ORIGINAL ARTICLE

CONTENTS

Management of damage control surgery and resuscitation at different stages of evacuation. Tough lesson from the frontier of Russian–Ukrainian war

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ABSTRACT

Aim: To provide analyzes of practical implementation of Prolonged Casualty Care (PCC) and Damage Control Surgery (DCS) principles in Ukrainian frontline medical settings (MEDEVAC, Role I and Role II) under prolonged evacuation conditions during 2022–2024.

Materials and Methods: Clinical data were collected from multiple combat zones, focusing on indications for DCS, surgical interventions, postoperative complications, and patient outcomes.

Results: Among all casualties treated at Role II facilities, 43% underwent DCS procedures, often dictated more by tactical constraints than by medical necessity. The mortality rate in the DCS group was 5.9%, comparable to that of patients undergoing Early Total Care, definitive surgery on day of admission. The most frequent complications included intestinal anastomotic leaks, hernias, pneumonia (9.2%), acute kidney injury (10.4%), and anemia requiring transfusion (7.2%). Challenges in timely evacuation due to hostile drone activity, attacks on medical personnel, and terrain limitations led to a critical shift in trauma care paradigms.

Conclusions: Modern war dictate wider implementation of PCC and DCS.

KEY WORDS: damage control surgery, military medicine, blood transfusion, whole blood, hemorrhage management, tourniquet application, abdominal injuries, forward surgical teams

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DISCLAIMER

Taking into account the moments and precautions related to the military situation in Ukraine and National Security, all data and indicators are presented in relative values. Locations of Medical Treatment Facility (MTF) not disclosed. Current article is not official position of Ministry of Defence of Ukraine, just private point of view of authors.

INTRODUCTION

From the beginning of full-scale military invasion of Ukraine by the russian federation it was observed changes in the nature of military force. From the winter of 2022 both armies used standard doctrines and available weapons. But in the summer of 2023, the wide use of reconnaissance and strike drones, which were connected in a system of situational awareness. That made the battlefield transparent. And this gives unlimited opportunities for highly accurate strikes on the tactical level. Thus, due to absolute transparency, a 10-15 kilometer zone of continuous death was formed in front of the front line [1]. From the 2023 one can observe changes in structure of injuries. Before that maximum losses in the personnel of the armed forces were during accentuated offensive actions aimed at concentrating the enemy's main efforts in the main defense zone, as well as when counterattacks are carried out by the Defense Forces [2]. From the summer 2023 a lot of wounded were registered in more or less safe zones. What leads to increase of wounds and injuries of live critical organs, because in this zones military personal rarely wear body armor. Also a lot of attacks on civilian infrastructure was observed. Lot of civilian medicks were wounded and killed. In this group injures were different from those which were seen in military personal [3,4].

Another peculiarity of medical help during full scale aggression was inability of medical forces of armed forces of Ukraine to provide treatment to all injured, because of lack of armored evacuation vehicles; shortage of personnel, in particular certain categories of doctors and nurses. Thus it was created single medical space aim to establish cooperation at the level of each type of military and a certain (or group of) medical institutions under one commander [2,5].

In conditions when lot of Medical Treatment Facilities (MTF) with different levels were involved and continuous work of forward surgical teams (FST) in conditions of mass casualty incident (MASCAL), led to the necessity for strict restrictions on each level of medical care. For this, guiding documents were created that standardized and unified the scope of assistance and the organization of medical support. These documents took into account vertical and horizontal connections and were agreed upon at all levels of the military and civilian link of assistance. Which was extremely important, since the conduct of various types of military operations involves close interaction between different branches and types of troops [6].

In 2023, the Ministry of Defense of Ukraine approved by order the scope of medical care at the pre-hospital stage, clearly defining the necessary operations and manipulations that must be performed at each stage of providing assistance to the wounded [7].

