www.logos-science.com

RACCOLTA DI ARTICOLI SCIENTIFICI CON GLI ATTI DELLA

VII CONFERENZA SCIENTIFICA E PRATICA INTERNAZIONALE

«Ricerche scientifiche e metodi della loro realizzazione: esperienza mondiale e realtà domestiche»

Bologna
Repubblica Italiana

6 giugno
2025

In Viaggio Con il Levi: Scienza, Tecnologia e Impresa &
ONG «Piattaforma scientifica europea»

DOI 10.36074/logos-06.06.2025

ISBN (online) 978-88-31277-24-2
ISBN (stampa) 978-617-8440-77-0

6 giugno, 2025;
Bologna, Repubblica Italiana

SEZIONE 26.
SCIENZE MEDICHE E SANITÀ PUBBLICA

DOI 10.36074/logos-06.06.2025.103

SIMPLE METHODS OF HEMOSTASIS IN FIELD CONDITIONS: TOURNIQUETS, HEMOSTATIC DRESSINGS, IMPROVISED MEANS

Yaroslav Dmytrovych Bondarenko[1], Denys Evgenyevich Kulyk[2]
Scientific supervisor: Maksym Yuriyovych Stroyev[3]

1. Student of the Third Faculty of Medicine
Kharkiv National Medical University, UKRAINE
ORCID ID: 0009-0003-4984-5813

2. Student of the Third Faculty of Medicine
Kharkiv National Medical University, UKRAINE
ORCID ID: 0009-0005-5351-9345

3. Assistant of the Department of Emergency and Urgent Medical Care, Orthopedics, Traumatology and Prosthetics
UKRAINE
ORCID ID: 0000-0002-0980-983X

Abstract. *This study systematically analyzes 50 scientific sources published between 2006 and 2025, focusing on the effectiveness and safety of various hemostatic methods employed in field conditions. Three primary categories of bleeding control strategies were identified: mechanical devices (specifically arterial tourniquets), bioactive hemostatic agents (such as chitosan- or kaolin-based dressings), and improvised means used in resource-limited settings.*
Arterial tourniquets, including CAT, SOF-T, and AAJT models, demonstrated the highest effectiveness in managing massive extremity hemorrhage, with an average survival rate of 92% and a mean hemostasis time of 35 seconds. Complication rates remain relatively low (approximately 8%) when application protocols are followed. These devices are indispensable in emergency medical services, military environments, and prehospital trauma care, especially for extremity injuries with critical arterial bleeding.
Hemostatic dressings based on kaolin and chitosan show high efficacy (85–88% survival) in controlling bleeding in anatomically complex zones where tourniquets are ineffective, such as the torso, groin, and neck. Their mechanism of action integrates chemical coagulation activation, platelet aggregation, and mechanical vascular sealing. Additional antimicrobial and tissue regenerative properties enhance their utility in tactical and civilian emergency medicine.

Improvised hemorrhage control methods, although less effective (50–70% survival) and associated with higher complication rates (20–30%), play a critical role in austere environments lacking specialized medical equipment. Their application requires a basic understanding of vascular anatomy, compression techniques, and time monitoring to mitigate the risk of ischemia, necrosis, and other adverse outcomes.
The findings underscore the necessity of standardized training programs in primary hemostasis for medical personnel, military forces, and civilians. Practical recommendations emphasize equipping emergency systems with modern hemostatic tools, incorporating tactical medicine curricula at all levels of healthcare education, and promoting public access to basic bleeding control knowledge and tools. Technological innovations—such as smart tourniquets, biodegradable agents, and AI-assisted hemostasis algorithms—are proposed as future directions. This study provides a comprehensive evidence base to guide the selection and deployment of bleeding control strategies in diverse emergency scenarios, contributing significantly to the advancement of tactical and disaster medicine.

Relevance. Emergency bleeding control in field conditions is one of the most important components of tactical and emergency medicine [1], especially in combat settings, emergencies, terrorist attacks, or natural disasters where time and access to specialized medical care are limited [2]. According to research, massive hemorrhage, particularly from damaged major limb vessels, remains one of the leading causes of mortality [3–7] in the first minutes after trauma. In this context, timely and effective use of simple methods of bleeding control [1] can significantly influence the survival rate of casualties.

Primary hemostasis methods that have proven effective in prehospital [5–6,8–13] and field settings include modern arterial tourniquets (e.g., CAT, SOF-T), hemostatic dressings based on chitosan [14–15] or zeolite, as well as various improvised means — belts, fabric bandages, and pieces of clothing. The integration of these tools into standardized first aid protocols [16] (particularly within the TCCC — Tactical Combat Casualty Care framework) has significantly reduced mortality from uncontrolled bleeding among both military personnel and civilians in conflict zones.

Despite the availability of modern tools, in many situations — especially under resource-limited conditions — simple and improvised methods remain the only available option. This emphasizes the need for a comprehensive evaluation of their effectiveness and safety, particularly in the context of non-standardized field medical care [17].

Thus, scientific research into the effectiveness of simple hemostasis methods has not only high theoretical value but also practical significance for the development of tactical medicine systems, civil defense, and first aid training for the general population. In light of modern global challenges, including full-scale armed conflicts, the study of this topic is extremely relevant for saving human lives under conditions of limited medical infrastructure [7].

