DOI: https://doi.org/10.17816/RA637192 EDN: NEKEUU

Effectiveness of regional analgesia in the early postoperative period in patients with mine-explosion and gunshot shrapnel injuries of the limbs: A prospective controlled study

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ABSTRACT

BACKGROUND: Mine-explosion and gunshot shrapnel injuries of the limbs are accompanied by severe pain requiring effective analgesia. Comparing the analgesic efficacy of conduction anesthesia versus systemic postoperative analgesia is essential for optimizing treatment approaches, particularly under resource-constrained conditions in military medicine.

AIM: To compare the analgesic efficacy of conduction anesthesia and systemic postoperative analgesia in patients with mine-explosion and gunshot shrapnel injuries of the extremities.

METHODS: Patients (*n*=92) were enrolled in a prospective controlled study conducted from October 1 to December 31, 2023, at a level III military field hospital. Patients were divided into two groups based on the type of anesthesia: group 1 (*n*=68) underwent surgery under ultrasound-guided conduction anesthesia; group 2 (*n*=24) received general combined anesthesia (inhalational + non-inhalational, *n*=10), general non-inhalational anesthesia (*n*=4), or spinal anesthesia (*n*=10). Primary endpoints included pain intensity at rest and during movement, and the need for systemic opioid and non-opioid analgesics, assessed using the Numeric Rating Scale at 0, 3, 6, 9, 12, 15, 18, 21, and 24 h postoperatively.

RESULTS: Compared to group 2, patients who underwent surgery under conduction anesthesia reported significantly lower pain intensity during the early postoperative period at all 9 assessment points within 24 h. Peak pain intensity occurred 18 h postoperatively in both groups, but was significantly lower in group 1 (1.6±2.13) than in group 2 (5.6±2.13, *p*=0.00). At 24 h, pain levels remained lower in group 1 (the difference was not statistically significant, *p*=0.063). The need for systemic analgesics during the first 21 postoperative hours in all groups was also significantly lower ($p < 0.05$).

CONCLUSION: Ultrasound-guided conduction anesthesia is the method of choice for surgical treatment of mine-explosion and gunshot shrapnel injuries of the limbs at the qualified care stage in medical practice.

Keywords: mine-explosion injuries; gunshot wounds; limb surgery; nerve block anesthesia; systemic postoperative analgesia; pain management.

To cite this article:
Magomedaliev MO, Korabelnikov DI, Gafurov MA, Tkachenko EV. Effectiveness of regional analgesia in the early postoperative period in patients with mine-explosion and gunshot shrapnel injuries of the limbs: A prospective controlled study. *Regional anesthesia and acute pain management.* 2025;19(1):40–48. DOI: 10.17816/RA637192 EDN: NEKEUU

Received: 18.10.2024 **Accepted:** 31.03.2025 **Published online:** 05.04.2025

DOI: https://doi.org/10.17816/RA637192 EDN: NEKEUU

Эффективность регионарной анальгезии в раннем послеоперационном периоде у пациентов с минно-взрывными и огнестрельными осколочными ранениями конечностей: проспективное контролируемое исследование

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АННОТАЦИЯ

Обоснование. Минно-взрывные и огнестрельные ранения конечностей сопровождаются выраженным болевым синдромом, требующим эффективного обезболивания. Сравнение анальгетической эффективности проводниковой анестезии и системной послеоперационной анальгезии актуально для оптимизации подходов к лечению, особенно в условиях ограниченных ресурсов медицинской службы.

Цель. Сравнение анальгетической эффективности проводниковой анестезии и послеоперационной системной анальгезии у раненых с минно-взрывными и огнестрельными осколочными ранениями конечностей.

Материалы и методы. Пациенты (*n*=92) были распределены на две группы в зависимости от вида анестезиологического обеспечения: группа 1 (*n*=68) — пациенты, оперированные с применением проводниковой анестезии под ультразвуковой навигацией; группа 2 (*n*=24) — пациенты, которым выполнялась общая комбинированная (ингаляционная+неингаляционная) анестезия (*n*=10), общая неингаляционная (*n*=4) и спинальная анестезия (*n*=10). Контролируемое проспективное исследование проводилось с 01.10 по 31.12.2023 года в военно-полевом госпитале (третий уровень медицинской помощи). Первичными конечными точками исследования являлись динамика болевого синдрома в состоянии покоя и при движении, потребность в системных наркотических и ненаркотических анальгетиках, оцениваемые по цифровой рейтинговой шкале через 0, 3, 6, 9, 12, 15, 18, 21, 24 часа после операции.

