Navigating the 'Triangle of Death': A Multidisciplinary Approach in Severe Multi-Trauma Management

Clinical Medicine Insights: Case Reports
Volume 17: 1–6

DOI: 10.1177/11795476241271544

Yushan Zhang[1], Fuxia Jian[1], Liang Wang[2], Hao Chen[1], Zhengbin Wu[1] and Shili Zhong[1]

[1]Department of Intensive Care Medicine, Army Medical Center of PLA, Yuzhong District, Chongqing, China. [2]Dermatology, Army Medical Center of PLA, Yuzhong District, Chongqing, China.

ABSTRACT: This case report details the challenging management of a 45-year-old male construction worker who suffered severe multiple injuries after a fall and subsequent collision with cement mixers. The patient presented with extensive injuries, including amputation, fractures and internal bleeding, leading to a state known as the 'triangle of death'. Despite the initial grim prognosis, evidenced by an ISS score of 28 and a mortality risk coefficient of 89.56%, the patient was successfully resuscitated and managed through a multidisciplinary approach. This included damage control resuscitation, emergency vascular interventions and targeted temperature management for brain protection. The patient's recovery highlights the effectiveness of comprehensive trauma management and the critical role of coordinated care in severe multi-trauma cases.

KEYWORDS: Severe multiple injuries, triangle of death, damage control resuscitation, emergency vascular surgery, targeted temperature management, multidisciplinary trauma care

RECEIVED: February 12, 2024. **ACCEPTED:** June 26, 2024.

TYPE: Case Report

FUNDING: The author(s) disclosed receipt of the following financial support for the research, authorship and/or publication of this article: This study was supported by Chongqing Medical Key Discipline Construction Project (No. 2dxk202102).

DECLARATION OF CONFLICTING INTERESTS: The author(s) declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

CORRESPONDING AUTHOR: Shili Zhong, Department of Intensive Care Medicine, Army Medical Center of PLA, No.10 Changjiang Branch Road, Yuzhong District, Chongqing 400010, China. Email: 805646578@qq.com

Highlights

- Effective management of a severe multi-trauma case.
- Successful navigation of the 'triangle of death'.
- Implementation of damage control resuscitation.
- Utilization of targeted temperature management for brain protection.
- Coordinated care leads to successful recovery.

Introduction

Trauma, particularly resulting from high-energy impacts, stands as a leading cause of morbidity and mortality worldwide, especially among the working-age population. This case report introduces a 45-year-old construction worker who endured a catastrophic fall, followed by a collision with cement mixers, culminating in severe multiple injuries. These injuries, including amputation, fractures and internal bleeding, propelled the patient into a critical state known as the 'triangle of death'. This term refers to a dangerous combination of hypothermia, acidosis and coagulopathy, often associated with high mortality rates in trauma patients.[1,2] The complexity of this case is further amplified by the patient's high Injury Severity Score (ISS) of 28 and a mortality risk coefficient nearing 90%. This report aims to dissect the multifaceted challenges encountered in managing such severe trauma cases. It underscores the significance of a multidisciplinary approach, incorporating damage control resuscitation, emergency vascular interventions and targeted temperature management for optimal brain protection.[3,4] Through this case, we aim to contribute to the existing knowledge in trauma care, emphasizing the importance of coordinated care and comprehensive management strategies in improving outcomes for patients with severe multi-trauma.[5,6]

