

Khoroshun E.M.¹, Panasenکو S.I.², Negoduiko V.V.¹, Shypilov S.A.¹, Klapchuk Y.V.,
Kupriyanchuk V.V., Kerbakh N.R.²

Military Medical Teaching Center of the Northern Region of Ministry of Defense of Ukraine,
Kharkiv, Ukraine;

¹Kharkiv National Medical University, Kharkiv, Ukraine;

²Poltava State Medical University, Poltava, Ukraine

DAMAGE CONTROL TOURNIQUET AS A COMPONENT OF DAMAGE CONTROL SURGERY IN ISCHEMIA-REPERFUSION SYNDROME

e-mail: pansu@ukr.net

Severe ischemia-reperfusion syndrome in physiologically unstable patients with nonviable extremities remains a major challenge in damage control surgery. We analyzed 31 cases of tourniquet use aimed at preventing this syndrome in physiologically unstable patients with nonviable extremities treated in our center. Clinical, laboratory, imaging, intraoperative, and microcirculatory assessments were used to evaluate limb viability and guide surgical management. We propose the term damage control tourniquet (DACOTa) for planned tourniquet maintenance or application as a bridging strategy before life-saving amputation. This strategy was used in 5.7 % of tourniquet cases; lower extremity injuries predominated (78.9 %). Previously applied hemorrhage-control tourniquets were maintained in 74.2 % of cases. Thirty-one amputations were performed in 28 patients, predominantly as single-stage procedures (83.9 %). Overall mortality was 38.7 %, mainly due to post-resuscitation syndrome and multiple organ failure. The damage control tourniquet provides an effective bridging strategy, enabling definitive amputation after physiological stabilization and improving clinical classification of tourniquet use.

Key words: hemorrhage-control tourniquet, damage control tourniquet, tourniquet syndrome, ischemia-reperfusion syndrome, combat-related extremity trauma.

Хорошун Е.М., Панасенко С.І., Негодуйко В.В., Шипілов С.А., Клапчук Ю.В.,
Купріячук В.В., Кербаж Н.Р.

ТУРНИКЕТ КОНТРОЛЮ УШКОДЖЕНЬ ЯК СКЛАДОВА ХІРУРГІЧНОЇ ТАКТИКИ КОНТРОЛЮ КРИТИЧНИХ УШКОДЖЕНЬ ПРИ ІШЕМІЧНО-РЕПЕРФУЗІЙНОМУ СИНДРОМІ

Тяжкий ішемічно-реперфузійний синдром у фізіологічно нестабільних пацієнтів із нежиттєздатною кінцівкою залишається серйозною проблемою хірургії контролю uszkodжень. Ми проаналізували 31 випадок застосування турнікетів із метою запобігання цьому синдрому у фізіологічно нестабільних пацієнтів із нежиттєздатними кінцівками, які лікувалися у нашому центрі. Для оцінки життєздатності кінцівок та визначення тактики хірургічного лікування використовували клінічні, лабораторні, візуалізаційні, інтраопераційні та мікроциркуляторні методи дослідження. Ми пропонуємо термін «турнікет контролю uszkodжень» (damage control tourniquet - DACOTa) для позначення запланованого продовження використання або накладання турнікета як тимчасової стратегії до виконання життєзберігальної ампутації. Цю стратегію застосовували у 5,7 % випадків використання турнікетів; переважали uszkodження нижніх кінцівок (78,9 %). Турнікети, попередньо накладені для контролю кровотечі, продовжували використовувати у 74,2 % випадків. Виконано 31 ампутацію у 28 пацієнтів, переважно одномоментно (83,9 %). Загальна летальність становила 38,7 %, переважно внаслідок постресусітійного синдрому та поліорганної недостатності. Турнікет контролю uszkodжень є ефективною тимчасовою стратегією, що дає змогу виконати остаточну ампутацію після стабілізації фізіологічного стану пацієнта та вдосконалює клінічну класифікацію застосування турнікетів.

Ключові слова: кровоспинний турнікет, турнікет контролю uszkodжень, турнікетний синдром, ішемічно-реперфузійний синдром, бойова хірургічна травма.

The study is a fragment of the research project "Development of up-to-date approaches to diagnostics, observation, prognostication and treatment of surgical and traumatic pathologies", state registration No. 0125U002732.