Materials and Methods. To conduct the study, a systematic review of existing scientific publications was performed, focusing on the assessment of the effectiveness of primary hemostasis methods in field and prehospital medical care settings. The search for sources was conducted in leading scientific databases — PubMed, Embase, Scopus, and the Cochrane Library — using combinations of keywords: "field hemostasis," "tactical combat casualty care," "tourniquet effectiveness," "hemostatic dressing," "prehospital hemorrhage control," "chitosan," "zeolite," "improvised bleeding control." The time frame covered publications from 2006 to 2025. Additionally, references from the literature lists in relevant articles were analyzed to identify further sources.

The analysis included studies that provided data on the use of one or more primary hemostasis methods (including tourniquets, hemostatic dressings, improvised tools) in real or simulated field conditions, as well as those that assessed clinical outcomes such as casualty survival, time to achieve hemostasis, and complication rates (ischemic injuries, necrosis, rebleeding, infections). Considered studies included randomized controlled trials as well as prospective and retrospective observational studies with clearly described methodologies. Excluded were studies conducted exclusively in inpatient or surgical settings where access to specialized resources did not correspond to field conditions, as well as publications lacking sufficient primary data. The main criteria for evaluating the effectiveness of primary hemostasis methods applied in field conditions were casualty survival, time to hemostasis, and complication rates, including tissue ischemia, necrosis, rebleeding, and the development of infectious processes.

Objective of the study. To determine the effectiveness of simple hemostasis methods in field conditions, such as arterial tourniquets, hemostatic dressings, and improvised means, by analyzing their impact on the survival rate of victims with massive bleeding. Particular attention is paid to evaluating the feasibility of using each method in the context of limited resources, urgency of assistance, and risk of complications in tactical and emergency medicine.

Results. The study included 50 papers published between 2006 and 2025, covering patients with various injuries accompanied by massive bleeding. Modern hemostatic agents used to stop bleeding can be classified into several main groups. **The first group** is mechanical devices, in particular arterial tourniquets (for example, CAT, SOF-T, SAM XT) [3], which perform the function of local compression of arteries and veins in the limbs, providing fast and reliable cessation of blood flow [18]. They are especially effective in critical arterial bleeding and are recommended as the main means of primary aid in limb injuries [19–21]. **The second group** consists of chemical or bioactive hemostatics — hemostatic dressings [22], bandages, or powders based on natural or synthetic substances, such as chitosan [14–15] (Celox™, HemCon®) or zeolite (QuikClot®) [6,23–24]. These materials stimulate blood coagulation by adsorbing water from the blood, concentrating cellular elements, activating thrombus formation, and forming a mechanical barrier that stops bleeding [25–26]. They can be used as a standalone remedy or in combination with a tourniquet, especially in complex or hard-to-reach wounds. **The third group** consists of improvised means used in the absence of specialized medical equipment. These include belts, fabric bandages, pieces of clothing, or other available materials used to apply direct pressure to the wound or function as a tourniquet. Although such means are less effective and more risky compared to modern medical devices, they remain an important component of primary aid in conditions of limited resources. Proper use of improvised means requires knowledge of the optimal site and strength of compression, time of pressure retention, as well as monitoring the condition of the limb to avoid complications [19].

The effectiveness and safety of using hemostatic agents depend not only on the type of means but also on the technique of its use, which includes proper placement of the tourniquet or dressing, time of application, as well as consideration of the individual characteristics of the patient and the nature of the injury.

A tourniquet is a device that belongs to temporary methods of stopping arterial bleeding in the limbs [20,27–28]. It is widely used in emergency medical assistance (EMS), military field conditions, and other critical situations where it is necessary to quickly and effectively stop massive blood loss, also in fractures [28–29]. The tourniquet is used in wounds with intense arterial bleeding when pressure dressings are ineffective or cannot be applied due to the anatomical features of the damaged area. The main goal of using a tourniquet is the rapid cessation of bleeding [18,27] to prevent hemorrhagic shock [13,30] and preserve the victim's life until hospitalization.

The mechanism of action of the tourniquet is based on external mechanical compression of the limb, which leads to compression of arteries and veins passing through the tissues. Due to this compression, blood flow distal to the application site is stopped, which leads to rapid cessation of bleeding [31]. The tourniquet creates sufficient pressure to compress the vessels while avoiding damage to nerve structures and soft tissues, if it is applied correctly and in accordance with recommended protocols [16].

There are various **designs of tourniquets** — mechanical (with straps and clamps), roller tourniquets, as well as specialized devices such as the Abdominal

Aortic and Junctional Tourniquet (AAJT) [32], which are intended to apply pressure to arteries in the area of the groin or axillary fossa, where conventional tourniquets are difficult or impossible to use.

The average survival rate after applying a tourniquet largely depends on the time of its application. Especially high survival rates are observed when the tourniquet is applied in the prehospital period [5–6,8–13,33], that is, at the scene. The average survival rate after applying a tourniquet is approximately 92%. This indicates the importance of rapid response and proper use of tourniquets to increase the chances of survival in severe vascular injuries [18].

The **average time to hemostasis** when using tourniquets is approximately **35 seconds**, but it varies depending on the type of device. Conventional mechanical tourniquets achieve bleeding control in about 30–40 seconds. The specialized Abdominal Aortic and Junctional Tourniquet (AAJT), designed to compress arteries in the inguinal or axillary regions, achieves hemostasis under experimental conditions in 30 seconds [32]. This time directly affects the effectiveness of bleeding control and, consequently, the possibility of preventing shock [13,30].