AIM

The aim of the work is to provide analyzes of practical implementation of Prolonged Casualty Care (PCC) and Damage Control Surgery (DCS) principles in Ukrainian frontline medical settings (MEDEVAC, Role I and Role II) under prolonged evacuation conditions during 2022–2024.

MATERIALS AND METHODS

This is a retrospective descriptive study based on data collected from 2022 to 2024. Data were gathered on CASEVAC, MEDEVAC, Role I та Role II (all types), on different parts of the Ukrainian frontline. Another important question was the consequences of DCS on Role II. Complications and survival rate on hospital level. Complications reported included pneumonia, cardiac arrest, acute kidney injury, postoperative hernias, anemia requiring transfusion, chimerism, wound infections, peritonites, leakage of anastomosis and sepsis. Finally, intraoperative administration of blood products was reported including direct donor to casualty transfusion (walkin blood bank), whole blood, packed red blood cells (pRBC), Freeze dried plasma (FDP) and fresh frozen plasma (FFP). It was observed in separate cases of platelet infusion. Preparation and storage is too complicative for usage on Role I and Role II. The use of Cryoprecipitate and Antihemorrhagics containing a combination of blood clotting factors was sporadic and did not affect the overall picture in any way. All patients who were in 3 hours after injury got 2 ml. of tranexamic acid. Also all wounded get antitetanus and antibiotic prophylaxis in order to resent laws of Ukraine.

The obtained quantitative data were processed using descriptive statistics and graphical interpretation. The combination of different research methods provided a comprehensive assessment of the current situation.

Thus, the research design can be characterized as a descriptive case study, focused on evaluating a specific innovation in a specific context, using mixed methods to increase the reliability of the conclusions.

For reasons of national security, the location of the MTF is not disclosed, and all data is given in relative values.

RESULTS

The studied population was mostly homogeneous and consisted of male servicemen aged 27 to 55 years who were wounded as a result of combat operations. The average age was 44.3 ± 12.1. At the same time, all age and gender categories were represented among civilians. Youngest patient with DCS was an 11 years old boy, who was wounded during the shelling of a peaceful city with cassette bombs. He was in the car with father and his younger brother. He got multiple wounds of head, brain, chest, abdomen and extremities. The patient dies two days after surgery. The oldest patient was 72 years. He had abdominal wounds with massive injury to the liver. Heart arrest during the surgery. Non successful resuscitation.

The condition of patients in time of their delivery at the Role II was very serious, so we can not evaluate concomitant diseases, which can affect surgical treatment. (Fig. 1).

In most cases the only device to stop the bleeding on Role I was tourniquet. It was used in nearly 60% of all injuries. Other methods of massive hemorrhage management in the condition of MEDEVAC were the REBOA system and Abdominal Aortic and Junctional Tourniquet (AAJT). Dmytro Androshchuk [31] reported six cases of successful management of battlefield traumatic cardiac arrest using the AAJT. Four cases succeeded in surviving the patient, one patient died due to prolonged evacuation time and one after 10 days on the Role 3 because severe damage of thoraco-abdominal injuries.