Co-author: Fuxia Jian

Case Report

A 45-year-old male, while working at a construction site, sustained severe injuries after falling approximately 4 m from a wooden structure and subsequently being struck by a cement mixer weighing around 10 tons. The patient suffered a complete fracture of the left femur in its lower third and a complex, open, comminuted fracture of the right tibia and fibula. Additionally, there was a rupture of the right calf tendon, extensive soft tissue contusion and critical perineal injury.Following the accident, the patient was promptly transported to the local hospital, the patient was taken to a local hospital, where upon arrival his heart rate was 140-150 beats/min, his blood pressure was 80/50 mmHg, his respiratory rate increased to 35 beats/min.It is very noteworthy urgent hemoglobin test revealed a critically low level of 41 g/L. After infusion of 1200 suspended red blood cells and 800 mL fresh frozen plasma, the trauma surgeon and orthopedic surgeon decided to treat the patient surgically.The multifaceted surgical procedure included the repair of a completely severed left thigh, the exploration and repair of a ruptured left femoral vein, and the debridement and suturing of the right calf. Additionally, the medical team conducted a nerve exploration and an anastomosis of the right anterior tibial artery. The right tibia-fibula fracture was addressed with a reduction and fixation using a Kerr needle, followed by external fixation.

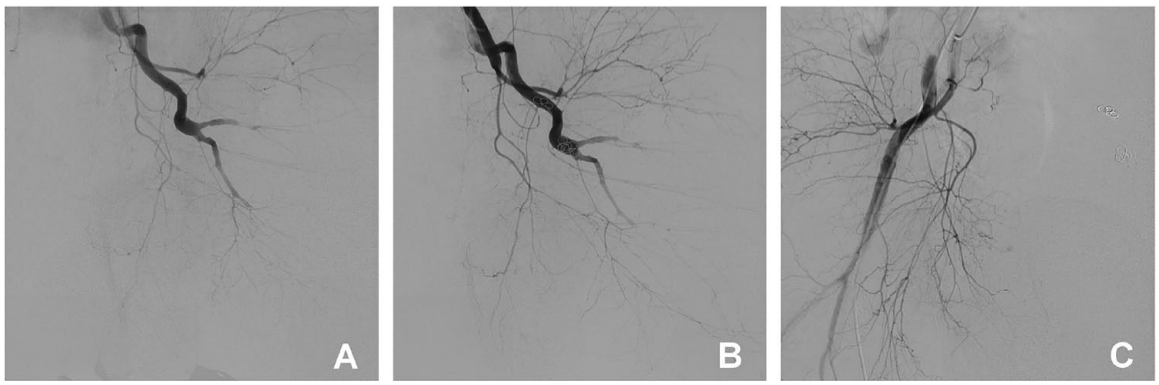

Figure 1. Vascular intervention in progress. A-B: Left femoral artery before and after embolization. C: Right femoral arteriovenous imaging.

Intraoperatively, the team discovered a complete severance of the middle part of the patient's left femur, characterized by a narrow skin bridge of approximately 1 cm and active hemorrhage at the fracture site. Other significant findings included pronounced swelling of the proximal left thigh, scrotal edema and multiple irregular wounds on the right calf. Post-operatively, the patient was transferred to the intensive care unit for further monitoring and treatment. The blood was maintained at a rate of 90/60 mmHg at 2 u/h of hypophysin and 2.0 ug/kg.min norepinephrine, and the heart rate was 120-130 beats/min.Blood lactic acid levels were recorded at 11.0 mmol/L Meanwhile, the patient received substantial transfusions, comprising 2000 mL of suspended red blood cells, 2800 mL of fresh frozen plasma and 26 units of cryoprecipitate.The patient's blood pressure was maintained by continuous transfusions of blood products, while hemoglobin fluctuated in the range of 58 and 65 g/L . Given the patient's critical condition of hemorrhagic shock, an additional transfusion was administered, including 4000 mL of suspended red blood cells, 3200 mL of fresh frozen plasma and 20 units of cryoprecipitate.

On the morning of the second day post-injury, at 9 am, the patient's hemoglobin levels showed improvement, reaching 66 g/L. Consequently, the norepinephrine dosage was reduced to 0.5 ug/kg.min to maintain blood pressure of about 100/60 mmHg and heart rate of about 110 beats/min, and administration of pituitrin was ceased. Blood lactic acid levels were recorded at 4.0 mmol/L. Later, at 11 pm, the patient,was transferred from a local hospital to our emergency department, a process that spanned approximately 4 hours. During the transfer, the patient experienced repeated episodes of ventricular tachycardia, necessitating the intravenous administration of lidocaine 100 mg, followed by continued maintenance of 50 ug/kg.min.