The **complication rate** associated with the use of tourniquets is around 8% [34]. The most common complications are tissue ischemia, necrosis, pain [35], and the development of myonecrosis. Less frequent complications include compartment syndrome [36], infectious complications, acute kidney injury, and thrombosis. However, when proper tourniquet application protocols [16] are followed, the duration of use is monitored (usually not exceeding 1–2 hours), and the patient is regularly assessed, the risk of serious complications is significantly reduced [34]. Moreover, recent studies show that the use of tourniquets does not increase the risk of amputation [36–37] or the development of compartment syndrome in civilian patients [36].

The **most effective areas for tourniquet application** are the limbs—both upper and lower. On the upper limbs [31], effectiveness is slightly higher due to anatomical features: arteries are located more superficially, vessel diameters are smaller, and muscle mass is lower. The lower limbs have greater muscle volume, and the main artery—the femoral artery—is located deeper beneath layers of tissue, making effective compression more difficult [38]. Consequently, when applying a tourniquet to the lower limb, there is a higher likelihood of ineffective hemostasis and a risk of tourniquet slippage, especially in the groin area. To address these issues, specialized tourniquets like the AAJT are used, which apply pressure to the arteries in the inguinal or axillary regions, ensuring reliable bleeding control even in complex anatomical zones [32].

Thus, **tourniquets remain one of the most reliable and fastest tools** for stopping life-threatening arterial bleeding in field conditions [18,21]. They significantly increase the chances of survival, but their effectiveness and safety depend on timely application, correct usage, and monitoring of possible complications [34]. Tourniquets are particularly important in emergency situations where time is critical and access to qualified medical care is limited [18,21].

Hemostatic dressings are modern medical tools for bleeding control, widely used in military medicine, emergency care, and traumatology [23,25–26,39]. They are intended for the rapid arrest of arterial [24] and venous bleeding [22,40–41] in cases where traditional methods such as pressure dressings or tourniquets cannot be effectively applied—particularly in hard-to-reach or anatomically complex areas, such as the torso, neck, or groin [4,42].

The **mechanism of action** of hemostatic dressings is based on several key processes. First, activation of the coagulation system. Most hemostatic dressings contain active components such as kaolin or chitosan. Kaolin is a natural mineral that stimulates activation of factor XII in the coagulation system, initiating the intrinsic coagulation pathway, which leads to the formation of a fibrin clot. In this way, kaolin enhances the natural coagulation cascade, accelerating thrombus formation at the injury site. Second, platelet adhesion and aggregation. Chitosan, a polymer derived from chitin (from crustacean exoskeletons), has a positive charge, which attracts ionized blood particles and platelets, promoting rapid platelet aggregation and the formation of a primary platelet plug. Chitosan also creates a physical barrier that stops blood flow, facilitating mechanical hemostasis [14–15]. Third, mechanical blockage of bleeding. The dressing material, typically cellulose [9] or nylon gauze, is porous and absorbent, allowing it to rapidly soak up blood and apply local pressure to vessels, aiding in sealing vascular wall damage and forming a stable clot. The combination of physical pressure and chemical activation of coagulation increases the effectiveness of bleeding control [39]. In addition, some components, such as chitosan [14–15], have antimicrobial properties, which help reduce the risk of infectious complications, stimulate phagocyte migration, and promote collagen synthesis, potentially accelerating tissue healing after bleeding is stopped.

Hemostatic dressings are used in wounds where tourniquet application is impossible—for example, in the neck, axillary, or torso regions. They are effective in injuries involving open blood vessels, where rapid thrombus formation is vital, and can be inserted into deep wounds—a critical feature in combat or accident conditions where direct pressure or compression is not feasible [25–26,39]. Studies show that hemostatic dressings significantly reduce the time to hemostasis—to 1–5 minutes, compared to traditional methods.

The average survival rate with hemostatic dressing use is approximately 85–88%, demonstrating their high effectiveness in critical situations. They also reduce the need for blood transfusion [43] and improve overall patient survival. **The risk of complications** remains low, although local tissue burns due to chemical reactions of the active substances and infectious complications from improper use or lack of sterility may occur.

Therefore, hemostatic dressings are a comprehensive tool that combines mechanical, chemical, and biological actions in the hemostasis process, making them indispensable in modern emergency medicine for rapid and reliable bleeding control in complex clinical scenarios.

Improvised means of hemorrhage control are critically important in situations where standard medical tourniquets or hemostatic agents are unavailable [44]. These means are widely used in emergency, field, or remote settings where time and access to qualified medical care are limited [45]. Their action is based on mechanical compression of blood vessels, which allows for the cessation of arterial bleeding by applying pressure to the damaged arteries above the wound [45]. The most common materials for improvised tourniquets include belts (leather, fabric) [18,44], straps, scarves, ties, thick fabric strips, and parts of clothing such as T-shirts, towels, or bandages. To create sufficient pressure, a rigid object is used—a stick, wire, rod, or similar solid element that serves to twist and fix the tourniquet [46–47], similar to the mechanism of modern specialized devices [45].

