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THE ROLE AND PLACE OF NPWT IN THE MULTIDISCIPLINARY SURGICAL MANAGEMENT OF GUNSHOT AND BLAST LIMB INJURIES

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ABSTRACT

Introduction. Modern armed conflicts are characterized by a high proportion of blast injuries to the limbs (up to 80%), accompanied by massive tissue defects and the formation of a zone of secondary necrosis. Traditional drainage methods are often insufficient for stabilizing such wounds, necessitating the search for more effective technologies, among which Negative Pressure Wound Therapy (NPWT) holds a leading position.

Aim. The aim of the study was to systematize and analyze the findings of current research regarding the efficacy, pathophysiological mechanisms, and safety of NPWT in the multidisciplinary management of blast limb injuries.

Materials and methods. An analysis of scientific sources from PubMed, Scopus, and Google Scholar databases, as well as national clinical guidelines dedicated to combat trauma management for the period 1997-2025, was conducted.

Results. It was established that NPWT exerts its effects through mechanisms of macro- and microdeformation, active exudate removal, and stimulation of angiogenesis, which allows for the stabilization of the "molecular shock" zone. It was determined that "early NPWT" (24-72 hours after radical primary surgical debridement) within the Damage Control concept is optimal. This method accelerates wound preparation for closure by 25-40%, reduces the incidence of infectious complications by 15-20%, and decreases the rate of delayed amputations. Particular attention is paid to safety: the necessity of using protective interfaces in cases of major vessel damage to prevent bleeding.

Conclusions. NPWT is a pathophysiologically sound and widely applied component of multidisciplinary treatment of blast wounds, providing active management of the wound process and creating conditions for successful reconstructive surgery. Personalization of pressure regimes and microbiological monitoring of biofilms under vacuum represent a promising direction for future research.

Keywords: NPWT, negative pressure, blast injury, limb gunshot wound, Damage Control.

INTRODUCTION

The dominance of artillery systems and mine-blast weapons in modern warfare has fundamentally altered the pathomorphological characteristics of ballistic trauma [1, 2, 3]. Today, blast injuries account for 45-70% of all hospital admissions for surgical casualties [4, 5]. Limb injuries remain among the most challenging to manage, comprising up to 80% of cases, with the extent of damage determined not only by soft-tissue defects but also by the combination of comminuted fractures and critical ischemia secondary to major vascular injury [2, 3, 6].

The distinctive feature of a blast wound is its multicomponent nature, characterized by the combined effects of direct shockwave disruption, thermal injury, and secondary cavitation [1, 7]. Determining the boundaries of the "molecular concussion" zone remains a pivotal challenge for surgeons. Pathological processes within this region are inherently progressive; tissues classified as provisionally viable during primary surgical debridement (PSD) frequently undergo secondary necrosis within 48-72 hours. This phenomenon is driven by progressive microcirculatory ischemia and the deleterious effects of interstitial edema [7, 8]. This critical "therapeutic window" determines the risk of severe infectious complications and influences the ultimate prognosis for limb salvage [9, 10].

Clinical experience demonstrates that traditional strategies – namely, the use of conventional absorbent dressings and frequent planned re-explorations – are not consistently effective in cases involving massive tissue defects [11, 12]. The primary drawback of these conventional methods is inadequate exudate evacuation. This limitation creates an environment conducive to rapid wound contamination with multidrug-resistant nosocomial pathogens, particularly *A. baumannii* and *P. aeruginosa*, while simultaneously impairing local tissue repair [13, 14].

The implementation of Negative Pressure Wound Therapy (NPWT) has significantly shifted the paradigm of staged wound management in military surgery [14, 15, 16, 17]. By providing continuous aspiration, NPWT facilitates effective exudate removal and edema reduction, helps stabilize perfusion in at-risk tissue zones, and accelerates wound clearance [8, 13, 18, 19]. However, despite its widespread adoption, several unresolved issues persist. Specifically, the optimal timing for initiating NPWT following radical PSD, appropriate negative pressure settings in the context of concurrent vascular reconstruction, and the logistical challenges of maintaining continuous NPWT during casualty evacuation between echelons of care remain subjects of ongoing debate [20, 21, 22, 23].