Upon arrival at our facility, the patient immediately exhibited ventricular fibrillation, leading to cardiac arrest within 10 seconds. Cardiopulmonary resuscitation (CPR) was promptly initiated. The resuscitation protocol included the administration of adrenaline to augment cardiac function and the reintroduction of norepinephrine at a rate of 2.0 ug/kg.min to sustain blood pressure. After 40 minutes of intensive resuscitative efforts, the patient's spontaneous cardiac rhythm was restored. Clinical observation noted bilateral pupils dilated to 3 mm with reactive light reflexes,stinging limb abnormal flexion, so the GCS score was 4T. Following resuscitation, an additional 2 units of suspended red blood cells were transfused.

Approximately 30 minutes after stabilization, the patient's blood pressure showed slight improvement. Subsequently, an emergency whole-body CT scan was conducted in the radiology department, after which the patient was immediately transferred to the intensive care unit. Upon admission, a repeat blood gas analysis revealed critical findings: hemoglobin was undetectable, and significant acidosis was present. The patient's heart rate was elevated at 123 beats/min, body temperature was low at 34.5℃, and blood pressure was measured at 72/40 mmHg despite the administration of norepinephrine at 2.0 ug/kg.min. These clinical indicators suggested the onset of the 'triad of death', characterized by hypothermia, acidosis and coagulopathy.

In response, the patient received aggressive resuscitative measures, including the continuous infusion of 4 units of suspended red blood cells, 800 mL of fresh frozen plasma, 1 unit of platelets, 20 units of cryoprecipitate and 3 g of human fibrinogen. These interventions successfully elevated the patient's hemoglobin to 65 g/L. Concurrently, in light of the patient's history of acute cerebral ischemia and hypoxia, body temperature was maintained around 36℃, with continuous cooling of the head using an ice cap.

The patient's Injury Severity Score (ISS) was 28, and the Acute Physiology and Chronic Health Evaluation II (APACHE II) score was 30, indicating a high mortality risk coefficient of 89.56%. Urgent consultations with the Departments of Trauma Surgery and Vascular Surgery led to the diagnosis of injuries to the left femoral arteriovenous vein, left external iliac vein and internal iliac vein. Emergency embolization of the left femoral artery was performed by the vascular surgery team (Figure 1). The trauma surgery team recommended delayed debridement and vascular ligation once the patient's overall condition stabilized (Figure 1A-D). Meanwhile,the pelvis and the left lower limb stump should be

Figure 2. Injuries before, during and after treatment. A-D: All injured parts of the body were examined after admission to our hospital. E: Prepare to apply pressure bandage to the pelvic and left lower limb stump wounds before vascular intervention. F: Exploratory scrotum in progress. G: Stump after 2 debridements. H: The patient successfully extubed the tube offline, and the treatment was successful.

fully pressurized and bandaged (Figure 2E). Postoperatively, the patient was administered 1 g of imipenem and cisteratin every 6 hours, the first 3 doses of teicoplanin every 12 hours, followed by a maintenance dose of 0.4 g daily. The patient also received continuous blood transfusion, hemostasis treatment, close monitoring of blood routine and coagulation (Table 1). The patient's liver function was mildly abnormal, but creatinine continued to rise, urine volume was only 20-30 mL/h, and systemic edema was obvious. Therefore, we gave the patient continuous renal replacement therapy (CRRT) with CVVHD mode and no anticoagulant. When the blood pressure gradually stabilized, the patient began to slowly ultrafiltration 100-200 mL/h.

On the second day post-admission, a comprehensive multidisciplinary team (MDT) consultation was conducted hospital-wide. Given the clinical finding of an impalpable right lower extremity dorsal foot artery and the indistinct boundary of necrosis, the trauma surgery team recommended initial debridement (Figure 2). Subsequently, the patient underwent debridement of the necrotic skin and subcutaneous tissue of both lower limbs, including the removal of hematomas at the stump of the left lower limb, and ligation of the left femoral artery and vein.