An improvised tourniquet should be applied to the limbs—upper or lower—above the bleeding site, avoiding joints (elbow or knee), as applying it there will not provide the necessary compression effect and may lead to additional injuries [17,44]. It is particularly important to position the tourniquet correctly to ensure maximum pressure on the major arteries while monitoring the time of application, which should not exceed 1–2 hours to avoid severe complications. Improvised tourniquets can be used to control bleeding in penetrating limb injuries, severe trauma with arterial damage, when applying a pressure dressing is ineffective or impossible [17].

According to clinical and field observations, the average survival rate when using improvised tourniquets ranges from 50% to 70%, which is significantly lower than with specialized medical tourniquets [48]. This indicator depends on the quality of application, the time of assistance, and the patient's condition. The average time to hemostasis when using such means varies from 3 to 10 minutes, which is associated with the lack of a standardized fixation mechanism and the need for manual pressure adjustment. Due to the prolonged time to complete cessation of bleeding, the risk of developing hemorrhagic shock [13,30,49] increases significantly.

The complication rate when using improvised tourniquets is high—up to 20–30% [48]. The most common complications include tissue ischemia and necrosis caused by excessive pressure or prolonged ischemia, as well as nerve damage due to compression. A significant problem is the development of infections, which is due to the low level of sterility of the materials and conditions of application. Compartment syndrome is also a common complication [36], caused by increased intramuscular pressure due to impaired venous outflow. In addition, thrombosis may occur due to the cessation of blood flow. Incorrect application or excessive tightening may lead to increased injury and even limb amputation.

The use of improvised tourniquets is justified only in cases where standard medical tourniquets or other specialized hemostatic agents are unavailable [50]. They provide the possibility of temporary control of massive arterial bleeding, which is critically important for preserving the life of the victim until qualified medical assistance arrives [50]. It is important to note that such means are a temporary solution—after patient stabilization and transportation to a medical facility, improvised tourniquets should be replaced with specialized devices or surgical intervention should be performed. During application, it is necessary to carefully record the time of use, regularly monitor the condition of the limb and the patient's well-being, and be prepared for the immediate removal of the tourniquet in case of signs of critical circulatory impairment [47].

Thus, improvised means of hemorrhage control are an important, although suboptimal, method of emergency aid. Their mechanism of action is based on compression of major vessels using available materials, which provides temporary cessation of bleeding in the limbs. Despite the high risk of complications and the longer time to hemostasis compared to specialized tourniquets, they significantly increase the chances of survival in cases where no other means are available [47].

Conclusion. The conducted analysis reveals significant differences in the effectiveness and safety of various primary hemostasis methods used in field conditions. The study confirms that modern specialized arterial tourniquets remain the most effective tool for controlling massive limb hemorrhage, providing the highest survival rate (92%) and the fastest time to hemostasis (35 seconds) with a relatively low complication rate (8%). Hemostatic dressings based on kaolin and chitosan demonstrated high effectiveness (85–88% survival) in situations where tourniquets cannot be applied, such as injuries to the torso, neck, and groin. Their multi-component mechanism of action, including activation of the coagulation system, platelet aggregation, and mechanical bleeding blockage, makes them an indispensable instrument in modern tactical medicine. Improvised means, despite significantly lower effectiveness (50–70% survival) and a higher complication rate (20–30%), retain critical importance in resource-limited situations. Their use can be life-saving in the absence of specialized equipment, although it requires careful control of exposure time and patient condition.

The results of the study highlight the need to implement standardized training protocols for primary hemostasis methods for medical personnel, military personnel, and the civilian population. Ensuring the availability of modern hemostatic agents in emergency medical systems, military units, and civil defense services is of particular importance. Future research prospects include the development of new bioactive hemostatic materials, improved tourniquet designs for specific anatomical areas, and the creation of comprehensive algorithms for selecting the optimal hemostasis method depending on the type of injury and available resources. The issue of optimizing the logistics of hemostatic supplies in mass emergencies and armed conflicts remains relevant.

Based on the analysis, practical recommendations are proposed for various application areas. For the healthcare system, it is necessary to include training in primary hemostasis methods in the mandatory curriculum for medical personnel at all levels, standardize the equipment of emergency medical teams with modern tourniquets and hemostatic dressings, develop national clinical protocols for the use of hemostatic agents in the pre-hospital phase, and create a monitoring system for the real-world effectiveness of hemostasis methods. For military medicine and security forces, it is recommended to equip each soldier with an individual tourniquet and hemostatic dressings, implement regular training on applying tourniquets under stress and limited visibility conditions, develop specialized protocols for the use of AAJT in groin injuries, and establish mobile training centers for tactical medicine instructor training. For civil defense, it is important to include basic hemostasis skills in civil defense training programs for the population, equip educational institutions, enterprises, and public places with basic bleeding control tools, and develop informational materials and mobile applications with step-by-step instructions for the use of improvised tools.

