or chest and lung injuries. Subsequently, different surgical methods were used to restore the anatomical structure of the fracture end depending on the type of fracture.

2.2.2 Treatment methods in DCO group

Patients in the observation group were treated under the guidance of DCO concept. (1) Control of primary injury: a. Condition assessment and auxiliary examination: physical condition and body status were quickly assessed by physician from traumatology department. Blood routine test, bedside X-ray examination and electrocardiograph monitoring were performed, and 2 intravenous channels were established for rapid fluid infusion; b. Injury-controlled fluid resuscitation: restrictive fluid resuscitation was achieved through intravenous channels, and the speed of fluid infusion was controlled to ensure that the patient's SBP was maintained between 80–90 mmHg to prevent quick hemorrhage due to increased blood pressure. Vasoactive substances were used to maintain basic blood pressure to ensure blood perfusion to important organs; c. Priority handling for those requiring emergency surgery: among the 3 cases combined with craniocerebral injury, 1 was cerebral contusion laceration and 2 were intracranial hematoma, which were subjected to trauma debridement suturing and fenestration decompression. Among the 9 cases combined with abdominal injuries, 3 were given splenectomy, 5 received liver repair, and 1 had bladder fistulation. Those with combined hemopneumothorax underwent chest closure drainage; d. Simple fixation of fractures: (a). In addition to the temporary fixation of fractures by external fixing frames, microsurgical techniques were used to repair damaged blood vessels for open fractures, debridement was performed for open wounds to avoid infection; (b). As for closed fractures: gypsum fixation was preferentially given to fractures of upper limbs. Skeletal traction was applied to fractures of lower limbs, and thoracic band fixation was given to fractures of ribs; Patient with thoracolumbar vertebral fractures was strictly bedridden in hard bed and adopted axial turnovers; patient with pelvic fractures were fixed with pelvic bands, external fixations or pelvic C-clips at early stage. Skeletal traction was used to prevent fracture displacement if necessary, and those with large vascular injuries were given tamponade to stop bleeding, and if necessary, vascular embolism was performed. (2) ICU monitoring and support: after delivery to the ICU, patient was ensured with unobstructed respiratory tract. Abnormal conditions such as hypothermia, hypoxemia, acidosis and anticoagulant abnormalities were corrected to restore blood volume and maintain hemodynamic stability. (3) Determination of surgery: after the patient's physiological functions were stably restored, different surgical treatment measures were implemented according to the type of fracture.

2.2.3 Observational indexes

The time from admission to definitive surgery, blood transfusion volume during treatment, orthopedic surgery duration, total hospital stay, postoperative complications, and number of death after treatment were compared between the two groups.

Patients were followed up for 6–8 months after discharge from hospital and fracture healing was counted in both groups

based on the X-ray of the patient's follow-up diagnosis. In particular, 6 to 8 months after operation, fracture without healing was judged if the X-ray showed: no new bone trabecula was across the broken end; the fracture line was still obviously visible; the medullary cavity was obstructed; the broken end was hardened; there was callus hyperplasia or absence at the fracture site. Fracture healing was judged if the X-ray showed: the fracture line was blurred; there was a continuous callus across the fracture line; the physical examination was normal without tenderness and the local activity was good.

2.2.4 Statistics

SPSS 19.0 software (SPSS Inc., Chicago, IL, USA) was used for data analyses. Quantitative and enumeration data were respectively represented as mean ± standard deviation ($\bar{x} \pm s$) and proportion (%) respectively. t test for independent samples was used for quantitative data and Chi-square test was used for enumeration data. All quantitative data were verified to be normally distributed by the normal distribution and homogeneity of variance tests. A p value less than 0.05 was considered to be statistically significant.

3. Results

3.1 Comparison of time from admission to definitive surgery between DCO and control groups

The time from admission to definitive surgery was longer in DCO group than that in control group, and the difference was statistically significant ($p < 0.05$). As shown in Table 1.