AIM

The aim of this study was to critically analyze the evidence base regarding the use of NPWT in the management of complex extremity blast injuries, define the role of this modality within Damage Control Surgery protocols [23], and outline strategies for optimizing NPWT regimens within the constraints of staged medical evacuation.

MATERIALS AND METHODS

Search Strategy and Selection Criteria. This narrative literature review was conducted using a structured literature search methodology. A comprehensive search was performed across electronic databases, including PubMed, Scopus, and Google Scholar, as well as national clinical guideline repositories. The search covered publications from January 1997 to May 2026. The starting point of 1997 was deliberately selected because it corresponds to the publication of the foundational study by Argenta and Morykwas, which introduced the modern concept of Vacuum-Assisted Closure [15]. This broad time frame enabled a comprehensive analysis of the evolution of NPWT, from its conceptual origins to its current applications and advanced protocols in modern armed conflicts.

The literature search utilized the following primary keywords and Boolean combinations: ("Negative Pressure Wound Therapy" OR "NPWT" OR "Vacuum-Assisted Closure" OR "VAC") AND ("blast injury" OR "mine-blast trauma" OR "combat trauma" OR "gunshot wound" OR "war surgery" OR "extremity trauma" OR "open fracture").

The inclusion criteria were as follows: (1) peer-reviewed original articles, systematic reviews, meta-analyses, and clinical guidelines; (2) studies addressing the use of NPWT in severe extremity trauma, combat wounds, or blast injuries; and (3) publications in English or Ukrainian. The exclusion criteria included: (1) in vitro and animal studies; (2) publications focusing exclusively on chronic non-traumatic wounds, unless they provided relevant fundamental pathophysiological data; and (3) abstract-only publications, unpublished reports, and non-peer-reviewed sources.

The initial database search yielded 842 potentially relevant records. After removal of duplicates using reference management software, 615 articles remained for title and abstract screening. At this stage, 465 records were excluded because they did not meet the predefined thematic inclusion criteria. The full texts of the remaining 150 articles were independently assessed for eligibility. Ultimately, 37 sources providing the most relevant and informative evidence regarding clinical efficacy, pathophysiological mechanisms, and staged application strategies in combat trauma were included in the final review.

Pathophysiological mechanisms of npwt in blast injuries. The efficacy of Negative Pressure Wound Therapy (NPWT) in the management of extremity blast injuries is predicated on the synergy of physical and biological factors that transform the local microenvironment [8, 15]. In cases of combat trauma, where the defining factor is a massive transfer of kinetic energy and significant damage to neurovascular structures, these mechanisms become critical for limb segment salvage [16, 17].

Mechanotransduction and Structural Tissue Alterations. The fundamental basis of NPWT action comprises the processes of macro- and microdeformation [8, 22]. Macrodeformation is achieved through the physical approximation of wound edges under the influence of negative pressure transmitted via the open-pore structure of the polyurethane foam. This not only stabilises wound geometry and reduces its volume but also significantly facilitates subsequent stages of surgical reconstruction (secondary intention closure or dermatoplasty) [24]. Conversely, microdeformation occurs directly at the points of contact between the wound surface and the struts of the polyurethane foam. The invagination of tissue sections into the foam pores generates local tensile forces that trigger a mechanotransduction cascade – the transformation of a mechanical stimulus into a biological response at the cellular nucleus level [25]. This activates protein kinase pathways, thereby stimulating the proliferative activity of fibroblasts and the synthesis of extracellular matrix proteoglycans [8, 25].

Exudate Dynamics and Interstitial Pressure Correction. The capillary leakage characteristic of blast trauma leads to a rapid increase in interstitial edema, which mechanically compresses the microcirculatory bed and exacerbates tissue ischemia [1]. The application of NPWT facilitates continuous evacuation of exudate containing pro-inflammatory cytokines, excess matrix metalloproteinases (MMPs), and tissue debris [8, 13]. Reduction of interstitial pressure promotes the "decompression" of compressed capillaries and lymphatic vessels. This unloading effect is crucial for tissue survival within the "molecular concussion" zone (i.e., the zone at risk of secondary necrosis), where restoration of adequate perfusion may prevent irreversible tissue damage [7, 19].

