Tymchyshyn D. O., Budniuk O. O., Kalchev M. M., Palvashov R. G., Vastyanov M. R. Comparative analysis of systemic and regional analgesia effectiveness in wounded with combat surgical trauma of extremities at the stages of medical evacuation. Journal of Education, Health and Sport. 2026;93:74247. eISSN 2391-8306.
https://dx.doi.org/10.12775/JEHS.2026.93.74247
https://apcz.umk.pl/JEHS/article/view/74247
https://zenodo.org/records/21322390

The journal has had 40 points in Minister of Science and Higher Education of Poland parametric evaluation. Annex to the announcement of the Minister of Education and Science of 05.01.2024 No. 32318. Has a Journal's Unique Identifier: 201159. Scientific disciplines assigned: Physical culture sciences (Field of medical and health sciences); Health Sciences (Field of medical and health sciences). Punkty Ministerialne 40 punktów. Załącznik do komunikatu Ministra Nauki i Szkolnictwa Wyższego z dnia 05.01.2024 Lp. 32318. Posiada Unikatowy Identyfikator Czasopisma: 201159. Przypisane dyscypliny naukowe: Nauki o kulturze fizycznej (Dziedzina nauk medycznych i nauk o zdrowiu); Nauki o zdrowiu (Dziedzina nauk medycznych i nauk o zdrowiu).
The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 07.06.2026. Revised: 10.06.2026. Accepted: 20.06.2026. Published:30.06.2026.

UDK 616-001.45:616.71-001.515:616-071.4

COMPARATIVE ANALYSIS OF SYSTEMIC AND REGIONAL ANALGESIA EFFECTIVENESS IN WOUNDED WITH COMBAT SURGICAL TRAUMA OF EXTREMITIES AT THE STAGES OF MEDICAL EVACUATION

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Abstract

Combat surgical trauma of the extremities is accompanied by a pronounced pain syndrome, which requires effective control at all stages of medical evacuation. Regional anesthesia is considered a promising component of multimodal analgesia. The purpose of the study was to evaluate the effectiveness of different perioperative analgesia regimens in wounded with combat surgical trauma of the extremities. The prospective study included: patients of Group 1 (n=50) received general anesthesia with systemic analgesia, patients of Group 2 (n=50) – combined anesthesia with regional blocks. Pain intensity was assessed at four stages. Upon admission, pain level was 7 points (6; 8) without intergroup differences (p=0.57). After surgery, pain was significantly lower in Group 2 – 1 point (1; 2) vs 3 points (3; 4) (p<0.05). At the evacuation stage, values were: 1 point (1; 2) and 3 points (2; 3), respectively (p<0.05). After

transportation, the difference persisted: 1 point (1; 2) vs 5 points (4; 6) ($p<0.05$). Intraoperative fentanyl consumption was lower (0 vs 0.3 mg), as well as propofol (3.3±0.7 vs 8.5±1.2 mg/kg/h). Awakening time was 0 min vs 10 min. Opioids in the postoperative period were used in 6% of patients in Group 2 vs 74% of patients in Group 1, and during transportation – in 6% vs 24%, respectively. Regional analgesic blocks provide more effective pain control, reduce the need for opioids, and improve the course of the postoperative period in wounded with combat surgical trauma of the extremities.

Key words: combat surgical trauma; gunshot wound; regional anesthesia; pain.

The war in Ukraine is the largest conflict in Europe since World War II, accompanied by a large number of casualties among military personnel and civilians [1]. The enemy often uses high-energy weapons with great destructive force, such as artillery shells, cruise missiles, unmanned aerial vehicles, as well as expanding bullets prohibited by international humanitarian law [2]. As a result of the use of such weapons, gunshot wounds of the extremities are characterized by extensive damage to soft tissue structures [3] and large defects of limb bones [4].

The organization of emergency surgical and anesthesiological care for the wounded, in frontline hospitals, as well as during the follow-up medical evacuation between hospitals of the hospital levels of medical care remains problematic [5]. Emergency medical care for the wounded at Role 1 and Role 2 levels is usually provided under conditions of danger and limited resources, which critically complicates the possibilities of standard medical care and requires adaptation of clinical protocols [6].