Результаты. В группе пациентов, оперированных с применением проводниковой анестезии, по сравнению с группой 2 выраженность болевого синдрома в раннем послеоперационном периоде во всех 9 контрольных точках (в течение 24 часов после операции) была статистически значимо меньшей. Максимальная выраженность болевого синдрома после окончания операции в обеих группах развивалась через 18 часов, при этом в группе 2 боль статистически значимо более выражена — 5,6±2,13 по сравнению с группой 1 — 1,6±2,13 (*p*=0,00). Через 24 часа выраженность болевого синдрома также была меньше в группе 1 (статистически незначимо, *p*=0,063). Потребность в системных анальгетиках в послеоперационном периоде (до 21 часа) была статистически значимо меньше (*p* <0,05).

Заключение. Проводниковая анестезия с УЗ-навигацией является методом выбора при оперативных вмешательствах по поводу минно-взрывных и огнестрельных осколочных ранений конечностей на этапе квалифицированной медицинской помощи.

Ключевые слова: минно-взрывные ранения; огнестрельные ранения; операции на конечностях; проводниковая анестезия; послеоперационная системная анальгезия; обезболивание.

Как цитировать:
Магомедалиев М.О., Корабельников Д.И., Гафуров М.А., Ткаченко Е.В. Эффективность регионарной анальгезии в раннем послеоперационном периоде у пациентов с минно-взрывными и огнестрельными осколочными ранениями конечностей: проспективное контролируемое исследование // Регионарная анестезия и лечение острой боли. 2025. Т. 19, № 1. С. 40–48. DOI: 10.17816/RA637192 EDN: NEKEUU

Рукопись получена: 18.10.2024 **Рукопись одобрена:** 31.03.2025 **Опубликована:** 05.04.2025

BACKGROUND

Adequate analgesia is critical for medical evacuation. It significantly reduces the risk of traumatic shock, protects the wounded from surgical stress, prepares them for the next stage of evacuation, and prevents pain-induced hypersensitization during transport, often caused by ineffective and inadequate analgesia, especially during mass casualty events and in cases of medical personnel shortages [1].

Comprehensive pain management blocks the stress-induced pain response. It prevents negative effects on the cardiovascular, respiratory, gastrointestinal, urinary, neuroendocrine, musculoskeletal, and central nervous systems, as well as on hemostasis [2].

The use of systemic analgesics has been reported to have both positive and negative effects. For example, postoperative systemic opioid analgesia may exacerbate adverse effects such as tolerance, nausea, vomiting, constipation, drowsiness, respiratory depression, and cognitive impairment [3].

Ultrasound (US)-guided nerve block is the least invasive and safest option for ensuring adequate intraoperative anesthesia and early postoperative analgesia. This technique has many advantages for field settings, including mobility, accessibility, relative safety, suitability for patients with full stomachs (due to the lower risk of aspiration), a lower risk of pneumothorax, puncture, and injury to major vessels and nerve trunks. It also requires no complex, bulky medical equipment, minimal systemic monitoring, and has a long-term analgesic effect.

There are no published studies that have evaluated the effectiveness of nerve blocks for postoperative pain management in patients with blast and fragmentation injuries. This supports the present study, which includes a detailed analysis of pain progression in this patient population.

The **study aimed** to compare the perioperative analgesic effectiveness of nerve block and postoperative systemic analgesia for wounded personnel with blast and fragmentation injuries of the limbs.

METHODS

Study design

This was a prospective controlled study that included 92 male patients over 18 years old with blast and fragmentation injuries of the limbs requiring surgery (Fig. 1).

Eligibility criteria

The inclusion criteria were as follows: emergency or scheduled surgery for blast and fragmentation injuries of the upper or lower limbs and their sequelae.

The *exclusion criteria* were as follows: life-threatening conditions, significant comorbidities, allergic reactions to local anesthetics, and patient refusal to participate.

Study setting and duration

The study was conducted from October 1, 2023 to December 31, 2023, at the Vityaz Field Hospital (tertiary medical facility).

Intervention

Patients were divided into two groups based on their anesthetic care type. The groups were homogeneous in terms of sex, age, weight, and height. The extent and impact of surgeries were similar in both groups.