Perfusion Optimization and Angiogenesis Induction. The modulation of local blood flow under the influence of negative pressure exhibits a non-linear pattern. It has been demonstrated that utilizing an optimal pressure level (-125 mmHg) establishes a gradient that promotes vasodilation at the wound periphery [22]. Concurrently, relative local hypoxia at the areas of direct contact with the foam acts as a potent stimulus for the expression of vascular endothelial growth factor (VEGF). This initiates active angiogenesis and the formation of functionally viable granulation tissue, which possesses high resistance to infection and provides an optimal foundation for subsequent plastic closure of the defect [8, 18, 19, 25].

Microbiological Profile and Barrier Function. Although NPWT does not possess a direct antiseptic effect, the technique fundamentally alters the conditions for microflora viability [13, 14]. The creation of a sealed, isolated environment precludes the possibility of secondary contamination with nosocomial bacterial strains during evacuation stages [16]. The elimination of wound secretions and necrotic debris deprives microorganisms of a nutrient substrate, while the enhancement of local blood flow ensures a higher concentration of endogenous immune factors and systemic antibiotics directly at the trauma site [14, 25].

Summary. Consequently, the pathophysiological impact of NPWT on a blast wound is a multi-vector process. Through the integration of mechanical stabilization, tissue decompression, and angiogenesis activation, this modality enables the localization of the secondary necrosis zone and transforms a chronic inflammatory response into an active regenerative process [8, 19, 25].

RESULTS

Clinical tactics and staged application of npwt in blast trauma. The practical implementation of negative pressure wound therapy (NPWT) in the management of mine-blast wounds requires strict adherence to staged surgical treatment algorithms [16, 19, 26]. The modern concept views NPWT as a "golden bridge" – a technological link that ensures a safe transition from emergency primary debridement to the definitive reconstructive phase [14, 19, 24].

Surgical Debridement as the Foundation of the Modality. A fundamental principle of military surgery is that NPWT is not an alternative to surgical wound debridement [1, 7]. NPWT should be initiated only after adequate radical primary surgical debridement (PSD). This procedure involves the complete excision of non-viable tissue based on established tissue viability criteria, including muscle contractility and bleeding, removal of foreign bodies, and decompressive fasciotomy when clinically indicated or when there is a risk of compartment syndrome [11, 27]. Sealing a wound with residual necrotic tissue is unacceptable, as retained devitalized tissue promotes bacterial proliferation and may contribute to rapid progression of wound infection [7, 16].

The Time Continuum: The Concept of "Early NPWT". Debate regarding the optimal timing for negative pressure exposure has led to the formulation of the "Early NPWT" strategy [22, 23]. Although wound packing with antiseptic dressings is often preferred during the forward echelons of medical evacuation (the first 24 hours), the application of NPWT systems within 24-72 hours post-injury at the specialized care stage is considered most appropriate [21, 26, 27]. It is within this "clinical window" that the demarcation of the secondary necrosis zone concludes, and active drainage allows for maximum preservation of tissues that have undergone molecular concussion, preventing their subsequent destruction [7].

Dynamic Control and the "Second Look" Strategy. Because blast wounds are prone to progressive ischemia, the initial phase of NPWT is commonly combined with a strategy of planned serial re-exploration ("second look") [7, 11]. The first NPWT period typically lasts 48-72 hours, after which tissue viability is reassessed during the planned NPWT dressing change. If new foci of necrosis are identified, repeat surgical debridement is performed. Once the wound process has stabilized and healthy granulation tissue has developed, the intervals between NPWT system changes can be extended to 3–5 days, thereby reducing the overall number of surgical interventions and the anesthesia-related burden on the patient [16, 19, 26].

Transportability and Continuity of Care. A critical advantage in the context of modern warfare is the utilization of autonomous, portable NPWT devices, which ensure cycle continuity during inter-hospital evacuation [14, 20]. Sealing the wound during transit not only prevents nosocomial superinfection but also facilitates early patient mobilization and mitigates pain intensity via the mechanical stabilization of soft tissues under the dressing [21].