High-quality analgesia for wounded patients with combat trauma, at all stages of medical evacuation, is one of the priority areas of military medicine [7]. Acute pain, in the absence of timely treatment, often leads to chronic pain syndrome, which negatively affects quality of life after injury [8]. The study of pain specifics in wounded patients requires in-depth research, since subjective sensations and emotional experiences that a person feels at the moment of injury in combat conditions have their own unique features [9].

The lack of data in the medical literature regarding the study of the effectiveness of regional anesthesia in wounded with combat trauma of the extremities during care at early hospital stages of medical evacuation determined the relevance of this study.

The aim of the work was to analyze the effectiveness of analgesia in wounded with combat surgical trauma of the extremities who received different perioperative analgesia regimens during care at early hospital stages of medical evacuation.

Materials and methods

The study is prospective in nature. The study was conducted in compliance with the ethical principles set out in the Declaration of Helsinki of the World Medical Association regarding medical research involving humans. The study protocol was approved by the Bioethics Commission of Odesa National Medical University (protocol No. 18 dated 06.12.2023). Prior to inclusion in the study, all participants signed informed consent.

The study included 100 wounded patients with combat surgical trauma of the extremities who during 2024–2025 received emergency surgical and anesthesiological care in frontline hospitals, followed by evacuation to hospitals of subsequent levels of medical care. Patients were divided into two groups depending on the analgesia approach. Group 1 (n=50) included patients who received general anesthesia, and only systemic analgesia was used for postoperative pain relief. Patients of Group 2 (n=50) were treated using regional anesthesia.

Inclusion criteria were: age over 18 years, availability of informed consent, as well as isolated gunshot injury of the one extremity (upper – not higher than the upper third of the shoulder, lower – not higher than the knee joint). Exclusion criteria: age under 18 years, refusal to participate in the study, inability to obtain consent due to severe condition (in particular, in massive blood loss with Algover–Burri shock index > 1 or impaired consciousness – < 12 points on the Glasgow Coma Scale), as well as presence of drug allergy to medications used in the study.

Pain intensity was assessed using the visual analog scale (VAS, 0–10 points). Registration of indicators was carried out at four stages: upon admission to the frontline hospital; after completion of surgery; at the beginning of medical evacuation; after completion of interhospital transportation. Additional indicators of analgesia effectiveness included: intraoperative consumption of opioids and anesthetics, duration of awakening after surgery, need for opioid use in the postoperative period, need for correction of pain syndrome (including with opioids) during interhospital transportation.

All patients were male. The study groups did not differ between themselves by age (38.5±9.4 years and 37.2±9.3 years, respectively; $p = 0.49$), height (177.2±7.3 cm and 177.6±6.1 cm, respectively; $p = 0.77$), and weight (Me = 71 kg (65; 85) and 77 kg (70; 86), respectively; $p = 0.24$). Upon admission, the patient groups also did not statistically differ in mean arterial pressure (Me = 103 mmHg (94; 116) and 104.5 mmHg (96; 114), respectively; $p = 0.53$), heart rate (Me = 108 bpm (96; 114) and 108 bpm (96; 114), respectively; $p = 0.81$), and hemoglobin level (Me = 129.5 g/L (119; 137) and 133 g/L (122; 141), respectively; $p = 0.22$).

Each of the study groups included an equal number of wounded patients with combat surgical trauma of the upper and lower extremities: subgroup 1.1 (n=25) and subgroup 2.1 (n=25) included patients with combat surgical trauma of the upper of extremities, respectively, subgroup 1.2 (n=25) and subgroup 2.2 (n=25) included patients with combat surgical trauma of the lower extremities.