By the third day, the urology department engaged in a scrotal incision and exploration procedure to evacuate additional blood clots. Notably, there were no discernible abnormalities in the testis, epididymis and spermatic cord (Figure 2F).

On the fifth day of hospitalization, there was a notable stabilization in the patient's hemochrome and coagulation profiles. The patient's urine volume gradually recovered and CRRT treatment was discontinued. The boundary of necrosis on the patient's right lower limb, below the knee joint, became clearly demarcated. Consequently, the trauma surgery department proceeded with the debridement of the left lower limb and amputation of the right lower leg.

Seven days following admission, with the reduction of sedation and analgesia, the patient regained clear consciousness and was able to comply with verbal instructions. This progress allowed for the initiation of continuous off-line rehabilitation training.

On the eighth day, significant advancement in the patient's recovery was marked by successful extubation and transition to oral tube intubation(Figure 2G-H).

Discussion

Trauma, particularly high-energy incidents like traffic accidents and falls from height, is a leading cause of mortality in

Table 1. Changes of clinical treatment indexes after arrival in ICU of our hospital.

LABORATORY TEST RESULT	ARRIVE AT ICU	POSTOPERATIVE VASCULAR INTERVENTION	2 HOURS AFTER SURGERY	4 HOURS AFTER SURGERY	6 HOURS AFTER SURGERY	8 HOURS AFTER SURGERY
Hemoglobin (g/L)	65	72	70	75	76	78
Platelet count (10^9/L)	56	62	65	65	68	72
APPT (s)	62	48	42	38.1	34	32
PT (s)	17.2	15	14	14.2	13.8	13.5
FIB (g/L)	0.8	1.2	2.1	2.0	2.4	2.3
Creatinine (umol/L)	385	400	CRRT	CRRT	CRRT	CRRT
Hypophysin (u/h)	2	1.5	1	0.5	0	0
Norepinephrine dose (ug/kg.min)	2	1.5	1.0	0.8	0.5	0.2
PH	7.10	7.3	7.32	7.35	7.35	7.35
Calcium ion (mmol/L) (1.15-1.6 mmol/L)	0.85	1.4	1.5	1.4	1.6	1.5
Lac (mmol/L)	12	10	8.5	5.6	3.2	1.7
Red blood cell suspension (mL)	1600	0	400	0	0	0
Fresh frozen plasma (mL)	800	400	0	0	0	0
Platelet (u)	1	0	0	0	0	0
Fibrinogen (g)	3	3	0	0	0	0

the young and middle-aged population globally.[7-9] This case exemplifies the complexities involved. Using the Abbreviated Injury Scale (AIS) and the Injury Severity Score (ISS) is pivotal in assessing the overall severity of trauma injuries.[10-12] In this case, the patient's ISS score was 28, categorizing the injuries as severe.

Upon arrival at our emergency department, the patient experienced ventricular fibrillation and cardiac arrest. Subsequent blood gas analysis revealed no signs of acidosis or electrolyte imbalance, leading to the conclusion that hemorrhagic shock was the primary cause. This aligns with Robert T's 2022 assertion that hemorrhagic shock is the most frequent cause of death in trauma cases.[4] Immediate interventions included blood transfusion, cardiac support and intensive cardiopulmonary resuscitation for 40 minutes, culminating in the restoration of the patient's spontaneous heartbeat (Figure 3).[13]

Despite hypothermia upon ICU admission, efforts for cerebral resuscitation were not abandoned.[3] The patient received warm infusions and external warming measures, alongside targeted temperature management via an ice cap to reduce brain cell metabolism. This approach is in line with Callaway CW's findings, which advocate for mild hypothermia as a therapeutic strategy in comatose adult patients post-cardiac arrest.[14] The efficacy of high-quality cardiopulmonary resuscitation and brain protection was pivotal in the patient's subsequent recovery of consciousness.