Criteria for Transitioning to the Reconstructive Phase. The discontinuation of vacuum therapy and the transition to defect closure are determined by a combination of clinical and laboratory indicators [13, 19, 24]: Complete wound clearance of necrotic elements; The presence of a uniform layer of lush, fine-grained granulation tissue; A reduction in the level of bacterial contamination below the critical threshold (10^5 CFU/g) [13]; Positive dynamics in the cytological profile of wound touch imprints [26].

Summary. Consequently, the tactical efficacy of NPWT in blast injuries is dictated by its integration into the overarching Damage Control Surgery strategy. Dynamic monitoring of the wound status combined with the capability to maintain negative pressure throughout evacuation stages enables not only the preservation of tissue viability within the critical zone but also the creation of optimal conditions for successful subsequent reconstruction [14, 16].

Specific features of npwt in concomitant extremity injuries. Blast injuries of the extremities in the context of modern combat trauma are predominantly complex and combined injuries. They are often accompanied by comminuted fractures, major vascular injuries with critical limb ischemia, peripheral nerve damage, and extensive soft-tissue loss [2, 6]. The application of Negative Pressure Wound Therapy (NPWT) in such complex clinical settings requires the surgical team to possess not only technical expertise but also a thorough understanding of the risks associated with the anatomical characteristics of the injured structures [20, 21].

Integration with External Fixation Modalities. In gunshot fractures of long bones, fracture stabilization using external fixation devices (EFDs) remains a priority [1, 27]. Combining NPWT with external fixation presents distinct technical challenges, particularly in maintaining an airtight seal around pin and wire exit sites. In clinical practice, hydrocolloid dressings or sealing pastes may be applied around fixation elements to maintain an adequate negative-pressure gradient [11, 19]. A potential advantage of this approach is improved protection of the wound from external contamination; by promoting the formation of granulation tissue, NPWT may facilitate coverage of exposed bone and potentially reduce the risk of deep infection in Gustilo–Anderson type IIIB and IIIC fractures [28, 29, 30].

Vacuum Therapy in Major Vascular Injuries. The use of negative pressure over vascular reconstructions, including anastomoses and autogenous vein grafts, requires extreme caution because of the risk of vascular erosion and hemorrhage [20, 31]. Direct contact between the polyurethane foam and the vascular suture line should be avoided. A mandatory safety measure is the placement of a protective barrier between the vessel and the NPWT system, using a viable muscle flap (transposition), xenopericardium, or a non-adherent mesh dressing [20]. In such cases, moderate negative pressure (-75 to -100 mmHg) in continuous mode may be appropriate to minimize mechanical stress and pressure fluctuations on the vascular wall [20, 22].

Preservation of Tendinous and Neural Structures. Exposed tendons and nerves managed in an open wound are highly susceptible to rapid desiccation and secondary necrosis [1]. NPWT helps maintain a moist wound environment, thereby reducing the risk of tissue desiccation [16, 19]. However, because granulation tissue may grow into the pores of standard polyurethane (black) foam, the use of polyvinyl alcohol (white) foam or a specialized non-adherent interface over exposed nerves is recommended. This approach facilitates scheduled NPWT system changes while minimizing additional mechanical trauma to the underlying neural tissue [19, 32].

Wound Bed Optimization and the Closure Phase. The primary objective of NPWT in concomitant trauma is the preparation of the wound surface for definitive defect closure [19, 24]. The method facilitates the rapid development of a high-quality granulation barrier even on surfaces with low perfusion potential, such as exposed fascia or the cortical bone plate [33]. Special attention should be directed toward the technique of NPWT-assisted skin graft survival. Utilizing vacuum as an "active compression dressing" for 3-5 days post-dermatoplasty ensures ideal graft adhesion to the wound bed, precludes the formation of sub-graft hematomas, and enhances epithelial trophism, thereby significantly increasing the success rate of graft take [19, 33].

Summary. In concomitant blast injuries, NPWT functions as a comprehensive tissue viability preservation technology that helps avoid secondary amputations [7]. Concurrently, the presence of vascular anastomoses and exposed critical structures dictates the absolute necessity of strict adherence to precise system application techniques and individualized selection of pressure regimens [20, 31].