TABLE 1. Comparison of time from admission to definitive surgery between DCO and control groups ($\bar{x} \pm s$, h).

Group	n	Time from admission to definitive surgery
DCO group	39	9.78 ± 2.15
Control group	39	5.46 ± 1.44
t		10.426
p		<0.001

DCO: damage control orthopaedics.

3.2 Comparison of blood transfusion volume between DCO and control groups

DCO group used less suspended red blood cells, fresh frozen plasma and platelet compared with that in the control group, and the difference was statistically significant ($p < 0.05$). As shown in Table 2.

3.3 Comparison of orthopedic surgery duration and total hospital stay between DCO and control groups

The time of orthopedic surgery was similar between DCO and control groups ($p > 0.05$). However, the total hospital stay was shorter in DCO group than that in control group, and the difference was statistically significant ($p < 0.05$). As shown in Table 3.

3.4 Comparison of postoperative complications between DCO and control groups

The rate of postoperative complications, including postoperative infection, acute respiratory distress syndrome and multiple organ failure, was lower in DCO group than that in control group, and the difference was statistically significant ($p < 0.05$). As shown in Table 4.

3.5 Comparison of mortality between DCO and control groups

The rate of mortality was lower in DCO group than that in the control group, and the difference was statistically significant ($p < 0.05$). As shown in Table 5.

3.6 Comparison of fracture healing between the two groups

The patients were followed up for 6–8 months, with average of (6.87 ± 1.15) months. The results showed that the fracture healing rate in DCO group was higher than that in control group, and the difference was statistically significant ($p < 0.05$). As shown in Table 6.

4. Discussion

High incidence of hemorrhagic shock and infection is observed in patients with severe traumatic fractures combined with heavy bleeding. These patients exhibit severe body stress response, multiple complications, and a high risk of death in the later stage [11–14]. Severe traumatic fractures with heavy bleeding are mostly caused by high-energy injuries, and fractures are often combined with organ injuries, soft tissue injuries, head damage, *etc.* Due to the different severity of injuries in different parts of the body, it is easy dwell on trivialities during the treatment progress, leading to compromised prognosis [15–17]. How to properly arrange the treatment process and improve the treatment outcome is the focus of current research in patients with severe traumatic fractures combined with massive bleeding.

In the past, definitive surgery was usually initiated after assessing the patient's injuries, aggressive volume expansion, and treatment of serious complications in the abdomen, chest, lung and head to restore the normal anatomical structure of the fracture end. However, the removal of tissues and periosteum during surgery could further reduce the patient's blood volume, enhance the body's stress response, bringing about problems such as decreased body temperature and coagulation dysfunction, resulting in acidosis and even a "fatal triad", ultimately increasing the risk of death [18–21].

Based on the DCO concept, a phased intervention was implemented. First, the patient's condition was effectively evaluated, followed by immediate damage control fluid resuscitation (DCR). DCR allows for hypotension resuscitation, which can prevent hemodilution and increased blood pressure

TABLE 2. Comparison of blood transfusion volume between DCO and control groups ($\bar{x} \pm s$).

Group	n	Suspended red blood cells (U)	Fresh frozen plasma (mL)	Platelet (U)
DCO group	39	14.45 ± 2.17	921.15 ± 96.58	5.43 ± 1.17
Control group	39	16.74 ± 2.26	1201.43 ± 105.98	7.89 ± 2.05
t		4.545	12.270	6.509
p		<0.001	<0.001	<0.001

DCO: damage control orthopaedics.

TABLE 3. Comparison of orthopedic surgery duration and total hospital stay between DCO and control groups ($\bar{x} \pm s$).

Group	n	Time of orthopedic surgery (min)	Total hospital stay (d)
DCO group	39	278.45 ± 23.69	28.15 ± 2.48
Control group	39	281.89 ± 26.11	33.42 ± 3.15
t		0.609	8.209
p		0.544	<0.001

DCO: damage control orthopaedics.

TABLE 4. Comparison of postoperative complications between DCO and control groups (n, %).