The absence of imaging data during the patient's initial treatment outside the hospital presented significant diagnostic and therapeutic challenges. In the emergency room, a multidisciplinary team, including trauma surgery, intensive care medicine and the emergency department, deliberated and determined a high likelihood of pelvic hemorrhage. Consequently, a pelvic belt was applied for compression and stabilization. Despite the risks, it was decided to proceed with a whole-body CT scan to identify the precise locations of surgical intervention and bleeding. The CT scan revealed multiple hematomas and active bleeding in the abdominal pelvic wall, penis, scrotum and soft tissue of the left thigh, suggesting potential bleeding from the left femoral artery and vein, as well as bilateral internal and external iliac veins.

The patient's critical state, described as being 'trapped in the triangle of death,' necessitated the adoption of damage-controlled resuscitation strategies. This approach, distinct from the treatment provided at the outside hospital, included damage-control surgery and field transfusion. Following the principles of 'loss control surgery,' we initially focused on pressure hemostasis of the left lower limb and pelvis, simultaneously moving the patient to the ICU for damage control resuscitation. This step was crucial to correct the triad of death: hypothermia, acidosis and coagulopathy. Once the systemic condition was stabilized, definitive exploration and repair of each injury were conducted in the operating room on the second day.[15,16]

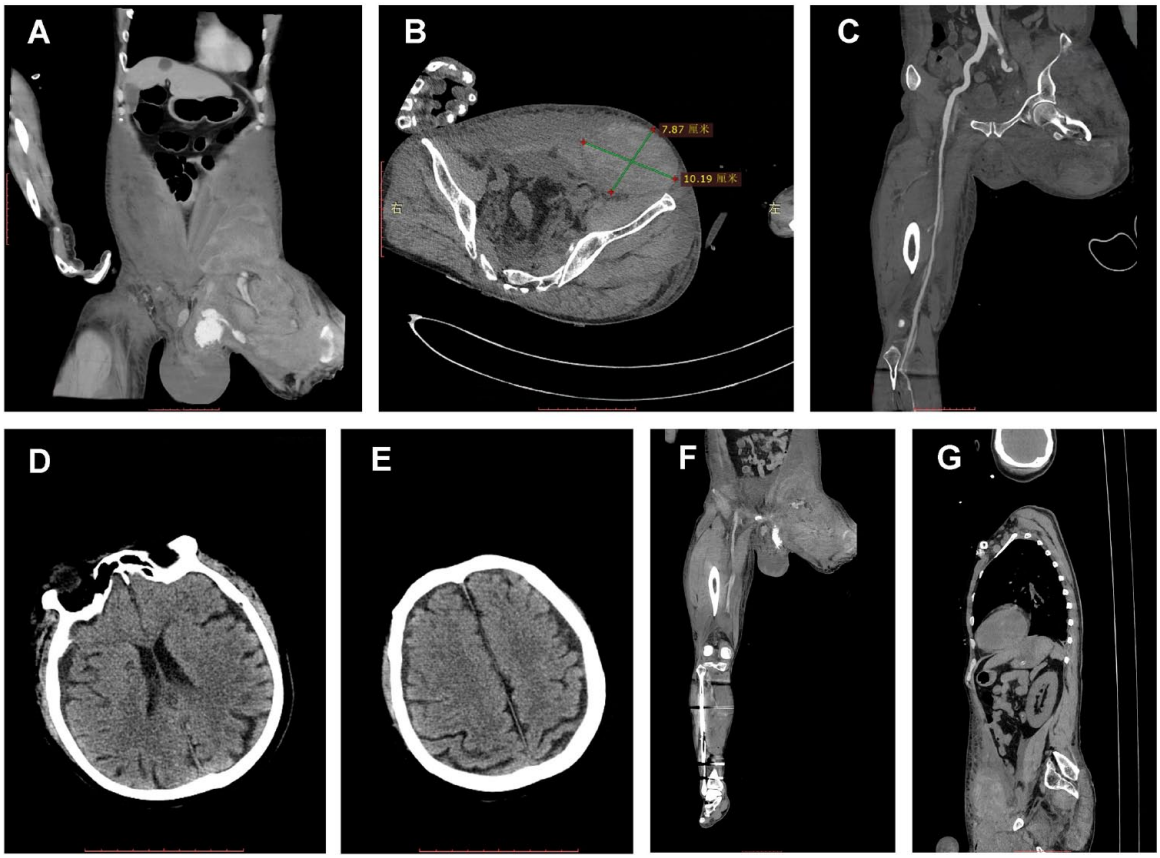

Figure 3. Whole body CT scan was performed after successful CPR. A-C: Found a massive hematoma in the abdominal wall. D-E: Vascular CTA of both lower limbs. F-G: Head CT 40 minutes after CPR

Rentas F's 2012 study highlighted the successful application of 'damage control resuscitation' by the US military during conflicts in Afghanistan and Iraq, which significantly reduced casualty mortality rates to 50%.[17] In line with the principles of field blood transfusion, we employed a 1:1:1 transfusion ratio of suspended red blood cells, fresh frozen plasma and platelets. This was supplemented with coagulation factors and human fibrinogen to ensure comprehensive management of the patient's condition.[18]