In the structure of contemporary combat-related surgical trauma, a significant proportion is occupied by severe, nonspecific injuries to the extremities characterized by massive tissue destruction, prolonged compression, or a combination of both. These mechanisms lead to the development of ischemia-reperfusion syndrome (IRS), followed by hemodynamic instability and acute kidney injury (AKI) secondary to endotoxemia. In the majority of cases (65 %), such injuries are associated with bone fractures, while in 35 % they are combined with trauma to other anatomical and functional regions.

The scientific literature describes this type of combat injury using a variety of terms reflecting its etiopathogenetic and morphological features, including "crush syndrome," "ischemic muscle necrosis," "prolonged limb compression syndrome," "traumatic toxicosis," "reperfusion (release) syndrome," and "compartment syndrome" [3, 11, 12]. These injuries are characterized by complex pathophysiology, a polymorphic clinical presentation, and significant challenges in both clinical management and healthcare system organization. They are also associated with high rates of disability and mortality, reaching up to 40 % [1, 13].

A unifying feature across these injury patterns is the development of IRS varying severity, ranging from mild oliguria to persistent acute kidney injury, which subsequently triggers downstream mechanisms of thanatogenesis. From the standpoint of IRS – albeit with certain reservations – tourniquet syndrome (TS) can also be included within this spectrum of combat trauma, the relevance of which is particularly pronounced in the context of the ongoing war in Ukraine [4, 7-9].

Concerns regarding the use of hemorrhage-control tourniquets date back to World War I. In 1916, Captain M. Blackwood wrote in the *Royal Army Medical Corps Journal*: “The tourniquet is an instrument of the devil that sometimes saves a life” [10]. The potential for severe complications associated with tourniquet use is also emphasized in *Advanced Trauma Life Support* (ATLS), which notes that in cases of life-threatening arterial hemorrhage, the “judicious use of a pneumatic tourniquet” can be both beneficial and lifesaving.

The criteria guiding the application of surgical technologies in critically ill trauma patients are well established, and the concept of damage control surgery (DCS) is widely accepted. Indications for DCS include systolic blood pressure below 90 mmHg, serum lactate levels above 7.5 mmol/L, and core body temperature below 35.5 °C – parameters that define a physiologically unstable patient profile. At the same time, it is recognized that the arsenal of technical approaches within DCS for certain types of injuries remains limited or insufficiently developed [10].

Changes in the nature of modern warfare, along with organizational and methodological challenges in the evacuation and medical support systems for military personnel, have led to increased recognition of tourniquet syndrome as a distinct clinical entity. During the initial phase of the war (2014-2022), only sporadic reports of TS were documented. However, since 2022, it has emerged as a leading indication for limb amputation [3, 5, 13].

Tourniquet syndrome develops primarily as a result of improper or prolonged use of hemorrhage-control tourniquets. It is characterized by severe, специфічне traumatic injury involving circumferential compression (effectively a “guillotine-like” mechanism) of tissues beneath the tourniquet, prolonged tissue ischemia distal to the device, and subsequent reperfusion injury upon restoration of blood flow, ultimately resulting in the development of IRS [13, 14].

Notably, a review of the available scientific literature did not reveal clear recommendations regarding specific technical strategies aimed at preventing IRS within the framework of DCS in critically ill patients with physiologic instability.

The purpose of the study was to validate a novel clinical definition of the “damage control

tourniquet” and to propose strategies for its use in patients at risk of developing severe IRS within the framework of DCS tactics.

Materials and methods. We analyzed 31 cases of Damage Control Tourniquet (DCT) application in patients with a physiologically unstable profile treated at the Military Medical Clinical Center of the Northern Region over a defined study period. In all cases, hemorrhage-control tourniquets had been applied at earlier stages to the upper arm and/or thigh segments. At the time of decision-making regarding DCT application, 11 (35.5 %) patients were in the early post-cardiac arrest period following successful cardiopulmonary resuscitation, while the remaining 20 (64.5 %) were assessed as critically ill with ongoing physiologic instability. All patients were admitted to intensive care units. After stabilization and normalization of physiological parameters, 28 patients subsequently underwent surgical intervention at various time points.