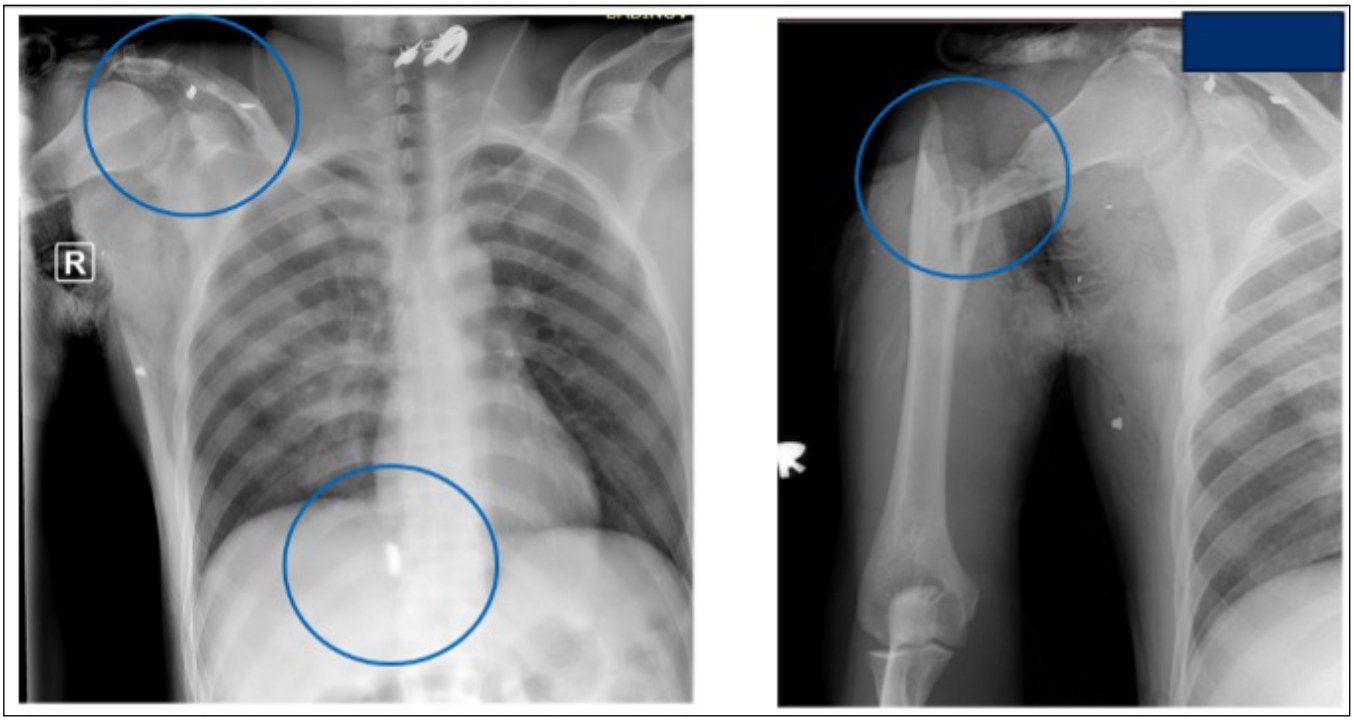

Fig. 1. Multiple life-threatening injuries
Picture taken by the authors

I.A.Lourin and authors in the abstract [8] shows the difference in the effectiveness of AAJT, Reboa and aortic clamping, emphasizing the appropriateness of each of these methods at a certain stage of care.

In contrast, Dmytro Samofalov reported a comparable number of traditional management techniques, including emergency thoracotomy with aortic clamping. Just 25% of cases achieved the restoration of rhythm, with exitus letalis in a further ten days. On delivery to FST all wounded undergo trauma assessment with laboratory and instrumental check up according to the defined algorithm. Also, vascular access was established to all patients. In definite cases central lines (jugular vein) with ultrasound control. All casualties undergo vital signs check, blood samples, X-ray and extended Focused Assessment with Sonography in Trauma (eFAST). Patients with unstable hemodynamics, signs of shock and positive eFAST immediately were transported to operative theatre for laparotomy in rare cases thoracotomy as well. Stabile patients who have uncertain eFAST undergo additional tests. Among the patients with penetrating abdominal wounds it was injuries of small intestine (28,2 %), colon (26.2%), liver (19.7%), and spleen (13.6%). This was similar to other series reports from Ukranian battleline [9,10]. In FST we provided DCS – 56 %, Early Total Care (ETC) (definitive surgery on day of admission) – 35%. At 9% just exploratory laparotomy was provided. During explorative laparotomy shrapnel was found or in greater momentum or separate in the abdominal cavity.

DISTRIBUTION OF INJURIES

In general, the distribution of wounded who were delivered to FST is shown in Table 1.