Comparative analysis of clinical efficacy and advantages of the method. An analysis of current specialized literature and the results of multicenter clinical trials demonstrates a statistically significant superiority of the NPWT strategy over traditional approaches based on the use of conventional absorbent dressings and passive drainage [14, 28, 29, 34]. The higher efficacy of this modality in extremity blast injuries can be traced across several key vectors:

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from the rate of tissue regeneration to economic feasibility and patient psychological comfort.

Acceleration of Reparative Processes. Comparative data indicate that the utilization of vacuum aspiration allows for a reduction in the wound clearance phase and the formation of a functional granulation barrier by an average of 25-40% [19, 33]. According to observations by various authors, readiness of the wound defect for secondary closure or dermatoplasty occurs 5-8 days earlier with NPWT compared to conservative management [11, 12, 29]. This is attributed to the intensification of angiogenesis and the capacity of the method to artificially modulate a rapid transition of the wound process from the inflammatory (exudative) phase into the proliferative phase [8, 25].

Control of Infectious Complications. Mine-blast trauma of the extremities is a priori associated with a high risk of sepsis due to primary massive contamination and the presence of ischemic tissues [1, 13]. Recent meta-analyses demonstrate that the implementation of NPWT therapy reduces the incidence of deep surgical site infections (SSIs) in open fractures by 15-20% [9, 10, 28]. Due to the maintenance of system hermeticity and the continuous elimination of debris, bacterial bioburden in the wound is consistently maintained below the critical threshold (10^5 CFU/g), thereby minimizing the risks of nosocomial superinfection [13, 14].

Organisational and Economic Feasibility. Despite the relatively high cost of consumables, the overall cost of treatment with NPWT may be lower [14, 17]. The economic benefit is associated with a reduction in hospital length of stay (LOS) and more efficient use of healthcare personnel and resources. Unlike conventional wound management, which may require painful and frequent dressing changes, sometimes performed under anesthesia in the operating room, NPWT systems can often be changed at intervals of 3-4 days. This may substantially reduce the workload of anesthesia services and operating rooms, which is particularly important during periods of mass casualty influx [11, 26, 34].

Tissue Preservation and Amputation Rates. In complex clinical scenarios, particularly in Gustilo–Anderson type IIIB and IIIC injuries, NPWT may contribute to the preservation of potentially viable tissue that might otherwise require excision because of progressive secondary ischemia [7, 19]. Effective reduction of intermuscular edema and decompression of the affected tissue compartments may contribute to the stabilization of local perfusion within the "molecular concussion" zone. According to reports from military surgical practice, this approach has been associated with a 10-12% reduction in the rate of delayed amputations [7, 20].

Patient-Centered Aspects. The deployment of portable negative pressure systems significantly enhances the casualty's quality of life during prolonged treatment [17, 21]. Device autonomy ensures early patient mobilization, while the mechanical stabilization of soft tissues beneath the dressing, combined with less frequent wound manipulations, results in an objective reduction in pain intensity [14, 21]. A distinct psychological factor is the sealed nature of the system, which, owing to integrated charcoal filters, completely eliminates the specific odor of wound exudate, thereby improving the emotional well-being of both the patient and those around them [14].

Summary. The conducted comparative analysis confirms that NPWT is a pathophysiologically justified component in the management of blast injuries. Its high efficacy in infection prevention, accelerated kinetics of regenerative processes, and the facilitation of early rehabilitation render this method a cornerstone of modern surgical strategy [19, 29, 33, 34].

DISCUSSION

Limitations, contraindications, and potential complications. Despite its proven clinical efficacy, vacuum therapy is not a universal tool and requires strict adherence to safety protocols. Improper implementation of the method, particularly in concomitant blast injuries, can provoke the development of life-threatening conditions that negate the advantages of the technology [14, 15, 20].