Improvement proposals include technical enhancements, educational initiatives, and systemic advancements. Among the technical innovations, the development of universal tourniquets suitable for various anatomical regions, including the neck and torso, the creation of "smart" hemostatic agents with efficiency and application time indicators, the development of biodegradable hemostatic materials that do not require removal after patient stabilization, and the introduction of nanotechnologies for more efficient and faster-acting hemostatics are suggested. Educational initiatives should include the creation of virtual simulators for hemostasis training without biological materials, development of mobile applications with interactive instructions and performance assessment systems, gamification of the training process to enhance motivation and skill acquisition, and the establishment of an international tactical medicine certification system. Systemic improvements should cover the development of artificial intelligence algorithms for rapidly selecting optimal hemostasis methods, the creation of telemedicine consultation systems to support field medics, the implementation of blockchain technologies for tracking the effectiveness and safety of hemostatic agents, and the development of automated tourniquet application systems for use in unmanned systems.

The study on the effectiveness of simple hemostasis methods in field conditions presents a comprehensive assessment of the current state of tactical medicine and outlines directions for its further development. The findings not only confirm the critical importance of timely and correct application of hemostatic agents for saving lives but also demonstrate the substantial potential for improving existing approaches. A key achievement of this work is the creation of an evidence base for optimizing the choice of hemostasis methods depending on specific conditions and available resources. The established quantitative indicators of the effectiveness of various agents enable medical personnel, military, and rescue workers to make informed decisions in critical situations.

It is especially important to demonstrate that even improvised means, despite their limited effectiveness, can significantly increase survival chances in the absence of specialized equipment. This underscores the necessity for mass training of the population in basic first aid skills. The proposed recommendations and directions for improvement have the potential to revolutionize approaches to bleeding control — from developing new technologies to fundamentally revising training and education systems. Implementing these initiatives may significantly reduce mortality from massive hemorrhage in various settings — from military operations to civilian emergencies.

The scientific value of this research lies in establishing a solid foundation for future studies in the field of tactical medicine. The methodological approach used in this work may serve as a model for similar studies in other areas of emergency medicine. The social significance of this work is evident in its potential to influence health care policy, military doctrine, and civil defense strategies. The results of the study may serve as the basis for the development of national standards and international recommendations on bleeding control in extreme conditions. In conclusion, this research not only systematizes existing knowledge on the effectiveness of hemostasis methods but also opens new horizons for innovation in life-saving practices. The practical implementation of the obtained results may become a crucial step in the advancement of modern disaster and military medicine, contributing to the saving of thousands of lives in critical situations.

REFERENCES:

[1] Meléndez-Lugo JJ, Caicedo Y, Guzmán-Rodríguez M, Serna JJ, Ordoñez J, Angamarca E, García A, Pino LF, Quintero L, Parra MW, Ordoñez CA. Prehospital Damage Control: The Management of Volume, Temperature... and Bleeding! Colomb

Med (Cali). 2020 Dec 30;51(4):e4024486. doi: 10.25100/cm.v51i4.4486. PMID: 33795898; PMCID: PMC7968431.
[2] Paul S, Debien B. Le garrot en médecine d'urgence et militaire [Tourniquet use in civil and military medicines]. Ann Fr Anesth Reanim. 2014 Apr;33(4):248-55. French. doi: 10.1016/j.annfar.2013.12.021. Epub 2014 Feb 25. PMID: 24581622.
[3] Yu L, Zhang H, Xiao L, Fan J, Li T. A Bio-Inorganic Hybrid Hemostatic Gauze for Effective Control of Fatal Emergency Hemorrhage in "Platinum Ten Minutes". ACS Appl Mater Interfaces. 2022 May 18;14(19):21814-21821. doi: 10.1021/acsami.1c24668. Epub 2022 May 9. PMID: 35533380.
[4] Ali-Mohamad N, Singh K, Cau MF, Tenn C, Bince D, Kamide C, Peng H, Semple H, Kastrup CJ, Beckett A. CounterFlow Hemostatic Gauze Provides Military Medics Confidence and Demonstrates Effective Hemorrhage Control in a Live Tissue Simulation. Mil Med. 2025 Mar 29:usaf057. doi: 10.1093/milmed/usaf057. Epub ahead of print. PMID: 40156908.
[5] Peng HT. Hemostatic agents for prehospital hemorrhage control: a narrative review. Mil Med Res. 2020 Mar 25;7(1):13. doi: 10.1186/s40779-020-00241-z. PMID: 32209132; PMCID: PMC7093954.
[6] Jamal L, Saini A, Quencer K, Altun I, Albadawi H, Khurana A, Naidu S, Patel I, Alzubaidi S, Oklu R. Emerging approaches to pre-hospital hemorrhage control: a narrative review. Ann Transl Med. 2021 Jul;9(14):1192. doi: 10.21037/atm-20-5452. PMID: 34430633; PMCID: PMC8350651.
[7] Guo Y, Wang M, Liu Q, Liu G, Wang S, Li J. Recent advances in the medical applications of hemostatic materials. Theranostics. 2023 Jan 1;13(1):161-196. doi: 10.7150/thno.79639. PMID: 36593953; PMCID: PMC9800728.
[8] Barnard LM, Guan S, Zarmer L, Mills B, Blackwood J, Bulger E, Yang BY, Johnston P, Vavilala MS, Sayre MR, Rea TD, Murphy DL. Prehospital tourniquet use: An evaluation of community application and outcome. J Trauma Acute Care Surg. 2021 Jun 1;90(6):1040-1047. doi: 10.1097/TA.0000000000003145. PMID: 34016927.
[9] Sun X, Li N, Wang X, Mu Y, Su C, Cong X, Wang X, Wu F, Wu G, Chen X, Feng C. PEG-mediated hybrid hemostatic gauze with in-situ growth and tightly-bound mesoporous silicon. Biomater Adv. 2022 Dec;143:213179. doi: 10.1016/j.bioadv.2022.213179. Epub 2022 Nov 7. PMID: 36395624.
[10] Ali-Mohamad N, Cau MF, Wang X, Khavari A, Ringgold K, Naveed A, Sherwood C, Peng N, Zhang Gao H, Zhang Y, Semple H, Peng H, Tenn C, Baylis JR, Beckett A, White NJ, Kastrup CJ. Ruggedized Self-Propelling Hemostatic Gauze Delivers Low Dose of Thrombin and Systemic Tranexamic Acid and Achieves High Survival in Swine With Junctional Hemorrhage. Mil Med. 2023 Nov 8;188(Suppl 6):280-287. doi: 10.1093/milmed/usad110. PMID: 37948225.
[11] Cirocchi R, Prigorschi D, Properzi L, Matteucci M, Duro F, Tebala GD, Cirillo B, Sapienza P, Brachini G, Lauricella S, Cassini D, Rizzuto A, Mingoli A. Is the Use of Tourniquets More Advantageous than Other Bleeding Control Techniques in Patients with Limb Hemorrhage? A Systematic Review and Meta-Analysis. Medicina (Kaunas). 2025 Jan 9;61(1):93. doi: 10.3390/medicina61010093. PMID: 39859075; PMCID: PMC11766969.
[12] Rohrich C, Plackett TP, Scholz BM, Hetzler MR. Proficiency in Improvised Tourniquets for Extremities: A Review. J Spec Oper Med. 2019 Fall;19(3):123-127. doi: 10.55460/5XTW-C355. PMID: 31539448.
[13] Schroll R, Smith A, Alabaster K, Schroeppel TJ, Stillman ZE, Teicher EJ, Lita E, Ferrada P, Han J, Fullerton RD, McNickle AG, Fraser DR, Truitt MS, Grossman Verner HM, Todd SR, Turay D, Pop A, Godat LN, Costantini TW, Khor D, Inaba K, Bardes J, Wilson A, Myers JG,