Group	n	Postoperative infection	Acute respiratory distress syndrome (ARDS)	Multiple organ failure (MOF)	Total
DCO group	39	2 (5.13)	1 (2.56)	1 (2.56)	4 (10.26)
Control group	39	6 (15.38)	3 (7.69)	2 (5.13)	11 (28.21)
χ^2		–	–	–	4.044
p		–	–	–	0.044

DCO: damage control orthopaedics.

TABLE 5. Comparison of mortality between DCO and control groups (n, %).

Group	n	Number of death
DCO group	39	1 (2.56)
Control group	39	8 (20.51)
χ^2		4.522
p		0.033*

*Note: *p represents Chi-square test for continuous correction. DCO: damage control orthopaedics.*

TABLE 6. Comparison of fracture healing between the two groups (n, %).

Group	n	Fracture healing
DCO group	38	38 (100.00)
Control group	31	26 (83.87)
χ^2		4.426
p		0.035*

*Note: *p represents Chi-square test for continuous correction. DCO: damage control orthopaedics.*

due to rapid fluid resuscitation and exacerbation of bleeding due to thrombotic destruction. It can also correct hypothermia and metabolic acidosis, and then restores blood perfusion and oxygen supply to vital organs and improves microcirculatory disorders, thereby correcting hemorrhagic shock [22–25]. In addition, DCO then treats head injuries and abdominal injuries that require emergency surgery, provides simple fixation of the fracture site, and then arranges the patient to the ICU to further correct hypothermia, hypoxemia, acidosis and coagulation abnormalities, *etc.*, thereby ensuring a stable recovery of vital signs. Finally, definitive surgical treatment was performed after the patient's condition was relatively stable.

This study found that the DCO group spent significantly longer time than the control group from admission to confirmation of surgery, but the amount of suspended red blood cells, fresh frozen plasma and platelets during treatment was less than that in the control group, suggesting that the DCO concept could guide fluid recovery more accurately. Additionally, the DCO group showed a shorter total length of hospital stay, fewer postoperative infections, and a lower incidence of postoperative complications such as ARDS and MOF than those of the control group. In the DCO group, only one patient died after postoperative treatment failure and the cause of death was ARDS, compared to a total of 8 patients died in the control group, indicating that DCO significantly reduced late mortality and improved the therapeutic safety in patients with

severe traumatic fractures complicated by massive bleeding. This is related to the staged therapeutic intervention of DCO for patients, which allows for the accurate implementation of appropriate treatment according to the patient's condition. The implementation of definitive surgery enhances the body's tolerance to surgery and reduces the risk of surgery while ensuring the stability of vital signs [26–28].

Fracture healing requires the cooperation of all systems of the body, and blood supply is an important factor in determining the healing of fractures in patients. Studies have shown that hemorrhagic shock will delay the early healing of fractures [29, 30]. In this study, the postoperative fracture healing rate of the DCO group was higher than that of the control group, which may be related to the fact that DCO can effectively restore the body's blood flow perfusion and ensure the healing effect of the fracture in the later stage.

5. Conclusions

Taken together, the concept of DCO can properly guide the treatment of severe traumatic fractures complicated by massive hemorrhage, and improve the therapeutic safety, reduce the incidence of postoperative complications and mortality, as well as improve the patient's late fracture healing.

AVAILABILITY OF DATA AND MATERIALS

The authors declare that all data supporting the findings of this study are available within the paper and any raw data can be obtained from the corresponding author upon request.

AUTHOR CONTRIBUTIONS

HYZ—designed the research study. HYZ, JYS, HMG, XML and JZW—performed the research. HYZ, JYS, HMG, XML and JZW—analyzed the data. HTZ, JYS, HMG, XML and JZW—wrote the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the Ethics Committee of the Affiliated Hospital of Chengde Medical University (Approval no. CYFYLL2022494). Written informed consent was obtained from a legally authorized representative(s) for anonymized patient information to be published in this article.

ACKNOWLEDGMENT

Not applicable.