The structure of injury localization and the nature of surgical interventions were comparable between the groups: gunshot wounds of the shoulder were observed in 17 patients (Group 1 – n=9; Group 2 – n=8), forearm – in 26 patients (Group 1 – n=13; Group 2 – n=13), hand – in 7 patients (Group 1 – n=3; Group 2 – n=4), shin – in 22 patients (Group 1 – n=12; Group 2 – n=10), foot – in 28 patients (Group 1 – n=13; Group 2 – n=15); extremity amputation were performed in 20 patients (Group 1 – n=11; Group 2 – n=9), external fixation of the gunshot fractures of the extremity bones – in 25 patients (Group 1 – n=12; Group 2 – n=13), surgical debridement of gunshot wounds – in 55 patients (Group 1 – n=27; Group 2 – n=28).

Anesthesiological support in patients of Group 1 was performed using total intravenous anesthesia (TIVA) either with tracheal intubation and mechanical ventilation (MV) or with preservation of spontaneous breathing. In patients of Group 2 – combined anesthesia (intravenous anesthesia + regional analgesic blocks).

For visualization of nerve structures, a linear probe VF13-5 of the ultrasound scanner “SIEMENS ACUSON P500” (Germany) was used. Depending on the localization of the gunshot wounded of the upper extremities, corresponding blocks were performed: in combat surgical trauma of the upper extremities – brachial plexus block via supraclavicular approach (bupivacaine perineurally, 0.5% solution in a volume of 20 ml); in combat surgical trauma of the lower extremities – sciatic nerve block via popliteal approach (bupivacaine perineurally, 0.5% solution in a volume of 20 ml) in combination with femoral nerve block (bupivacaine perineurally, 0.5% solution in a volume of 10 ml).

In patients of the study groups, postoperative analgesia was carried out according to the principles of multimodal analgesia, in accordance with the Protocol “Pain management of patients with gunshot and mine-explosive injuries at stages of treatment in healthcare institutions of the system of the Ministry of Defense of Ukraine”, approved by the Commander of the Medical Forces of the Armed Forces of Ukraine on December 1, 2022. In patients of Group 1, postoperative analgesia was performed by administration of non-opioid analgesics, nonsteroidal anti-inflammatory drugs, analgesic adjuvants, and opioid analgesics as needed. In severe pain: morphine hydrochloride 10 mg or trimeperidine 20 mg every 6–8 hrs, dexketoprofen 50 mg

every 8 hrs, paracetamol 1000 mg every 12 hrs, nefopam 20 mg every 8 hrs, pregabalin 75–150 mg (as an analgesic adjuvant) every 8–12 hrs.

In pain of moderate intensity: dexketoprofen 50 mg every 8 hrs, paracetamol 1000 mg intravenously every 12 hrs, nefopam 20 mg every 12 hrs, pregabalin 75 mg every 12 hrs. In patients of Group 2, taking into account the prolonged analgesic effect of regional analgesic blocks performed as a component of combined anesthesia, postoperative administration of opioid analgesics was only as needed. The following multimodal analgesia regimen was used: dexketoprofen 50 mg every 8 hrs, paracetamol 1000 mg every 12 hrs, pregabalin 75 mg every 12 hrs. If the duration of the block ended before interhospital transportation, repeated regional analgesic blocks were additionally performed, but not less than 1 hr before the planned medical evacuation.

Statistical data analysis was performed using Statistica for Windows, version 12.6. The normality of data distribution was assessed using the Shapiro–Wilk test. In cases of normally distributed variables, results are presented as the mean±standard deviation (M±σ), and the Student's t-test was used to determine the statistical significance of differences between groups. When the null hypothesis of normal distribution was rejected, results are presented as the median (Me) with the 25th and 75th percentiles (Q_{25}; Q_{75}), and the Mann–Whitney U test was applied to assess the statistical significance of differences between groups. The Wilcoxon signed-rank test was used to evaluate the significance of differences between dependent variables over time. To determine the distribution of observations between two categorical variables, the two-sided Fisher's exact φ-test was used. A p-value < 0.05 was considered statistically significant.

Results

A comparative analysis of pain intensity levels in patients of the study groups is presented in Table 1 and Figure 1.