While this case exemplifies the successful treatment of severe multiple injuries, there were noteworthy challenges, including the absence of a pulse in the patient's right dorsal foot artery upon arrival at our hospital, compounded by the lack of external imaging data. A plausible explanation for these findings is the development of compartment syndrome in the bone fascia, leading to muscle necrosis and nerve ischemia. The patient's markedly elevated creatine kinase level (13023.30 u/L), in conjunction with renal failure, suggested the presence of crush syndrome. Consequently, the treatment plan included volume expansion and Continuous Renal Replacement Therapy (CRRT) to maintain internal homeostasis and mitigate inflammatory factors.

Historically, the mortality rate associated with crush syndrome has been high, as evidenced during World War II with rates as high as 91%.[19] However, advancements in medical interventions have led to significant improvements. For instance, during the Korean War, the pre-dialysis mortality rate was reduced to 84%, and further to 53% post-dialysis.[19] Furthermore, Li Wenfang's 2009 study on the 2008 Wenchuan earthquake victims revealed that CRRT treatment effectively normalized elevated levels of creatine kinase, creatinine and urea nitrogen in 19 patients with crush injuries.[20] The key to managing crush injury, distinct from other trauma types, lies in the early and timely expansion of blood volume to ensure renal perfusion, correct acidosis and alleviate limb swelling.

In this case, the patient's renal function normalized within 3 days following the initiation of CRRT. Notably, levels of creatine kinase, creatinine and urea nitrogen decreased to within normal ranges, with no rebound observed post-cessation of CRRT treatment. This outcome underscores the efficacy of prompt and appropriate intervention in crush syndrome management.

Conclusion

The management of severe multiple trauma cases is inherently complex and challenging. In the initial stages, a detailed assessment of injuries is crucial to determine the need for damage control resuscitation. Enhancing imaging diagnostics is pivotal in informing subsequent diagnosis and treatment plans. Additionally, the management of occult abdominal injuries and

crush syndrome, often overlooked in polytrauma, is critical. Prompt blood purification treatments have emerged as the most effective strategy for managing crush syndrome. This highlights the necessity of an integrated approach that combines rapid assessment, advanced imaging techniques and timely intervention for optimal patient outcomes in severe multiple trauma cases.

Author Contributions

Shili Zhong: review of the article, correspondence.
Yushan Zhang: writing of the article, data collection.
Fuxia Jian:data collection.
Liang Wang: image processing.
Hao Chen: contribution to the radiology part of the article.
Zhengbin Wu: treat this patient.

Ethical Review

The ethics committee of Chongqing Army Specialty Medical Center has passed the ethical review.