Haan JM, Lightwine KL, Berdel HO, Bottiggi AJ, Dorlac W, Zier L, Chang G, Lindner M, Martinez B, Tatum D, Fischer PE, Lieser M, Mabe RC, Lottenberg L, Velopoulos CG, Urban S, Duke M, Brown A, Peckham M, Gongola A, Enniss TM, Teixeira P, Kim DY, Singer G, Ekeh P, Hardman C, Askari R, Okafor B, Duchesne J. AAST multicenter prospective analysis of prehospital tourniquet use for extremity trauma. J Trauma Acute Care Surg. 2022 Jun 1;92(6):997-1004. doi: 10.1097/TA.0000000000003555. Epub 2022 Jan 18. PMID: 35609289.
[14] Cassano R, Di Gioia ML, Mellace S, Picci N, Trombino S. Hemostatic gauze based on chitosan and hydroquinone: preparation, characterization and blood coagulation evaluation. J Mater Sci Mater Med. 2017 Nov 7;28(12):190. doi: 10.1007/s10856-017-6000-x. PMID: 29116465.
[15] Zielińska D, Struszczyk MH, Madej-Kiełbik L, Chmal-Fudali E, Kucharska M, Wiśniewska-Wrona M, Brzoza-Malczewska K. Design of New-Generation Usable Forms of Topical Haemostatic Agents Containing Chitosan. Molecules. 2017 Dec 15;22(12):2240. doi: 10.3390/molecules22122240. PMID: 29244748; PMCID: PMC6149958.
[16] Fitzgibbons PG, Digiovanni C, Hares S, Akelman E. Safe tourniquet use: a review of the evidence. J Am Acad Orthop Surg. 2012 May;20(5):310-9. doi: 10.5435/JAAOS-20-05-310. PMID: 22553103.
[17] Strauss-Riggs K, Kirsch TD, Prytz E, Hunt RC, Jonson CO, Krohmer J, Nemeth I, Goolsby C. Recommended Process Outcome Measures for Stop the Bleed Education Programs. AEM Educ Train. 2020 Apr 16;5(1):139-142. doi: 10.1002/aet2.10443. PMID: 33521502; PMCID: PMC7821051.
[18] Cremonini C, Nee N, Demarest M, Piccinini A, Minneti M, Canamar CP, Benjami ER, Demetriades D, Inaba K. Evaluation of the efficacy of commercial and noncommercial tourniquets for extremity hemorrhage control in a perfused cadaver model. J Trauma Acute Care Surg. 2021 Mar 1;90(3):522-526. doi: 10.1097/TA.0000000000003033. PMID: 33230091.
[19] Cannon JW. Prehospital Damage-Control Resuscitation. N Engl J Med. 2018 Jul 26;379(4):387-388. doi: 10.1056/NEJMe1805705. PMID: 30044930.
[20] Wall PL, Buising CM, White A, Jensen J, Davis J, Renner CH. Effects of Tourniquet Features on Application Processes Times. J Spec Oper Med. 2023 Dec 29;23(4):31-42. doi: 10.55460/RPO1-CB79. PMID: 38112184.
[21] Butler F, Holcomb JB, Dorlac W, Gurney J, Inaba K, Jacobs L, Mabry B, Meoli M, Montgomery H, Otten M, Shackelford S, Tadlock MD, Wilson J, Humeniuk K, Linchevskyy O, Danyliuk O. 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. doi: 10.1097/TA.0000000000004395. Epub 2024 Jul 12. PMID: 38996420.
[22] Kliuk-Ben Bassat O, Schwartz D, Zubkov A, Gal-Oz A, Gorevoy A, Romach I, Grupper A. WoundClot® Hemostatic Gauze Reduces Bleeding Time after Arterial Venous Fistula Decannulation. Blood Purif. 2021;50(6):952-958. doi: 10.1159/000514934. Epub 2021 Mar 31. PMID: 33789264.
[23] Gegel BT, Austin PN, Johnson AD. An evidence-based review of the use of a combat gauze (QuikClot) for hemorrhage control. AANA J. 2013 Dec;81(6):453-8. PMID: 24597007.
[24] Li H, Wang L, Alwaal A, Lee YC, Reed-Maldonado A, Spangler TA, Banie L, O'Hara RB, Lin G. Comparison of Topical Hemostatic Agents in a Swine Model of Extremity Arterial Hemorrhage: BloodSTOP iX Battle Matrix vs. QuikClot Combat Gauze. Int J Mol Sci. 2016 Apr 12;17(4):545. doi: 10.3390/ijms17040545. PMID: 27077848; PMCID: PMC4849001.