At the stage of awakening after surgery, a decrease in pain intensity compared to the baseline level was observed in patients. None of the patients reported high-intensity pain. In Group 1, moderate pain was noted by 23 patients, whereas 27 patients assessed pain within 1–3 points on the VAS. In Group 2, only 1 patient complained of moderate pain, whereas 49 patients reported 1–3 points on the VAS.

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Table 1

Comparative analysis of pain intensity levels in patients of the study groups

Parameter	***Group 1 (n=50)***	***Group 2 (n=50)***	***p***
VAS 1 (points) Me (Q_{25}; Q_{75})	7 (6; 8)	7 (6; 7)	0.57
VAS 2 (points) Me (Q_{25}; Q_{75})	3 (3; 4)	1 (1; 2)	< 0.05
VAS 3 (points) Me (Q_{25}; Q_{75})	3 (2; 3)	1 (1; 2)	< 0.05
VAS 4 (points) Me (Q_{25}; Q_{75})	5 (4; 6)	1 (1; 2)	< 0.05

Note: the Mann–Whitney U test was used to determine the statistical significance of differences between groups.

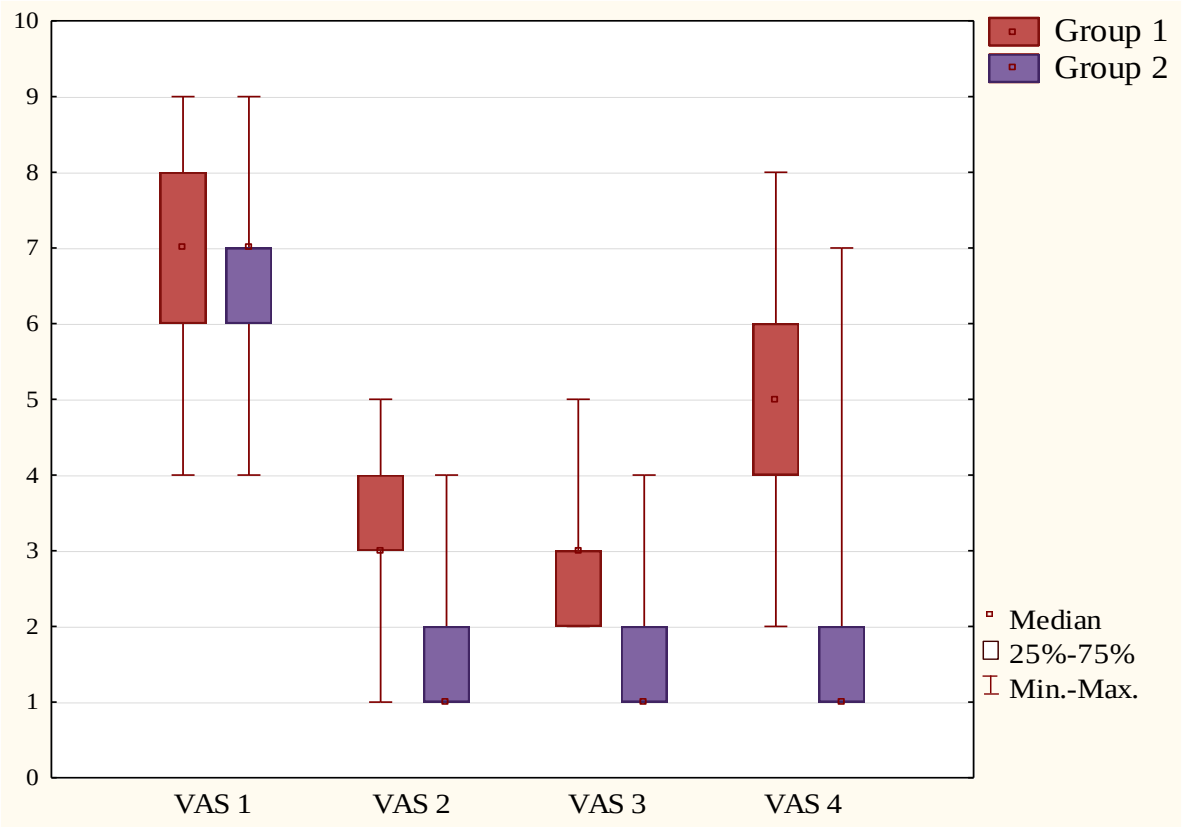

Fig. 1. Comparative analysis of the values of the level of intensity of pain syndrome in dynamics, in patients of study groups

Note: On the Y axis – numerical assessment in points, according VAS.