Most of the patients on FST were moderate and needed just primary surgical care for their wounds. Up to 13% were severe and needed advanced surgeries, such as laparotomy, thoracotomy, external fixation of bones, amputations, fasciotomies, temporary shunting of great vessels Etc. The distribution of patients who underwent advanced surgery is shown in Table 2.

As shown in Table 2. The total number of surgeries is greater than 100%, which is due to the necessity to conduct two and more surgeries in patients with multiple injuries. Most often a combination was laparotomy and pleural drainage. Rarely we provided laparotomy with thoracotomy, or laparotomy and greater vessels temporary shunting. Also for safe transportation to the next level we used provision tourniquet to renal pedicle. In case if bleeding, from a packed kidney, renews during the transportation of the patient, one can just tighten a tourniquet to achieve hemorrhage control.

During laparotomies, the most common procedures performed were abdominal packing (14%), obstructive resection of the small intestine (7%), and colon (21%).

Among the patients in DCS group were those with high Injury Severity Score (ISS) with average score 32 (23-37). To compared with patients who undergo early total care (ECT) ISS was 15 (11-17). One of the important

Table 1. Structure of wounds in patients who were delivered to the advanced surgical group Role 2

	Head	Thorax	Abdomen	Extremities	Multiple
2022	8,5 %	6,3 %	1,1 %	29,0 %	45,2 %
2023	8,8 %	6,9 %	2,9 %	39,2 %	42,2 %
2024	11,7 %	7,5 %	3,6 %	52,9 %	24,3 %

Source: compiled by the authors of this study

Table 2. Advanced surgeries

Laparotomy	Thoracotomy	Pleural drainage	External fixation of bones	Surgery on graeate vessels	Extremities amputation
31,1 %	4,4 %	16,2 %	35,5 %	14,6 %	15,5 %

Source: compiled by the authors of this study

Fig. 2. Vacuum-assisted temporary closure of laparotomy wound
Picture taken by the authors

indicators for choosing surgical tactics was the injury isolated or multiple. All patients with multiple injuries of the intestine were operated on in DCS approach. During explorative laparotomy we find few injuries of pancreas (%). In all cases at the FST pancreas was packed, and the abdominal wall was temporarily closed. Other indications for DCS were: level of consciousness (stunning, sopor, coma), body temperature less than 35 °C, blood saturation less than 85%, liquid (blood) in abdominal cavity during eFAST. We didn`y use Algover's shock index as it was not informative in condition of permanent combat stress.

For temporary closure of abdominal wall in contaminated cavity without signs of hemorrhage we used vacuum assisted closure (VAC). (Fig. 2)

In risk of hemorrhage, temporary sutures or Bogota bag (Fig. 3).

Mandatory yarly administration of tranexamic acid (TXA), which was shown in the CRASH-2 trial to reduce mortality, has been applied in combat situations. But due to delayed evacuation it was used rarely.

A blood transfusion as a routine medical procedure was started before or parallel with surgical intrusion, and lasted up to stabilisation and evacuation of the patient to the next Role. In some cases we continued hemotransfusion in evacuation vehicles.

From the middle of 2023, the amount of blood transfusions during MEDEVAC increased significantly. This was largely facilitated by the provision of the necessary equipment and training among the personnel of evacuation teams. Training for providers operating in prehospital settings (Role 1 stabilisation points) is conducted by charitable organisation jointly with Ukrainian Transplant coordination centre and in accordance with the Ministry of Health of Ukraine roadmap. It integrates compliance with national standards and best practices from the Trauma Hemostasis & Oxygenation Research (THOR) network's

Fig. 3. Temporary closure of laparotomy wound: plastic interface shields the bowel, then loose sutures are added
Picture taken by the authors

field transfusion course. A critical component of this program is realistic simulation-based education.

Also important role in this increason played legal regulation of the right (if necessary) to transfuse blood to the wounded during their evacuation from the battlefield by military personnel without medical education after completing the relevant courses [11].