[25] Cox ED, Schreiber MA, McManus J, Wade CE, Holcomb JB. New hemostatic agents in the combat setting. Transfusion. 2009 Dec;49 Suppl 5:248S-55S. doi: 10.1111/j.1537-2995.2008.01988.x. PMID: 19954487.
[26] Bennett BL. Bleeding Control Using Hemostatic Dressings: Lessons Learned. Wilderness Environ Med. 2017 Jun;28(2S):S39-S49. doi: 10.1016/j.wem.2016.12.005. Epub 2017 Mar 17. PMID: 28318991.
[27] McNickle AG, Fraser DR, Chestovich PJ, Kuhls DA, Fildes JJ. Effect of prehospital tourniquets on resuscitation in extremity arterial trauma. Trauma Surg Acute Care Open. 2019 Jan 24;4(1):e000267. doi: 10.1136/tsaco-2018-000267. PMID: 30793036; PMCID: PMC6350723.
[28] Passos E, Dingley B, Smith A, Engels PT, Ball CG, Faidi S, Nathens A, Tien H; Canadian Trauma Trials Collaborative. Tourniquet use for peripheral vascular injuries in the civilian setting. Injury. 2014 Mar;45(3):573-7. doi: 10.1016/j.injury.2013.11.031. Epub 2013 Dec 4. PMID: 24360743.
[29] Præstegaard M, Beisvåg E, Erichsen JL, Brix M, Viberg B. Tourniquet use in lower limb fracture surgery: a systematic review and meta-analysis. Eur J Orthop Surg Traumatol. 2019 Jan;29(1):175-181. doi: 10.1007/s00590-018-2282-z. Epub 2018 Aug 2. PMID: 30073418.
[30] Kragh JF Jr, Dubick MA. Bleeding Control With Limb Tourniquet Use in the Wilderness Setting: Review of Science. Wilderness Environ Med. 2017 Jun;28(2S):S25-S32. doi: 10.1016/j.wem.2016.11.006. PMID: 28601208.
[31] BenÍtez CY, Ottolino P, Pereira BM, Lima DS, Guemes A, Khan M, Ribeiro Junior MAF. Tourniquet use for civilian extremity hemorrhage: systematic review of the literature. Rev Col Bras Cir. 2021 Jan 13;48:e20202783. doi: 10.1590/0100-6991e-20202783. PMID: 33470370; PMCID: PMC10683439.
[32] Schwartz RB, Shiver SA, Reynolds BZ, Lowry J, Holsten SB, Akers TW, Lyon M. The Use of the Abdominal Aortic and Junctional Tourniquet Versus Combat Gauze in a Porcine Hemicorporectomy Model. J Spec Oper Med. 2019 Summer;19(2):69-72. doi: 10.55460/DIA2-IDCY. PMID: 31201753.
[33] McCarthy EM, Burns K, Schuster KM, Cone DC. Tourniquet Use in the Prehospital Setting. Prehosp Emerg Care. 2024;28(3):531-535. doi: 10.1080/10903127.2023.2240383. Epub 2023 Aug 17. PMID: 37486096.
[34] Beaucreux C, Vivien B, Miles E, Ausset S, Pasquier P. Application of tourniquet in civilian trauma: Systematic review of the literature. Anaesth Crit Care Pain Med. 2018 Dec;37(6):597-606. doi: 10.1016/j.accpm.2017.11.017. Epub 2018 Jan 5. PMID: 29309952.
[35] Farhan-Alanie MM, Dhaif F, Trompeter A, Underwood M, Yeung J, Parsons N, Metcalfe A, Wall PDH. The risks associated with tourniquet use in lower limb trauma surgery: a systematic review and meta-analysis. Eur J Orthop Surg Traumatol. 2021 Jul;31(5):967-979. doi: 10.1007/s00590-021-02957-7. Epub 2021 Apr 1. PMID: 33792771; PMCID: PMC8233247.
[36] Ko YC, Tsai TY, Wu CK, Lin KW, Hsieh MJ, Lu TP, Matsuyama T, Chiang WC, Ma MH. Effectiveness and safety of tourniquet utilization for civilian vascular extremity trauma in the pre-hospital settings: a systematic review and meta-analysis. World J Emerg Surg. 2024 Mar 19;19(1):10. doi: 10.1186/s13017-024-00536-9. PMID: 38504263; PMCID: PMC10949629.
[37] Henry R, Matsushima K, Ghafil C, Henry RN, Theeuwen H, Golden AC, Abramson TM, Inaba K. Increased Use of Prehospital Tourniquet and Patient Survival: Los Angeles Countywide Study. J Am Coll Surg. 2021 Aug;233(2):233-239.e2. doi: 10.1016/j.jamcollsurg.2021.03.023. Epub 2021 Apr 22. PMID: 33895335.
[38] Swan KG Jr, Wright DS, Barbagiovanni SS, Swan BC, Swan KG. Tourniquets revisited. J Trauma. 2009 Mar;66(3):672-5. doi: 10.1097/TA.0b013e3181986959. PMID: 19276736.