Analysis of intragroup dynamics of pain intensity indicators demonstrated that in the period between the 1st and 2nd stages of the study in both groups there was a statistically significant decrease in pain level between VAS 1 and VAS 2 values ($p<0.05$ in both groups; Wilcoxon signed-rank test). However, intergroup analysis of VAS 2 indicators revealed a statistically significant difference (Me = 3 points (3; 4) and Me = 1 point (1; 2), respectively; $p<0.05$, Mann–Whitney U test).

At the beginning of medical evacuation to hospitals of subsequent levels of medical care, no severe pain syndrome was registered in patients of the study groups. In Group 1, moderate pain was observed in 11 patients, whereas 39 patients reported mild pain. In Group 2, the corresponding values were 3 and 47 patients. In the period between the 2nd and 3rd stages of the study, patients of Group 1 demonstrated a further statistically significant decrease in pain intensity ($p<0.05$; Wilcoxon signed-rank test), whereas in Group 2 the pain level remained stably low without statistically significant changes ($p = 0.11$; Wilcoxon signed-rank test). However, comparison of VAS 3 values between groups demonstrated a statistically significant difference (Me = 3 points (2; 3) and Me = 1 point (1; 2), respectively; $p<0.05$, Mann–Whitney U test).

After completion of interhospital transportation, differences in the dynamics of pain intensity between patients of the study groups were noted. In Group 1, severe pain was registered in 5 patients, moderate pain in 39 patients, whereas mild pain in 6 patients. In Group 2, severe pain was noted in 2 patients, moderate in 5 patients, and the majority of patients (n=43) assessed pain as mild. In the period between the 3rd and 4th stages of the study, patients of Group 1 demonstrated a statistically significant increase in pain intensity ($p<0.05$; Wilcoxon signed-rank test), whereas in Group 2 changes did not reach the level of statistical significance ($p = 0.07$; Wilcoxon signed-rank test). VAS 4 values significantly differed between groups (Me = 5 points (4; 6) and Me = 1 point (1; 2), respectively; $p<0.05$, Mann–Whitney U test).

Comparative analysis of intraoperative consumption of opioids and anesthetics, duration of awakening after surgical intervention, the number of patients who received opioids in the postoperative period, and in whom pain syndrome correction was performed during interhospital transportation is presented in Table 2.

All patients of Group 1 underwent surgical interventions under general anesthesia. Among them: 25 patients (subgroup 1.1 – 11 patients, subgroup 1.2 – 14 patients) received TIVA + mechanical ventilation, 25 patients (subgroup 1.1 – 14 patients, subgroup 1.2 – 11 patients) received TIVA with preserved spontaneous breathing.

Table 2

Comparative analysis of intraoperative consumption of opioids and anesthetics, duration of awakening after surgical intervention, the number of patients who received opioids in the postoperative period, and in whom pain syndrome correction was performed during interhospital transportation

Parameter	Group 1 (n=50)	Group 2 (n=50)	p
Intraoperative fentanyl consumption, mg Me (Q_{25}; Q_{75})	0.3 (0.2; 0.4)	0 (0; 0.1)	$< 0.05^{*}$
Intraoperative propofol consumption, mg/kg/hr, M±σ	8.5±1.2	3.3±0.7	$< 0.05^{**}$
Duration of awakening after surgery, min Me (Q_{25}; Q_{75})	10 (5; 15)	0 (0; 0)	$< 0.05^{*}$
Patients, who received opioids in the postoperative period, n (%)	37 (74 %)	3 (6 %)	$< 0.05^{***}$
Patients, who received painkillers during interhospital transportation, n (%)	26 (52 %)	7 (14 %)	$< 0.05^{***}$
Patients, who received opioids during interhospital transportation, n (%)	12 (24 %)	3 (6 %)	$< 0.05^{***}$

Note: * –the Mann–Whitney U test was used to determine the statistical significance of differences between groups; ** – the Student's t-test was used to determine the statistical significance of differences between groups; *** – to determine the distribution of observations between two categorical variables, the two-sided Fisher's exact φ-test was used.