The diagnosis of tourniquet syndrome was established based on the following parameters: duration of tourniquet application, level of placement, local clinical signs (edema, paresthesia, hypoesthesia, anesthesia, hypothermia, joint contractures), selected laboratory markers (creatinine, ALT, AST, creatine kinase, potassium, and myoglobin), presence of peripheral pulses, urine output, ultrasound evaluation of muscle tissue (including elastography), thermography, radiographic studies, and computed tomography in cases of combined injuries. Intraoperative assessment of muscle viability was performed during diagnostic dermatofasciotomy [3, 12, 13]. As a specialized method for evaluating the microcirculatory bed of the affected limb segment, laser Doppler flowmetry was employed. All investigations were conducted using modern, metrologically validated equipment.

Results of the study. Based on aggregated statistical data from the Military Medical Clinical Center of the Northern Region, there has been a progressive increase in the proportion of amputations attributable to tourniquet syndrome and compartment syndrome, rising from 9 % to 32 % over the most recent year of observation. Notably, in 20 % of cases of tourniquet syndrome resulting in limb amputation, the initial application of the hemorrhage-control tourniquet was not clinically indicated.

In cases of tourniquet syndrome and compartment syndrome, the incidence of rhabdomyolysis-associated acute kidney injury in the setting of IRS ranged from 35 % to 50 % [2,4,11].

In our cohort, the DCT strategy was employed in 31 cases involving patients with physiologic instability and nonviable extremities, accounting for 5.7 % of all recorded instances of hemorrhage-control tourniquet use.



Fig. 1. Patient K., 36 years old, in the shock resuscitation unit on post-injury day 2 following a blast injury (prolonged tactical evacuation delay). Hemorrhage-control tourniquets are present on the extremities at the time of admission.

A representative example of the DACOTa strategy in a physiologically unstable patient with nonviable extremities and previously applied tourniquets is illustrated in Fig. 1.

Selected characteristics of hemorrhage-control tourniquets and DCT, including their localization and duration of application in the setting of tourniquet syndrome among 31 physiologically unstable patients, are presented in Table 1.

In the vast majority of cases, tourniquets were applied to the lower extremities – 21 cases (68 %). In hemorrhage-control mode, the mean duration of application was 13 ± 2.8 hours, while in the DACOTa mode it was 12.6 ± 3.4 hours (range: 6-24 hours).

Table 1

Localization and duration of hemorrhage-control tourniquets and damage control tourniquets in patients with a physiologically unstable profile (n=31)

Ri*	Localization	Number of cases		Duration of hemorrhage-control tourniquet, hours	DACOTa, hours
		abs	%		
1	Lower extremity	21	68	13 ± 2.8	12.6 ± 3.4
2	Upper extremity	5	16	16 ± 3.2	8.3 ± 2.1
3	Both lower extremities	3	10	11 ± 3.1	14.5 ± 3.3
4	Upper and lower extremity	1	3	17	8.5
5	Both upper and both lower extremities	1	3	14	24

* Rating index at ranging.

In 5 cases (16 %), hemorrhage-control tourniquets were applied to the upper extremities with a mean duration of 16 ± 3.2 hours; following conversion to DCT mode, the duration decreased to 8.3 ± 2.1 hours (range: 6-24 hours).

Other, less common patterns of tourniquet localization subsequently converted to DACOTa were observed much less frequently, accounting in total for only 16 % of cases.

These findings suggest that the development of physiologic instability – and consequently the need for

DACOTa – is influenced more by the anatomical location of the injury and tourniquet application than by the number of injured limbs or the number of tourniquets used. Specifically, lower extremity involvement appears to play a more significant role. Moreover, DCT application on the lower extremity requires a longer period to achieve physiologic stabilization compared with patients presenting with physiologic instability and tourniquet syndrome of the upper extremities. The tactical and technical aspects of DACOTa application strategies are summarized in Table 2.

Table 2

Variants of damage control tourniquet application strategies

Ri*	Tactical and technological aspects	Total (n=31)	
		abs	%
1	Prolongation and transformation of the hemorrhage-control tourniquet to DCT	23	74
2	Application at administration	5	16
3	Application following hemorrhage-control tourniquet management measures	2	6
4	Additional application of DCT following hemorrhage-control tourniquet management measures	1	3

* Rating index at ranging.