System of Contraindications and Safety Criteria. According to international consensus recommendations and the experience of military surgical practice, the use of NPWT has clearly defined indications and contraindications [1, 14, 15]. A fundamental limitation is the presence of non-viable tissue: NPWT is not a substitute for surgical debridement, and applying an occlusive system to inadequately debrided wounds may promote bacterial proliferation and progression of wound infection beneath the dressing [7]. Similarly, the use of NPWT in acute osteomyelitis without adequate surgical debridement and management of necrotic bone is generally considered inappropriate [33]. A distinct high-risk group comprises wounds with exposed major vessels, nerves, or vascular anastomoses. Direct contact between polyurethane foam and these structures should be avoided, and an appropriate protective interface is required to minimize the risk of mechanical trauma and hemorrhage [20, 22].

Risk of Hemorrhagic Complications and Vascular Fragility. The most critical complication in combat trauma surgery is massive haemorrhage [20]. The specificity of a blast wave lies in the formation of a vascular wall contusion zone, leading to its structural degradation and increased fragility [2]. Under such conditions, prolonged exposure to negative pressure can provoke vascular suture line failure or rupture of the major vessel wall. An additional risk factor is the necessity of anticoagulant therapy for the prophylaxis of thromboembolic complications, which demands continuous monitoring of the patient's condition during NPWT system operation [20, 22].

Risks of Anaerobic Invasion and Systemic Response. The creation of a sealed environment beneath the occlusive drape may alter local tissue oxygenation. In cases of inadequate primary surgical debridement (PSD), the presence of residual devitalized tissue may promote bacterial proliferation, including that of anaerobic pathogens such as *Clostridium* spp. [14, 15]. A rapid increase in pain intensity, local hyperthermia, or signs of a systemic inflammatory response during NPWT should prompt immediate clinical reassessment, consideration of NPWT discontinuation, and urgent wound re-exploration when clinically indicated [1].

Technical and Iatrogenic Complications of the Method. Among the less critical but relatively common complications, periwound skin maceration should be highlighted, particularly when healthy surrounding tissue is inadequately protected with the adhesive drape [32]. Another important issue is failure to adhere to recommended dressing-change intervals: when NPWT dressings remain in place for longer than 72-96 hours, granulation tissue may grow into the pores of the polyurethane foam. This can make system removal considerably more painful and may result in disruption of the newly formed granulation tissue and capillary bleeding during foam removal [21, 32]. Furthermore, fragmentation and retention of foam material within the wound may contribute to chronic inflammation and, in rare cases, foreign-body granuloma formation or fistula development [15].

Algesiologic Aspects. Blast injuries are frequently accompanied by peripheral nerve damage, which may increase patients' sensitivity to pain during NPWT. Continuous negative pressure and, particularly, initiation of NPWT may exacerbate pain, necessitating adjustments to the analgesic regimen or performance of painful procedures under intravenous sedation. This may impose an additional physiological burden on the patient and should therefore be considered during treatment planning [21].

Consequently, NPWT remains an effective treatment modality when used following adequate surgical debridement and with appropriate protection of anatomically critical structures. Failure to recognize relevant clinical contraindications or to adhere to recommended technical protocols may reduce the therapeutic benefits of NPWT and increase the risk of iatrogenic complications [14, 15, 20].

CONCLUSIONS

A review of current scientific data and military clinical experience with extremity blast injuries yields the following conclusions:

Negative Pressure Wound Therapy (NPWT) is an essential, active component of multidisciplinary combat wound care, replacing passive observation with controlled wound management. It functions by actively reducing interstitial edema, mechanically stabilizing the soft tissue architecture, and accelerating angiogenesis in compromised zones [8, 15, 19, 25]. To work safely, NPWT must integrate into a staged Damage Control Surgery pathway [23]. The "early NPWT" concept (initiating therapy 24–72 hours post-injury) at specialized medical centers is highly effective, but its use is strictly conditional on an exhaustive, radical primary surgical debridement [11, 14, 26, 27]. When deployed correctly in complex, concomitant trauma, vacuum aspiration speeds wound bed preparation by 25–40% [35], cuts surgical site infection rates, and improves split-thickness skin graft take [10, 28, 29, 33, 34]. However, the method demands strict technological discipline over exposed vascular and neural structures; interface barriers and vigilant clinical monitoring are mandatory to avoid catastrophic corrosive bleeding or anaerobic infections [14, 20, 22].