All patients of Group 2 underwent surgical interventions under combined anesthesia (intravenous anesthesia + regional analgesic blocks). Techniques of regional analgesic blocks and doses of local anesthetic were identical in each subgroup of patients.

However, by type of intravenous anesthesia, patients of Group 2 differed among themselves. In 15 patients (subgroup 2.1 – 4 patients, subgroup 2.2 – 11 patients), as a component of combined anesthesia, intravenous anesthesia + mechanical ventilation (with fentanyl) was performed. In 4 patients (subgroup 2.1 – 1 patient, subgroup 2.2 – 3 patients), as a component of combined anesthesia, intravenous (with fentanyl) anesthesia with preserved spontaneous breathing was performed. In 31 patients (subgroup 2.1 – 20 patients, subgroup 2.2 – 11 patients), as a component of combined anesthesia, intravenous sedation (without fentanyl) with preserved spontaneous breathing was performed.

Thus, in 100% of patients of Group 1, fentanyl was administered during anesthetic support of surgical interventions. Median intraoperative fentanyl consumption in Group 1

patients was Me = 0.3 mg (0.2; 0.4). In contrast, only 29 patients of Group 2 (58%) received fentanyl during anesthetic support of surgical interventions. It should be noted that fentanyl was administered only during induction of anesthesia (to ensure tracheal intubation), and was not further used for intraoperative analgesia. Median intraoperative fentanyl consumption in Group 2 patients was Me = 0 mg (0; 0.1); median intraoperative fentanyl consumption among those Group 2 patients who received fentanyl was Me = 0.1 mg (0.1; 0.2).

Intraoperative maintenance of adequate anesthesia level was ensured by continuous infusion of propofol. The infusion rate of propofol was determined according to the "Instructions for medical use of the medicinal product": for patients of Group 1 within the range of 4–12 mg/kg/hr (which is indicated in the instruction as maintenance of general anesthesia), and for patients of Group 2 within the range of 1.5–4.5 mg/kg/hr (which is indicated in the instruction as maintenance of sedation during diagnostic and surgical procedures). Adjustment of propofol infusion rate was carried out according to clinical picture and hemodynamic parameters. Mean values of propofol infusion rate in patients of Group 1 were 8.5±1.2 mg/kg/hr, in patients of Group 2 – 3.3±0.7 mg/kg/hr.

The duration of awakening of wounded patients of the study groups after surgical interventions directly depended on the time of the last administration of fentanyl and the cessation of propofol infusion, as well as on the total amount of the above-mentioned drugs administered intravenously intraoperatively. Thus, in patients of Group 1, median awakening duration after surgical interventions was Me = 10 minutes (5; 15). In contrast, in 45 patients of Group 2 awakening was observed immediately after completion of operations (taking into account opioid-free/low-opioid intraoperative analgesia, the amount of administered propofol and its discontinuation during the final stages of operations), only in 1 patient – within 10 minutes, and in 4 patients – within 5 minutes. Thus, in patients of Group 2, median awakening duration after surgical interventions was Me = 0 minutes (0; 0).

The need for opioid use in postoperative analgesia regimens in wounded patients of the study groups was observed in 37 patients of Group 1 (subgroup 1.1 – 19 patients, subgroup 1.2 – 18 patients) and in 3 patients of Group 2 (subgroup 2.1 – 1 patient, subgroup 2.2 – 2 patients).

The need for additional pharmacological correction of pain syndrome during interhospital transportation in wounded patients of the study groups was observed in 26 patients of Group 1 (subgroup 1.1 – 10 patients, subgroup 1.2 – 16 patients) and in 7 patients of Group 2 (subgroup 2.1 – 3 patients, subgroup 2.2 – 4 patients).