According to our data, the tactical and technical characteristics of DCT application were as follows. In the vast majority of clinical cases, hemorrhage-control tourniquets were converted into DACOTa through prolonged application – 23 cases (74 %). In 5 patients (16 %), DCT was applied to extremities without a previously placed hemorrhage-control tourniquet or after its removal at an earlier stage of care. In 2 patients (6 %), after documented ineffectiveness of hemorrhage-control tourniquet during tourniquet reassessment, corrective measures were undertaken, and the device was subsequently reclassified in the medical record as a DACOTa. In 1 case (3 %), DCT was applied more proximally due to improper initial placement of the hemorrhage-control tourniquet, which was identified during tourniquet reassessment.

Delayed amputations were performed as single-stage procedures in 26 (83.9 %) cases, two-stage procedures in 4 (12.9 %) cases, and a three-stage procedure in 1 (3.2 %) case. In our cohort, single-stage operations predominated, which is typical in scenarios where DCT is applied to a single extremity. In cases involving multiple DCTs, staged surgical interventions on nonviable extremities were performed based on the patient's evolving physiological status.

Overall mortality in the study group was 12 (38.7 %), with nearly all deaths attributable to progression of post-resuscitation syndrome and multiple organ failure.

Discussion. The use of tourniquets has a long and well-established history, primarily associated with the

control of external hemorrhage at the prehospital stage, most often at the point of injury, particularly from extremity vessels [1, 9, 12]. Separately, tourniquet application in the prehospital setting has been discussed as a means of preventing IRS in crush injuries. However, the role and place of tourniquet use at the hospital level remain insufficiently addressed in both specialized and scientific literature.

It is well recognized that secondary shock-induced disturbances lead to multiple organ dysfunction and failure, thereby defining a physiologically unstable patient profile. For this reason, surgical decision-making in such patients is considered separately. These conditions significantly limit the range of feasible surgical interventions, narrowing it to the simplest and least traumatic procedures capable of creating conditions for survival in critically ill patients [15].

The concept of DCS, which emerged in the late 1990s, has become a cornerstone in trauma and military surgery, significantly improving survival in patients with critical injuries. From the perspective of DCS, the use of a tourniquet at the hospital level takes on a fundamentally different role compared to its traditional hemostatic function. Performing an amputation in a patient with a physiologically unstable profile is often a fatal step. What, then, can DCS offer in such situations? A review of the available literature did not provide a clear answer.

Given the critical nature of this clinical scenario, the primary surgical objective becomes the cessation of venous and lymphatic outflow without immediate amputation. From a formal and logical standpoint, this may be achieved through the application or continuation of a tourniquet. However, in this context, the indication is no longer hemostatic. A tourniquet applied to prevent IRS, when amputation is not feasible due to physiologic instability, should be regarded as a temporary bridging procedure within the DCS paradigm. It addresses key challenges in the survival pathway of critically ill patients, enabling stabilization prior to definitive surgical management (i.e., amputation).

Defining such a tourniquet as a distinct clinical entity allows for accurate medical documentation and appropriate stratification and coding of surgical procedures. A precise and information-rich definition ensures clarity in interpretation and consistency in clinical decision-making across different levels of care.

From a tactical and technical standpoint, the DACOTa strategy may be implemented through prolongation of a previously applied CT. In such cases, a tourniquet initially placed for hemorrhage control is, based on clinical justification for preventing IRS, functionally transformed into a DCT. In other instances, signs of IRS may be present in patients admitted without a tourniquet, yet their physiologic instability precludes definitive surgery; under such conditions, a DCT is applied upon hospital admission.

Our prior collaborative work with Euro-Atlantic colleagues on revising tourniquet use protocols achieved only partial success [5]. Notably, current Tactical Combat Casualty Care (TCCC) protocols do

not clearly distinguish between “tourniquet reassessment” and “tourniquet conversion.” Tourniquet reassessment involves a set of measures aimed at evaluating the appropriateness of application, level of placement, effectiveness, and duration. Tourniquet conversion refers to actions taken following reassessment and may include removal (transition to a provisional state), repositioning (distally or proximally), adjustment of pressure, or replacement with a safer yet equally effective method.

If, at the time of reassessment, a hemorrhage-control tourniquet has lost its hemostatic function but there is a risk or presence of IRS, then prolongation, repositioning, or pressure adjustment of the tourniquet constitutes a formal transformation of hemorrhage-control tourniquet into DCT.