Thus the amount of MTF Roll II, which uses no blood at all, was still high. Whole blood (WB) (0(I) Rh-) – was used at 32% from all the stabilisation units (Role 2). The whole picture was:

- WB (0(I) Rh-), and Packed red blood cells (pRBC) – 4%;
- WB (0(I) Rh-), Fresh frozen plasma (FFP) – 8%;
- WB (0(I) Rh-), pRBC, FFP – 4%;
- WB (0(I) Rh-), pRBC, FFP, Freeze-dried plasma (FDP) – 4%;
- WB (0(I) Rh-), pRBC, FFP, FDP, Cryoprecipitate Anti-hemophilic factor (AHF)- 2%;
- Only pRBC- 2%;
- pRBC, FDP – 2%;
- pRBC, FFP, AHF, FDP – 2%;
- FFP, AHF- 3%;
- 34% used no blood transfusions at all.

PATIENT OUTCOMES

Among all patients who undergo DCS and DCR case fatality rate (CFR) was 5,9 %. In 1,8 %, cases of death were severe extraabdominal injuries. Injures of the abdomen which lead to death were 3,6 %. In most cases multiple injuries of abdominal organs involving pancreas and duodenum.

In the ETC group we observed failure of intestinal anastomosis sutures and early postoperative hernias.

Among general complications most common were pneumonia (9.2%), anemia requiring transfusion (7.2%), cardiac arrest (6.4%) and acute kidney injury (10.4%).

DISCUSSION

John Chovanes et al. notes that philosophy DCS and DCR is to save patient's life at any costs [12]. Higa G et al. on the other hand insists, that DCS is used much more often than has a reasonable need [13]. Jiong Hao Tan et al. showed that in Borderline patients with polytrauma being adequately resuscitated may be treated with ETC [14]. However data from those studies are related to civilian trauma. And as discussed in a number of studies based on data from the modern russian-Ukrainian war (both its full-scale phase and in the conditions of the Anti-Terrorist Operation), indications for damage control are primarily determined by the tactical situation, and only secondarily by medical indications [15,16]. It is important that Role2 is situated near battle zone an always work in condition of conditional MASCAL. Even if in exact moment it is no delivery of multiple casualties group is still in permanent awaiting mode. Changes in tactical situation can be immidiate and unpredictable. That`s why time of surgery cant`t be longer than 90 min. That is the reason why we used DCS over the ETC. for maximum release of medical personnel. Regulated by the Order of the Ministry of Health of Ukraine dated March 8, 2022 № 431. Classically it is distinguished five

critical stages of DCS and DCR: I, patient selection and decision to perform damage control; II, operation and intraoperative hemorrhage management and prevention of contamination; III, resuscitation in the intensive care unit; IV, definitive surgery after returning to the operating room; and V, reconstruction and reabilitation [17,18].

For battlefield injury it is highly reasonable to add one more Phase 0 of DCS, termed «Damage Control Ground Zero,» [19].

In military conditions, time before getting professional surgical care can be quite prolonged.

In 2022 the average evacuation time was 134 min. And ranged from 15 minutes after injury to a maximum of 12 hours. In 2023, evacuation time was significantly increased due to prolonged waiting for evacuation. The average indicators were not representative, as they can be in range from a few hours to a few days. Maximum awaiting time of evacuation (47 days). Evacuation itself in this case, took less than two hours. Nowadays it is less than 10% of wounded who are delivered to the Role II during the Golden hour. It can be due to water barriers, drones, and heavy shelling [20]. The most important in Phase 0 was hemorrhage management, blood transfusion and prevention of hypothermia.