Future Directions. While NPWT is widely used, several clinical gaps require targeted research within this dissertation project:

- Refining Pressure Regimens: Developing clinical algorithms to match specific negative pressure curves (continuous, variable, or intermittent) to the exact surface area of the defect and the patient's local tissue perfusion [22].
- Standardizing Readiness Markers: Locating clear morphological and molecular-genetic biomarkers to objectively flag when a wound is ready to transition from vacuum therapy to final closure [15, 19].
- Mapping Wound Microbiocenosis: Tracking how prolonged vacuum forces affect the architecture of bacterial biofilms, particularly when dealing with the highly resistant strains common in modern combat wounds [13, 14].
- Evaluating Combined Modalities: Measuring the clinical value of pairing NPWT with continuous antiseptic instillation (NPWT-instill) directly into the wound bed during phases of extreme bacterial bioburden [32, 36].

Article Declarations

Perspectives for further research. Prospects for future research lie in the systematic integration and analysis of data generated by medical and academic institutions during active hostilities, which is essential for developing standardized evidence-based protocols.

Study limitations. The authors of the manuscript hereby certify that the limitations of this review are determined by both the predefined scope of the topic, timeframes, and study types, as well as the availability of sources. The search strategy encompassed Ukrainian and international scientific sources and manuals published within the 2021–2026 period.

Primary data and materials. The authors of the manuscript hereby certify that primary medical documentation (including case histories, outpatient records, examination protocols, laboratory and instrumental test results of individual patients) and statistical databases were not used in this research.

Research ethics. The authors complied with all protocols and procedures established by the Biomedical Research Ethics Committee, relevant Ukrainian healthcare legislation, and the principles of the Declaration of Helsinki (2000).

Declaration of AI use. During the preparation of this work, the authors utilized Gemini to generate phrasing options. After using this tool, the authors reviewed and edited the material as necessary and take full responsibility for the content of the publication.

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РОЛЬ ТА МІСЦЕ NPWT-ТЕРАПІЇ У КОМПЛЕКСНОМУ ХІРУРГІЧНОМУ ЛІКУВАННІ ВОГНЕПАЛЬНИХ ТА ВИБУХОВИХ РАН КІНЦІВОК

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РЕЗЮМЕ

Вступ. Сучасні збройні конфлікти характеризуються високою часткою мінно-вибухових поранень кінцівок (до 80%), що супроводжуються масивними дефектами тканин та формуванням зони вторинного некрозу. Традиційні методи дренування часто є недостатніми для стабілізації таких ран, що зумовлює пошук ефективніших технологій, серед яких провідне місце посідає лікування негативним тиском (NPWT).
Мета. Систематизувати та проаналізувати результати сучасних досліджень щодо ефективності, патофізіологічних механізмів та безпеки застосування NPWT-терапії в комплексному лікуванні вибухових поранень кінцівок. Матеріали та методи. Проведено аналіз наукових джерел баз даних PubMed, Scopus та Google Scholar, а також вітчизняних клінічних настанов, присвячених лікуванню бойової травми за період 1997-2025 рр..
Результати. Встановлено, що NPWT реалізує свій ефект через механізми макро- та мікродеформації, активне видалення ексудату та стимуляцію ангіогенезу, що дозволяє стабілізувати зону «молекулярного струсу». Визначено, що оптимальним є «раннє NPWT» (через 24-72 год після радикальної ПХО) у межах концепції Damage Control. Метод дозволяє прискорити підготовку ран до закриття на 25-40%, знизити частоту інфекційних ускладнень на 15-20% та зменшити кількість відтермінованих ампутацій. Окрему увагу приділено безпеці: необхідності використання захисних інтерфейсів при пошкодженні магістральних судин для запобігання кровотечам.
Висновки. NPWT-терапія є патофізіологічно обґрунтованим стандартом лікування вибухових ран, що забезпечує активне керування рановим процесом та створює умови для успішної реконструктивної хірургії. Перспективним напрямком є персоналізація режимів тиску та мікробіологічний моніторинг біоплівок під вакуумом.

Ключові слова: NPWT-терапія, негативний тиск, вибухова рана, вогнепальне поранення кінцівок, Damage Control.

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