ORCID iD

Shili Zhong https://orcid.org/0000-0002-0922-8787

REFERENCE

1. Gonzalez Balverde M, Ramirez Lizardo EJ, Cardona Munoz EG, et al. Prognostic value of the lethal triad among patients with multiple trauma. *Rev Med Chil* 2013;141:1420-1426.
2. Xu SX, Wang L, Zhou GJ, Zhang M, Gan JX. Risk factors and clinical significance of trauma-induced coagulopathy in ICU patients with severe trauma. *Eur J Emerg Med* 2013;20:286-290.
3. Leeper CM, Nasr I, McKenna C, Berger RP, Gaines BA. Elevated admission international normalized ratio strongly predicts mortality in victims of abusive head trauma. *J Trauma Acute Care Surg* 2016;80:711-716.
4. Winkelmann M, Wilhelmi M. Prehospital resuscitation of patients with multiple injuries. *Unfallchirurg* 2014; 117:99-104.
5. Gaasch S. Critical care considerations for damage control in a trauma patient. *AACN Adv Crit Care* 2021;32:64-75.
6. Schoeneberg C, Schilling M, Keitel J, Burggraf M, Hussmann B, Lendemans S. Mortality in severely injured children: experiences of a German level 1 trauma center (2002-2011). *BMC Pediatr* 2014;14:194.
7. Alberdi F, Garcia I, Atutxa L, Zabarte M, Trauma S. Neurointensive care work group of the, epidemiology of severe trauma. *Med Intensiva* 2014;38:580-588.
8. Lozano R, Naghavi M, Foreman K, et al. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012;380:2095-2128.
9. Timonin S, Shkolnikov VM, Jasilionis D, Grigoriev P, Jdanov DA, Leon DA. Disparities in length of life across developed countries: measuring and decomposing changes over time within and between country groups. *Popul Health Metr* 2016;14:29.
10. Rautji R, Bhardwaj DN, Dogra TD. The abbreviated injury scale and its correlation with preventable traumatic accidental deaths: a study from South Delhi. *Med Sci Law* 2006;46:157-165.
11. Baker SP, O'Neill B, Haddon W Jr, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma* 1974;14:187-196.
12. Briese T, Theisen C, Schliemann B, Raschke MJ, Lefering R, Weimann A. Shoulder injuries in polytraumatized patients: an analysis of the TraumaRegister DGU(R). *Eur J Trauma Emerg Surg* 2021;47:1921-1930.
13. Dobson GP, Morris JL, Letson HL. Why are bleeding trauma patients still dying? Towards a systems hypothesis of trauma. *Front Physiol* 2022;13:990903.
14. Callaway CW. Targeted temperature management with hypothermia for comatose patients after cardiac arrest. *Clin Exp Emerg Med* 2023;10:5-17.
15. Malgras B, Prunet B, Lesaffre X, et al. Damage control: concept and implementation. *J Visc Surg* 2017;154:S19-S29.
16. Mitra B, Tullio F, Cameron PA, Fitzgerald M. Trauma patients with the 'triad of death'. *Emerg Med J* 2012;29:622-625.
17. Alberdi F, Azaldegui F, Zabarte M, et al. Epidemiological profile of late mortality in severe polytraumatisms. *Med Intensiva* 2013;37:383-390.
18. Arango-Granados MC, Cruz Mendoza DF, Salcedo Cadavid AE, Garcia Marin AF. Amputation in crush syndrome: a case report. *Int J Surg Case Rep* 2020;72:346-350.
19. Li W, Qian J, Liu X, et al. Management of severe crush injury in a front-line tent ICU after 2008 Wenchuan earthquake in China: an experience with 32 cases. *Crit Care* 2009;13:R178.
20. Rentas F, Lincoln D, Harding A, et al. The armed services blood program: blood support to combat casualty care 2001 to 2011. *J Trauma Acute Care Surg* 2012;73:S472-S478.