TOURNIQUET APPLICATION

Lipsky et al. stands for that wide implementation of tourniquets, which decreased mortality from extremity hemorrhage by 85% [21]. And for the last years in Ukraine, the same as in the whole other world, tourniquets have become a standard piece of equipment for soldiers and officers on the field. But in the beginning of full scale aggression it was a problem to get enough tourniquets for the Ukrainian army, because a lot of civilians joined it. So the need for tourniquets reached more than two million. So a lot of poor quality tourniquets reached the soldiers. Also, overuse of tourniquets can be observed. Holcomb et al. note that, "recently the proper application of tourniquets for extremity hemorrhage has been increasingly underscored by experiences in Ukraine. With delay in evacuation (upward of 6 h), complications of limb ischemia from prolonged tourniquet applications have been observed" [22] Vladyslav Yatsun notifies that tourniquet application was appropriate in 24.6% of the wounded with tourniquets [23].

From all the wounded, who were transported to Role II 1,19% had tourniquet syndrome, which led to amputation. (64% from all cases of tourniquet syndrome) and in 46% to complicative vascular surgeries or/and fasciotomies. On other direction of buttle line it was 5,3% amputations from the total number of casualties. And tourniquet syndrome enriched 18,8% from the total amount of casualties.

In total, if to compare amount amputations due to tourniquet syndrom to amputations due to complicated extremities injuries it was 42±3% and 58±3% respectfully. Also we should mention 22±4% fasciotomies stipulated by long staying tourniquets.

This data corresponds with other studies. When evacuation was delayed more then for 3 hours in 20% of cases it was conversion of tourniquets by battle medics, in 26,7% conversion by FST, in all other cases no conversions at all. 34% of all cases extremities were amputated after relise of tuorniquets. 20% fasciotomis, 14% were in need of hemodialysis. Total mortality in this group was 14% (7% with hemodialysis and 7% with fasciotomy).

BLOOD TRANSFUSION IN PROLONGED CASUALTY CARE AND PROLONGED EVACUATION

Still it is no satisfactory fluid therapy for use during prolonged transport, but the whole blood or it's components. Current evidence show benefits of the implementation of whole blood transfusion in prehospital services. It was problems with platelet concentrates. In multiple studies it was shown that it usage fresh whole blood and cold-stored whole blood to patient care in austere environments is beneficial and leads to better survival rate [24,*25*].

Despite this in Ukraine up to middle of 2023 it was illigal for millitary stuff with out degree in medicine. Just in summer of 2023 the proper order was published by ministry of health. From that time amount of blood transfusions during prolonged casualty care (PCC) and prolonged evacuation increased several dozen times. For example all brigades of The Ukrainian Marine Corps were trained in blood transfusion and all nessesary equipment was given to them [26]. It played important role in saving lifes in situations when evacuation was seriously delayed or prolonged. During Krynky operation we observed that more than 70% of patient who received additional blood transfusions during the initial resuscitation phase – survived. There was less then 2% of cases of a minor adverse reaction that could be attributed to prehospital transfusion.

Based on the study conducted by Ukrainian military doctors about the thermal properties of blood, it can be concluded that the temperature range of +37–42°C is optimal for heating blood in terms of safety, with a temperature of +42°C demonstrating the best coagulation parameters and effectiveness in preventing hypothermia.

The rationale for this conclusion is provided below, considering key aspects:

1.Safety (Absence of Hemolysis)

•The study data indicate that at temperatures of +37–42°C, no hemolysis was observed in samples from groups A and B (0 damaged erythrocytes), confirming the safety of this range. Hemolysis begins at +43°C (0–1 erythrocytes in group B) and significantly increases at +44–45°C (2–3 erythrocytes in group A, 6–10 in group B).

2.Prevention of Hypothermia

•Heating to +37–42°C effectively prevents hypothermia, which is associated with coagulopathy due to reduced activity of coagulation factors and platelet adhesion.

3.Coagulation Parameters

•Coagulogram data show that from +37 to +42°C, there is an acceleration of coagulation (reduction of PT to 11.0–11.2 s, APTT to 23.0–26.1 s, $p < 0.05$), consistent with increased enzyme activity. D-dimer levels remain within normal limits (0.28–0.29 ng/mL), indicating no fibrinolysis.