Among wounded patients in the study groups who required additional pharmacological correction of pain syndrome during interhospital transportation, opioids had to be used in 12 patients of Group 1 (subgroup 1.1 – 4 patients, subgroup 1.2 – 8 patients) and in 3 patients of Group 2 (subgroup 2.1 – 1 patient, subgroup 2.2 – 2 patients).

Discussion

Thus, in patients of Group 1 and Group 2, at the stages of the study, a statistically significant difference ($p<0.05$) was found between indicators of intraoperative consumption of opioids and anesthetics, duration of awakening after surgical intervention, need for opioid use in the postoperative period, and need for correction of pain syndrome (including with opioids) during interhospital transportation.

According to many authors, reduction of pain level should be considered a moral, medical, and operational imperative, in order to improve the quality of life of those who survived gunshot injury [10].

Regional analgesic blocks, as part of multimodal pain therapy, improve long-term treatment outcomes and increase patient quality of life [11]. In the study by Laitselart P et al. (2025), it is noted that the earliest possible performance of regional anesthesia in wounded patients with combat trauma provides stable analgesia without disturbances of vital function parameters [12].

However, there is uncertainty regarding the effectiveness and safety of regional analgesic blocks specifically during emergency care for wounded patients with combat trauma. To date, very few studies have been published regarding the features of regional anesthesia in wounded patients with combat surgical trauma in the conditions of frontline hospitals. As noted in a study by scientists from the United Kingdom (2011), the priority task of military medicine during military conflicts of the 20th century was ensuring high-quality triage of the wounded, while the problem of pain treatment was not given significant attention [13].

Regarding emergency care in “peacetime” for patients and injured individuals, Alnsour TM et al. (2024) emphasize that in urgent situations, general anesthesia is traditionally more controllable, whereas regional methods of analgesia require more time for performance and waiting for sensory block [14]. In the review by Guay J et al. (2018), it is indicated that in patients with hypovolemia, the pharmacokinetics of local anesthetics changes, and as a result – the risk of accelerated diffusion of drugs into the systemic circulation increases [15].

In the work by Rauschenbach A et al. (2025), it is noted that lack of practical experience in ultrasound scanning and fear of neurological complications are the main reasons for limited use of regional anesthesia in emergency care [16]. Scientists from Canada (2020) conducted a survey among 1,435 emergency department physicians of medical centers in the country regarding the frequency of use of regional anesthesia during urgent care. The survey results indicate that only 149 physicians (10.4%) regularly use regional analgesic blocks in their practice [17].

The data obtained demonstrate significantly higher effectiveness of analgesia in patients who underwent regional analgesic blocks compared to patients who did not receive regional analgesic blocks.

Conclusions

1. The use of regional analgesic blocks in analgesia regimens of wounded with combat surgical trauma of the extremities provided a significantly lower level of pain after surgical interventions and during subsequent medical evacuation ($p<0.05$).

2. The need for additional analgesia using narcotic analgesics in the perioperative period and during interhospital transportation was significantly lower in the group of patients with regional anesthesia ($p<0.05$).

3. Regional analgesia is an effective and safe method of pain control in wounded with combat surgical trauma of the extremities at early hospital stages of medical evacuation

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Author Contributions

Conceptualization, (Budniuk O.O.); methodology, (Tymchyshyn D.O.); formal analysis, (Tymchyshyn D.O.); data curation, (Kalchev M.M.); writing - original draft preparation, (Kalchev M.M., Palvashov R.G., Vastyanov M.R.); writing - review and editing, (Budniuk O.O., Tymchyshyn D.O.); supervision, (Budniuk O.O.).

All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Institutional Review Board Statement

This scientific report did not require IRB approval, any patients were used to receive the information.

Informed Consent Statement

All participants signed informed consent regarding the use of their treatment data for scientific purposes.

Data Availability Statement

The data presented in this study are available on request from the author.

Conflicts of Interest

The authors declare no conflict of interest.