Application of a DCT can, in essence, be considered a “functional amputation” of the limb.

The primary objective of DACOTa in physiologically unstable patients with a nonviable extremity is to gain time for preparing the patient for a life-saving amputation. From the moment this strategy is initiated, the date and time of implementation are documented in the inpatient medical record, along with formal reclassification of the procedure. Following stabilization, definitive surgical intervention – amputation proximal to the tourniquet – is performed.

To simplify medical documentation and standardize the description of such clinical scenarios, we propose the use of the acronym DACOTa (Damage Control Tourniquet).

Within the framework of damage control surgery, the DACOTa strategy emphasizes that tourniquet use is a deliberate component of stabilization rather than a treatment error. Explicit documentation of DACOTa in the medical record eliminates ambiguity regarding potential “misuse.” This approach should be viewed exclusively as a bridging procedure to definitive surgery, involving the intentional maintenance or application of a tourniquet to a nonviable extremity.

The increasing incidence of tourniquet syndrome in modern combat trauma reflects both objective and subjective factors. Objective factors include the extreme challenges of tactical evacuation, often resulting in significant delays. However, our observations suggest that subjective factors also play a critical role. Even in the presence of prolonged evacuation delays, appropriate tourniquet reassessment and timely conversion could have prevented limb loss and the development of IRS in up to three-quarters of cases.

A concerning combination of passive oversight by medical authorities and overactive influence of non-expert opinion leaders continues to promote the indiscriminate application of tourniquets based on the principle of “as high and as tight as possible.” At the same time, we have observed cases of spontaneous, “intuitive” tourniquet conversion performed by patients themselves – often against the instructions of certified combat medics – which in some instances preserved both limb and life.

The current “epidemic” of tourniquet syndrome represents a systemic failure driven by insufficient expert oversight of tactical medicine training programs, inadequate professional standards among instructors, and outdated, dogmatic approaches that do not reflect the realities of modern warfare.

In our observations, we documented a case of tourniquet application maintained for 56 days in a patient who had no indication for its use. Predictably, patient developed irreversible ischemia and mummification of the right foot and lower leg as a

result of improper tourniquet reassessment and management.

The authors sincerely hope that this article will serve as a small but meaningful contribution of clinical common sense to the tactical use of tourniquets across diverse clinical scenarios – one that may gradually erode rigid protocol-driven dogma, and help ensure that tourniquets cease to be instruments of disability and instead fulfill their true purpose as life-saving tools in critical situations.

Conclusion

Hemorrhage-control tourniquets and DACOTa represent distinct clinical entities that describe technically similar but functionally different surgical interventions in combat-related extremity trauma.

The introduction of the DACOTa concept is driven by the need to differentiate tourniquet use according to its functional purpose, enabling accurate stratification and coding of surgical procedures in medical documentation and trauma registries.

In patients with a physiologically unstable profile and nonviable extremities, DACOTa serves as an effective bridging surgical strategy within the framework of damage control surgery at any level of care, allowing for life-saving stabilization and the relatively safe delayed amputation of nonviable limbs.

The application of DACOTa is associated with survival rates of up to 60 % in patients who would otherwise be considered clinically non-survivable.

Prospects for further research include further evaluation of DACOTa in the management of severe extremity trauma, with particular emphasis on its potential role in reducing ischemia–reperfusion injury and improving clinical outcomes.