FUNDING

This research received no external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

[1] Kashyap A, Arora S, Khan Y, Kumar S, Chopra RK. Traumatic posterior fracture-dislocation of the fifth lumbar vertebra: report of two cases with review of literature. Spinal Cord Series and Cases. 2021; 7: 30.

[2] Segal-Isaacson CJ, Tobin JN, Weiss SM, Brondolo E, Vaughn A, Wang C, *et al*. Improving dietary habits in disadvantaged women with HIV/AIDS: the SMART/EST women's project. AIDS and Behavior. 2006; 10: 659–670.

[3] Christian AB, Grigorian A, Nahmias J, Duong WQ, Lekawa M, Joe V, *et al*. Comparison of surgical fixation and non-operative management in patients with traumatic sternum fracture. European Journal of Trauma and Emergency Surgery. 2022; 48: 219–224.

[4] Tran A, Fernando SM, Brochard LJ, Fan E, Inaba K, Ferguson ND, *et al*. Prognostic factors for development of acute respiratory distress syndrome following traumatic injury: a systematic review and meta-analysis. European Respiratory Journal. 2022; 59: 2100857.

[5] Li Y, Liu Y, Chou H, Tseng H, Fu Y, Liu W. Concomitant post-traumatic ocular and cerebral fat embolism syndrome and thrombotic pulmonary embolism. Medicine. 2022; 101: e29331.

[6] Rondanelli AM, Gomez-Sierra MA, Ossa AA, Hernández RD, Torres M. Damage control in orthopaedical and traumatology. Colombia Médica. 2021; 52: e4184802.

[7] Eckhoff MD, Orr JD, Wells ME, Nesti LJ, Dunn JC. Response to letter to the editor "there is no role for damage control orthopedics within the golden hour". Military Medicine. 2022; 187: 38–39.

[8] Oitment C, Thornley P, Jentzsch T, Pahuta M. Damage control orthopaedics in spinal trauma. Journal of the American Academy of Orthopaedic Surgeons. 2021; 29: e1291–e1302.

[9] İskender Uysal P, Şahin Kavaklı H, Neşelioğlu S. Evaluation of the thiol disulfide homeostasis in patients with traumatic hemorrhagic shock. Turkish Journal of Trauma and Emergency Surgery. 2021; 27: 516–525.

[10] Sethi M, Heidenberg J, Wall SP, Ayoung-Chee P, Slaughter D, Levine DA, *et al*. Bicycle helmets are highly protective against traumatic brain injury within a dense urban setting. Injury. 2015; 46: 2483–2490.

[11] Koroki T, Abe T, Kamimura S, Ochiai H. Severe traumatic brain injury in a patient with von willebrand disease type 2A successfully treated with factor VIII/von willebrand factor concentrates: a case report. American Journal of Case Reports. 2022; 23: e936690.

[12] Theodorou CM, Coleman LE, Mateev SN, Signoff JK, Salcedo ES. Successful extracorporeal life support in a pediatric trauma patient following angioembolization of pelvic hemorrhage. Journal of Pediatric Surgery Case Reports. 2021; 67: 101812.

[13] Zygogiannis K, Manolakos K, Kalampokis A, Thivaios GC, Moschos S. Traumatic fracture of the thoracic spine with severe posterolateral dislocation: a case report. Cureus. 2022; 14: e23830.

[14] Fujiwara G, Okada Y, Ishii W, Iizuka R, Murakami M, Sakakibara T, *et al*. Association of skull fracture with in-hospital mortality in severe traumatic brain injury patients. The American Journal of Emergency Medicine. 2021; 46: 78–83.

[15] Weber C, Andreassen JS, Behbahani M, Thorsen K, Søreide K. Characteristics, image findings and clinical outcome of moderate and severe traumatic brain injury among severely injured children: a population-based cohort study. European Journal of Trauma and Emergency Surgery. 2022; 48: 4473–4480.