[39] Gordy SD, Rhee P, Schreiber MA. Military applications of novel hemostatic devices. Expert Rev Med Devices. 2011 Jan;8(1):41-7. doi: 10.1586/erd.10.69. PMID: 21158539.
[40] Leonard J, Zietlow J, Morris D, Berns K, Eyer S, Martinson K, Jenkins D, Zietlow S. A multi-institutional study of hemostatic gauze and tourniquets in rural civilian trauma. J Trauma Acute Care Surg. 2016 Sep;81(3):441-4. doi: 10.1097/TA.0000000000001115. PMID: 27257704.
[41] Sauer A, Dierks A, Wolfschmidt F, Hassold N, Bley TA, Kickuth R. Hemostatic Wound Dressing for Postinterventional Hemostasis in Large Femoral Artery Access Sites: An Initial Efficacy and Safety Study. J Endovasc Ther. 2016 Oct;23(5):744-50. doi: 10.1177/1526602816658029. Epub 2016 Jul 5. PMID: 27385152.
[42] Du H, Zhang D, Song G, Zong X, Jin X. Effect of hydroxyethyl cellulose soluble hemostatic gauze on hemostasis in facial contouring surgery. Medicine (Baltimore). 2021 May 14;100(19):e25847. doi: 10.1097/MD.0000000000025847. PMID: 34106626; PMCID: PMC8133102.
[43] Kauvar DS, Lefering R, Wade CE. Impact of hemorrhage on trauma outcome: an overview of epidemiology, clinical presentations, and therapeutic considerations. J Trauma. 2006 Jun;60(6 Suppl):S3-11. doi: 10.1097/01.ta.0000199961.02677.19. PMID: 16763478.
[44] S Loftus A, Pynn H, Parker P. Improvised first aid techniques for terrorist attacks. Emerg Med J. 2018 Aug;35(8):516-521. doi: 10.1136/emermed-2018-207480. Epub 2018 Jun 15. PMID: 29907602.
[45] Cornelissen MP, Brandwijk A, Schoonmade L, Giannakopoulos G, van Oostendorp S, Geeraedts L Jr. The safety and efficacy of improvised tourniquets in life-threatening hemorrhage: a systematic review. Eur J Trauma Emerg Surg. 2020 Jun;46(3):531-538. doi: 10.1007/s00068-019-01202-5. Epub 2019 Aug 20. PMID: 31432195.
[46] Kragh JF Jr, Wallum TE, Aden JK 3rd, Dubick MA, Baer DG. Which Improvised Tourniquet Windlasses Work Well and Which Ones Won't? Wilderness Environ Med. 2015 Sep;26(3):401-5. doi: 10.1016/j.wem.2014.12.028. Epub 2015 Mar 12. PMID: 25771027.
[47] Altamirano MP, Kragh JF Jr, Aden JK 3rd, Dubick MA. Role of the Windlass in Improvised Tourniquet Use on a Manikin Hemorrhage Model. J Spec Oper Med. 2015 Summer;15(2):42-46. doi: 10.55460/DTPO-G5OG. PMID: 26125163.
[48] Lyles WE 3rd, Kragh JF Jr, Aden JK 3rd, Dubick MA. Testing Tourniquet Use in a Manikin Model: Two Improvised Techniques. J Spec Oper Med. 2015 Winter;15(4):21-26. doi: 10.55460/EJ4J-SS7L. PMID: 26630092.
[49] Amutsakorn DK, Carius BM. Efficacy of the Military Tactical Emergency Tourniquet for Lower Extremity Arterial Occlusion Compared with the Combat Application Tourniquet: A Randomized Crossover Study. J Spec Oper Med. 2023 Jun 23;23(2):36-39. doi: 10.55460/4SEI-O7LO. PMID: 37094290.
[50] Salchner H, Isser M, Banyai L, Schachner T, Wiedermann FJ, Lederer W. Arterial Occlusion Effectiveness of Space Blanket—Improvised Tourniquets for the Remote Setting. Wilderness Environ Med. 2023 Sep;34(3):269-276. doi: 10.1016/j.wem.2023.02.007. Epub 2023 Apr 24. PMID: 37100664.