References

1. Akrivos VS, Koutalos A, Stefanou N, Koskinitis A, Arnaoutoglou C. Crush injury and crush syndrome: a comprehensive review. *EFORT Open Rev.* 2025 Jun 2;10(6):424-430. doi: 10.1530/EOR-2025-0055.
2. Bedri H, Ayoub H, Engelbart JM, Lilienthal M, Galet C, Skeete DA. Tourniquet Application for Bleeding Control in a Rural Trauma System: Outcomes and Implications for Prehospital Providers. *Prehospital Emergency Care*, 2022;26(2):246–254. DOI: 10.1080/10903127.2020.1868635
3. Butler F, Holcomb JB, Dorlac W, Gurney J, Inaba K, Jacobs L et al. Who needs a tourniquet? And who does not? Lessons learned from a review of tourniquet use in the Russo-Ukrainian war. *J Trauma Acute Care Surg.* 2024 Aug 1 ;97(2S Suppl 1):S45-S54. Epub 2024 Jul 12. DOI: 10.1097/TA.0000000000004395
4. Guryev SO, Kushnir VA, Solovyov OS, Panasenکو SI. Substantiation of indications for limb amputation in civilian victims with multisystem injuries as a result of modern warfare. *Ukrainian Journal of Clinical Surgery.* 2025 Jan-Feb;92(1):49-54. DOI: 10.26779/2786-832X.2025.1.49.
5. Hoey BA, Schwab CW. Damage control surgery. *Scand J Surg.* 2002;91(1):92-103. DOI: 10.1177/145749690209100115.
6. Johansson L, Wild H, O'Marr J, Nacanabo YA, Zeba ZA, Sanou Y et al. Assessing Evidence Bias for Prehospital Tourniquet Use: A Scoping Review. *World J Surg.* 2025;49:1471-1483. DOI: 10.1002/wjs.12596
7. Katzir A, Krispel J, Acker A, Jammal M, Mosheiff R, Liebergall M et al. Outcomes of Prolonged Tourniquet Application on the Battlefield: Is a Liberal Application Policy Always Justifiable?. *Journal of Orthopaedic Trauma.* 2026;40(1):44–50. DOI: 10.1097/BOT.0000000000003089
8. Li W, Liao Y, Chen J, Kang W, Wang X, Zhai X et al. Ischemia - Reperfusion injury: A roadmap to precision therapies. *Mol Aspects Med.* 2025 Aug;104:101382. DOI: 10.1016/j.mam.2025.101382
9. Masry MG, Gnyawali SC, Sen CK. Robust critical limb ischemia porcine model involving skeletal muscle necrosis. *Sci Rep* 13, 11574 (2023). DOI: 10.1038/s41598-023-37724-7
10. Medby C, Ricks J, Ingram B, Forestier C, Parkhouse D, Gurney I et al. Removal of tourniquets: the next step in saving lives and limbs. *BMJ Mil Health.* 2025;171:288-289. DOI: 10.1136/military-2024-002785.
11. Miyauchi H, Okubo K, Iida K, Kawakami H, Takayama K, Hayashi Y et al. Multiple site inflammation and acute kidney injury in crush syndrome. *Front. Pharmacol.* 2024;15:1458997. DOI: 10.3389/fphar.2024.1458997
12. Nola IA, Dvorski M, Žižak M, Kuliš T. Crush syndrome in earthquakes - stay and play or load and go?. *Acta Clin Croat.* 2023;62(Suppl2):158-165. DOI: 10.20471/acc.2023.62.s2.24
13. Stewart JJ, Faulk TI, Sosnov JA, Clemens MS, Elterman J, Ross JD et al. Rhabdomyolysis among critically ill combat casualties: Associations with acute kidney injury and mortality. *J Trauma Acute Care Surg.* 2016;80(3):492-498. DOI: 10.1097/TA.0000000000000933.
14. Wolf JM, Mathieu L, Tintle S, Wilson K, Luria S, Vandentorren S et al. A global perspective on gun violence injuries. *Injury.* 2023;54(7): 110763. DOI: 10.1016/j.injury.2023.04.050.
15. Xacur-Trabulce A, Casas-Fuentes G, Ruiz-Vasconcelos V, Reitz MM, Henry SM, Scalea TM et al. Tourniquet-related complications in extremity injuries: a scoping review of the literature. *World J Emerg Surg.* 2025;20:57. DOI: 10.1186/s13017-025-00625-3.

Conflict of interest. The authors have no conflicts of interest to declare.

ORCID: Khoroshun E.M. <https://orcid.org/0000-0003-1258-1319>, Panasenکو S.I. <https://orcid.org/0000-0003-2952-1670>, Negoduiko V.V. <https://orcid.org/0000-0003-4540-5207>, Shypilov S.A. <https://orcid.org/0000-0002-1689-2213>, Klapchuk Y.V. <https://orcid.org/0000-0003-1903-959X>, Kupriyanchuk V.V. <https://orcid.org/0009-0003-7478-4813>, Kerbakh N.R. <https://orcid.org/0000-0002-7722-9896>.

Article received: 25.07.2025