[16] Lu S, Du T, Sun Z, Xu L, Tong X, Yan H. Timing of extremity fracture fixation in patients with traumatic brain injury: a meta-analysis of prognosis. World Neurosurgery. 2020; 133: 227–236.

[17] Jalles F, Janeiro M, Gonçalves M. Traumatic laryngeal fracture: a case report. Trauma Case Reports. 2021; 36: 100539.

[18] Zhou S, Zhang Q, Ding X, Qin YY, Cai S. Locking plate external fixation combined with membrane induction technology for the treatment of open and comminuted tibial fractures with bone defects. China Journal of Orthopaedics and Traumatology. 2021; 34: 400–405. (In Chinese)

[19] Altomare M, Granieri S, Cioffi SPB, Spota A, Basilicò SA, Chiara O, *et al.* High-Grade Limbs Open Fractures: Time to Find Milestones in the Emergency Setting. Life. 2021; 11: 1226.

[20] Coleman JR, Carmichael H, Zangara T, Dunn J, Schroeppel TJ, Campion E, *et al*. A stitch in time saves clots: venous thromboembolism chemoprophylaxis in traumatic brain injury. Journal of Surgical Research. 2021; 258: 289–298.

[21] Horst K, Greven J, Lüken H, Zhi Q, Pfeifer R, Simon TP, *et al*. Trauma severity and its impact on local inflammation in extremity injury—insights from a combined trauma model in pigs. Frontiers in Immunology. 2020; 10: 3028.

[22] Gaasch S. Critical care considerations for damage control in a trauma patient. AACN Advanced Critical Care. 2021; 32: 64–75.

[23] Yu LQ, Meng CC, Jin XS, Cai J. Clinical study of sodium bicarbonated Ringer's solution on fluid resuscitation of patients with hemorrhagic shock. European Review for Medical and Pharmacological Sciences. 2022; 26: 1535–1542.

[24] Ribeiro-Junior MAF, Costa CTK, de Souza Augusto S, Néder PR, Elia YGB, Rattan R, *et al*. The role of direct peritoneal resuscitation in the treatment of hemorrhagic shock after trauma and in emergency acute care surgery: a systematic review. European Journal of Trauma and Emergency Surgery. 2022; 48: 791–797.

[25] Meléndez-Lugo J, Caicedo Y, Guzmán-Rodríguez M, Serna JJ, Ordoñez J, Angamarca E, *et al*. Prehospital damage control: the management of volume, temperature ... and bleeding! Colombia Medica. 2020; 51: e4024486.

[26] Ethiraj P, Shringeri AS, Prasad P A, Shanthappa AH, Nagarajan V. Early total care versus damage control orthopedics in floating knee injury: analysis of radiological and functional outcomes. Cureus. 2022; 14: e25615.

[27] Giral G, Grosset A, Podeur P, Bélot-de Saint Leger F. Successful deployment of the french damage control resuscitation and surgical team in 2021: lessons learned from its first massive casualty event. Military Medicine. 2022; 187: 40–41.

[28] Li F, Gao L, Zuo J, Liu G. Promotion of a damage control concept in repairing orthopedic lower limb trauma. American Journal of Translational Research. 2022; 14: 3278–3285.

[29] Fan H, Fei R, Guo C, Li Y, Yan C, Chen F, *et al*. Effects of emergency treatment mode of damage-control orthopedics in pelvic fracture complicated with multiple fractures. American Journal of Translational Research. 2021; 13: 6817–6826.

[30] Sanchez-Tamayo M, Sanchez-Martin ML, Garcia-Real E, Garcés-Tamayo MC. Essential aspects during the resuscitation of intravascular volume in polytraumatized patients. Medwave. 2020; 20: e7879. (In Spanish)

How to cite this article: Haiyang Zhao, Jingyuan Si, Hongmin Guo, Xiaoming Li, Jinzhu Wang. Application of damage control orthopaedics in treatment of massive hemorrhage in severe traumatic fractures. Signa Vitae. 2023; 19(3): 159-164. doi: 10.22514/sv.2023.031.