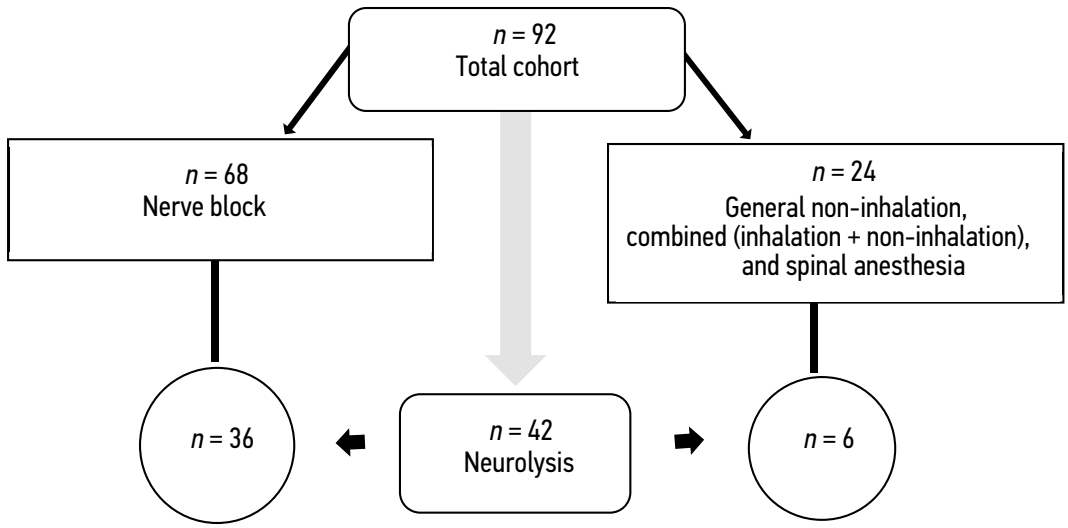

Fig. 1. Study design flow-chart.

The nerve block group had the following standardized techniques:

- For upper limb surgery, three approaches were used for a brachial plexus block: interscalene (Winnie technique), supraclavicular (Kulenkampff technique), and subaxillary approach.
- For lower limb surgery, a combined block was used, including popliteal sciatic nerve block and femoral nerve block (anterior approach).

All procedures were performed under ultrasound guidance using a linear transducer (10–15 MHz) and standard monitoring (electrocardiography, pulse oximetry, and non-invasive blood pressure measurement). The dose of 0.5% ropivacaine was calculated individually.

In group 2, the following types of anesthesia were performed using standard conventional techniques: general intravenous anesthesia, general combined anesthesia (inhalation + non-inhalation), and spinal anesthesia (SA).

Group 2 received intraoperative narcotic analgesics (fentanyl), excluding patients who underwent surgery under SA. The final dose was administered 10–15 minutes before the end of the procedure.

The Glasgow Coma Scale score for level of consciousness was 15 in both groups before and after surgery. This score allowed patients to accurately report their pain intensity during the 24-hour postoperative period and enabled them to control the timing of their analgesic (narcotic and/or non-narcotic) medication use.

Subgroup analysis

Group 1 included 68 patients who received US-guided nerve block using up to 200 mg of ropivacaine and 4 mg of dexamethasone as adjuvant [4]. No additional narcotic or non-narcotic analgesics were administered during the procedure. The patients remained conscious throughout the procedure. This group underwent nerve blocks for peripheral neurolysis (n = 36), soft tissue surgery (n = 10), and external limb fixation (n = 22).

Group 2 included 24 patients who received combined general anesthesia (inhalation + non-inhalation) (n = 10), general intravenous anesthesia (n = 4), and SA (n = 10). Several patients (n = 6) in this group underwent peripheral neurolysis without nerve block.

Outcomes registration

Pain intensity was assessed every three hours (at 0, 3, 6, 9, 12, 15, 18, and 21 hours after surgery) with focus on the highest pain intensity using the 10-point Numerical Rating Scale (NRS), where 0 means no pain, and 10 means the worst pain imaginable [5].

Analgesic effectiveness was evaluated before and after analgesic administration.

Main study outcome

The primary endpoints included longitudinal changes in pain intensity at rest and during movement at 0, 3, 6, 9, 12, 15, 18, 21, and 24 hours after surgery, as measured by the NRS scale. The need for systemic analgesics (both narcotic and non-narcotic) during the same time intervals (0–24 hours after surgery) was also assessed using the NRS scale.