•At +44–45°C, group B exhibits significant acceleration of coagulation (PT 11.0 s, APTT 37.2 s, $p < 0.01$) and a decrease in fibrinogen (from 2.9 to 2.4 g/L), suggesting hypercoagulation due to hemolysis and a risk of DIC (Bouchama et al., 2002). In group A at +44°C, prolongation of PT (14.3 s) and APTT (34.6 s) is observed, along with an increase in D-dimers (0.33 ng/mL), indicating the onset of coagulation disturbances.

DCS IN ABDOMINAL AND THORACIC INJURIES

A significant cause of combat deaths is from noncompressible torso hemorrhage. There are just two methods that can reduce intra abdominal bleeding in sewear abdominal injury: REBOA system and AAJT. REBOA system showed good results [27], but it is not easy to mount it in a field environment. On other hand AAJT easy to aply [28], and showed good results in controlled swine studies, healthy human volunteer and mannikin study [29,30]. But reports on the use of AAJT in combat conditions are began to appear only last year in limited reports of Ukrainian military doctors. They have good results but are limited in use by trauma to the pelvis, lower extremities, and aorta zone 3.

As it was shown, we often used DCS not just due to life threatening hemorrhage but also due to tactical condition and severe contamination of the abdominal cavity. That gives the opportunity to compare the DCS and ETC groups results.

Among the observed patients CFR, after 5 days of treatment was comparable among both groups. What can be explained by the bigger number of patients who undergo DCS not due to medical, but to tactical indications. Postoperative mortality, in the 7 day period following surgery, was slightly higher in the DCS group.

Most common organs to be injured, were momentum and small bowel. If we find nothing but momentum injuries, we just finished in ETC approach, leaving control drainage in case of hidden hemorrhage not noticed by surgeon. In injury of the small intestine, we used both ETC and DCS. In case of DCS mostly at first stage it was obstructive resection and anastomosis the next day on the next level. No abdominal complication or mortality observed in these two groups.

Among all patients after DCS worst results were observed in those patients who have injuries of pancreas and duodenum. This patient has abdominal adhesions, postoperative hernias and even one lethal case after two months of treatment.

CONCLUSIONS

The evolving nature of the russian-Ukrainian war, especially with the introduction of integrated drone reconnaissance-strike systems, has significantly altered the pattern of injuries and the demands on military medical support. The resulting «zone of continuous death» and delayed evacuation due to tactical conditions have necessitated widespread use of Damage Control Surgery (DCS) and Damage Control Resuscitation (DCR), even in scenarios where Early Total Care (ETC) might be preferable under peacetime or civilian trauma settings.

This study confirms the effectiveness of DCS/DCR approaches under MASCAL conditions at Role II facilities, particularly in the context of delayed evacuation, hypovolemia, and resource scarcity. While DCS resulted in a slightly higher complication and postoperative mortality rate compared to ETC, it was indispensable for patients with high Injury Severity Scores (ISS), unstable vitals, and multiple organ injuries, particularly involving the pancreas or duodenum.

Additionally, innovations in field resuscitation, such as the deployment of whole blood transfusion during MEDEVAC and the use of AAJT devices, have contributed to increased survival rates. The integration of these practices into a single medical space–standardized across civilian and military systems–ensured coordinated and timely care despite logistical limitations.

However, the data also highlights critical challenges, including overuse and complications from tourniquets, inconsistent access to blood products, and the need for better triage and surgical timing protocols. The formalization of Phase 0 in the DCS framework–focused on hemorrhage control, hypothermia prevention, and blood transfusion at the point of injury–has proven essential in this conflict and may serve as a valuable model for future high-intensity warfare settings.

In conclusion, this experience emphasizes that surgical decision-making in modern warfare is often dictated more by tactical realities than purely by medical criteria. The findings support continued refinement of DCS/DCR protocols, greater investment in evacuation capabilities, and expansion of prehospital transfusion training for combat medics.

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CONFLICT OF INTEREST

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