Ethics approval

The study was approved by the Independent Ethics Committee of the Moscow Medical and Social Institute named after Friedrich Haass (Resolution No. 3, dated September 29, 2023). The study was conducted in accordance with the guidelines of Good Clinical Practice (GCP) and national medical care standards to ensure the safety and well-being of the participants. The ethical principles outlined in the World Medical Association Declaration of Helsinki were observed to protect the participants, and the study complied with the current legislation of the Russian Federation.

Prior to all surgical procedures, a formal voluntary informed consent was obtained for the anesthetic management of the medical procedure.

Statistical analysis

Microsoft Excel (2021) (Microsoft Corporation, USA) was used to create the database. Standard methods with STATISTICA v. 10 (StatSoft Inc., USA) were used for statistical processing. The statistical significance of intergroup differences was assessed using the non-parametric Mann–Whitney U test.

The sample size was calculated to be at least three participants per group for the Mann–Whitney U test. Quantitative parameters were described using the mean (M) and standard deviation (SD), as well as the median (Me) and interquartile range (Q1 and Q3). Results were considered statistically significant at $p < 0.05$.

RESULTS

Participants

This study included 92 patients with combat-related limb injuries. Table 1 shows the key characteristics of the study cohort, including baseline demographic characteristics (age), anthropometric measurements, and clinical parameters of the participants.

Primary results

Table 2 shows longitudinal changes in pain intensity as measured by the NRS. The pain intensity was statistically significantly lower in group 1 than in group 2 at each of the nine time points. In both groups, peak pain intensity was observed at 18 hours after the end

of surgery. At this time, however, the pain level was significantly higher in group 2 (5.60 ± 2.13) than in group 1 (1.60 ± 2.13) (p = 0.000).

Table 2 and Figure 2 show longitudinal changes in pain intensity in neurolysis on the NRS (M ± SD). Pain intensity during neurolysis with nerve block was statistically significantly lower at seven out of eight time points. At the last time point (24 hours), group 1 had lower pain intensity than group 2 (1.00 ± 1.64 vs. 3.60 ± 0.57), but this difference was not statistically significant (p = 0.063).

Tables 3 and 4 show agents and frequency of analgesic use by groups. Our data show that, regardless of the severity or nature of their limb surgeries, patients who received nerve block required additional analgesia significantly less frequently within 24 hours after surgery than patients who received other types of anesthesia support (46 vs. 70 cases, respectively).

Patients in group 2 who required additional analgesia primarily received non-opioid analgesics, such as non-steroidal anti-inflammatory drugs (NSAIDs) like ketorolac and non-steroidal analgesics like nefopam. During the postoperative period, group 1 did not require a combination of systemic analgesics.

Group 2 received both non-narcotic analgesics (tramadol, ketorolac, nefopam, and metamizole) and narcotic analgesics (trimeperidine, promedol). Two patients (9%, n = 24) received a combination of a NSAID and a non-steroidal analgesic with different mechanisms of action to achieve a synergistic effect (i.e., multimodal analgesia), because they did not experience adequate pain relief with a single analgesic agent.

DISCUSSION

The management of pain of varying intensity and postoperative analgesia block the cascade of pathophysiological mechanisms that trigger traumatic disease. This improves treatment outcomes for wounded patients [1].

No relevant studies were found in the available bibliometric databases. Some publications indicate that nerve blocks effectively reduce pain during and after arthroscopic surgeries on the lower limbs [6].

Our study provides evidence that analgesia was effective for both groups during the postoperative period. However, pain intensity was statistically significantly lower in group 1 than in group 2 at all nine time points: 0 h, p = 0.000; 3 h, p = 0.000; 6 h, p = 0,000; 9 h, p = 0.000; 12 h, p = 0.000; 15 h, p = 0.000; 18 h, p = 0.000; 21 h, p = 0.001; 24 h, p = 0.000.

In addition, group 2 required larger volumes and higher doses of systemic analgesics, including opioids, for postoperative pain management: 3 h, 0.00002 ($p < 0.05$); 6 h, 0.00805 ($p < 0.05$); 9 h, 0.00008 ($p < 0.05$); 12 h, 0.00562 ($p < 0.05$); 15 h, 0.00008 ($p < 0.05$); 18 h, 0.48530 ($p > 0.05$); 21 h, 0.00681 ($p < 0.05$). There was no difference in the need for analgesia at the 0-hour and 24-hour time points: 0.07435 ($p > 0.05$) and 0.06030 ($p > 0.05$), respectively. We suggest that persistent effective analgesia at the 0-hour point without a statistically significant difference in the need for analgesia is associated with the continued effect of intraoperative systemic analgesics or the persistent effects of SA.

The statistically significant difference in the need for analgesia at the 24-hour time point may be related to the nerve block wearing off after the 18-hour time point (p = 0.414).

Successful surgery requires selecting correct regional anesthesia techniques and local anesthetic agents. The onset

Table 1. Distribution of patients by age, sex, anthropometric measurements, and time of injury

Parameter	Total (n = 92)	Group 1 (n = 68)	Group 2 (n = 24)	Mann–Whitney U test	p
Age, years	34 (28; 43)	34 (28; 47)	35 (26; 41)	U = 184,0; Z = 0,346	0,728
Height, cm	174 (169; 180)	174 (169; 178)	175 (168; 180)	U = 170,0; Z = 0,420	0,673
Body weight, kg	75 (65; 80)	75 (65; 80)	72 (64,5; 81.5)	U = 181,0; Z = -0,108	0,913
BMI	23.93 (22.6; 26.0)	24.3 (22.7; 26.0)	22.6 (22,3; 27.1)	U = 155,5; Z = -0,811	0,416

Note. BMI, body mass index.

Table 2. Longitudinal changes in pain intensity as measured by the Numeric Rating Scale (M ± SD).

Anesthesia type and technique	0 h	3 h	6 h	9 h	12 h	15 h	18 h	21 h	24 h
Total cohort (*n* = 92)	0.3 ± 1.26	0.7 ± 2.07	0.9 ± 2.10	1.1 ± 2.37	1.4 ± 2.26	1.4 ± 2.22	2.3 ± 2.63	1.8 ± 2.25	1.9 ± 2.09
Nerve block (*n* = 68)	0.0 ± 0.16	0.2 ± 1.18	0.2 ± 0.83	0.2 ± 0.94	0.6 ± 1.51	0.7 ± 1.56	1.6 ± 2.13	1.2 ± 1.77	1.3 ± 1.92
General non-inhalation, general combined (inhalation + non-inhalation), and spinal anesthesia (*n* = 24)*	1.5 ± 2.72	3.1 ± 3.31	4.1 ± 2.99	5.0 ± 2.87	4.4 ± 2.66	4.4 ± 2.32	5.6 ± 2.13	4.5 ± 2.39	4.0 ± 1.31
Mann–Whitney *U* test	U = 73.0; Z = -3.729; ***p* = 0.000**	U = 57.5; Z = -4.248; ***p* = 0.000**	U = 39.0; Z = -4.620; ***p* = 0.000**	U = 22.5; Z = -5.139; ***p* = 0.000**	U = 35.0; Z = -3.261; ***p* = 0.000**	U = 33.0; Z = -3.996; ***p* = 0.000**	U = 26.5; Z = -3.734; ***p* = 0.000**	U = 42.0; Z = -3.279; ***p* = 0.001**	U = 37.5; Z = -3.338; ***p* = 0.000**
Neurolysis (*n* = 42)	0.1 ± 0.51	0.7 ± 2.25	0.7 ± 1.64	0.9 ± 2.09	0.8 ± 1.52	1.1 ± 1.71	1.6 ± 2.06	1.6 ± 2.29	1.2 ± 1.74
Neurolysis under nerve block (*n* = 36)	0.0 ± 0.23	0.3 ± 1.64	0.2 ± 0.94	0.2 ± 0.94	0.5 ± 1.29	0.7 ± 1.44	1.1 ± 1.79	1.0 ± 1.64	1.0 ± 164
Neurolysis without nerve block (*n* = 6)	1.0 ± 1.00	3.0 ± 4.35	4.0 ± 1.00	5.0 ± 2.64	3.0 ± 1.00	3.6 ± 0.57	4.3 ± 1.52	5.3 ± 2.30	3.6 ± 0.57
Mann–Whitney *U* test	U = 10.0; Z = -2.725; ***p* = 0.006**	U = 10.5; Z = -2.640; ***p* = 0.008**	U = 1.48; Z = -2.967; ***p* = 0.000**	U = 1.50; Z = -3.667; ***p* = 0.000**	U = 5.00; Z = -2.714; ***p* = 0.006**	U = 4.50; Z = -2.647; ***p* = 0.008**	U = 6.00; Z = -2.290; ***p* = 0.021**	U = 3.00; Z = -2.622; ***p* = 0.008**	U = 6.00; Z = -1.853; ***p* = 0.063**
Soft tissue surgery of the limbs without neurolysis with nerve block (*n* = 10).	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	1.4 ± 3.13	0.6 ± 1.34	1.0 ± 1.41
External fixation of long bones (*n* = 17)** and distal third transtibial amputation (*n* = 5) under nerve block	0.0 ± 0.00	0.0 ± 0.00	0.2 ± 0.90	0.3 ± 1.20	1.0 ± 1.84	0.5 ± 1.29	1.9 ± 1.64	1.8 ± 1.99	1.6 ± 1.89

Note. * General combined (inhalation + non-inhalation) anesthesia: *n* = 10; * General non-inhalation anesthesia: *n* = 4; * Spinal anesthesia: *n* = 10. ** Except femurs.

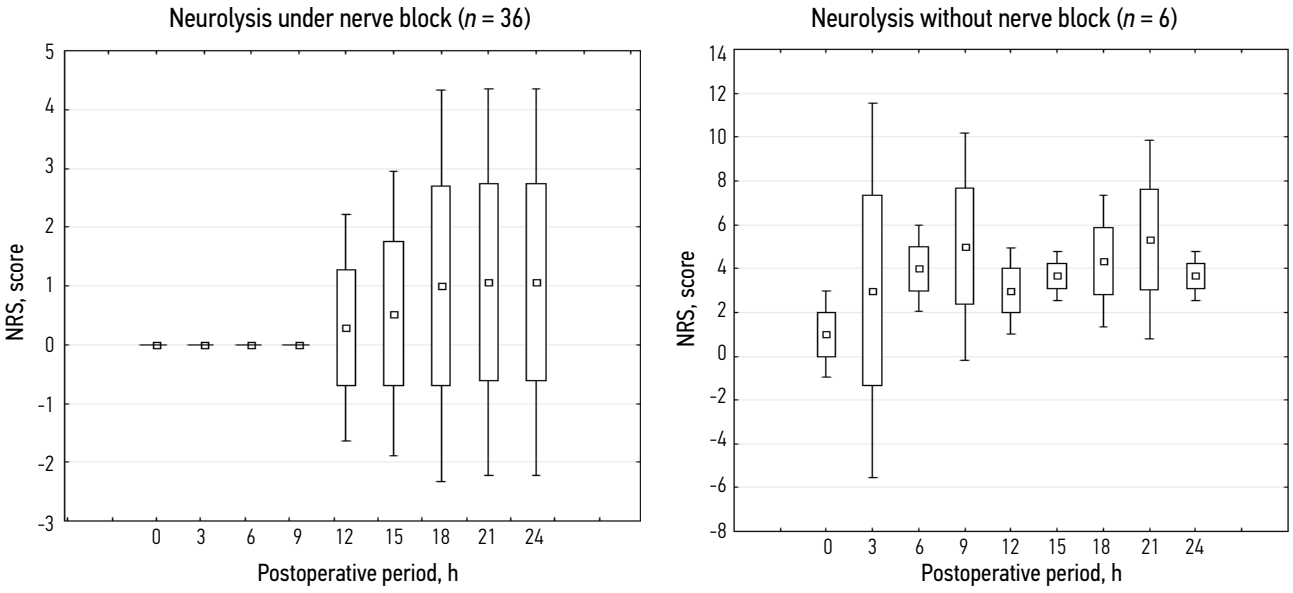

Fig. 2. Longitudinal changes in pain intensity in neurolysis, as measured by the Numeric Rating Scale (M ± SD). NRS, Numeric Rating Scale.

Table 3. Frequency of postoperative use of systemic analgesics (M ± SD)

Anesthesia type and technique	0 h	3 h	6 h	9 h	12 h	15 h	18 h	21 h	24 h
Total cohort (*n* = 92)	0.0 ± 0.145	0.0 ± 0.282	0.1 ± 0.337	0.2 ± 1.330	0.1 ± 0.359	0.1 ± 0.337	0.3 ± 0.471	0.1 ± 0.379	0.1 ± 0.311
Nerve block (*n* = 68)	0.0 ± 0.000	0.0 ± 0.000	0.0 ± 0.235	0.2 ± 1.521	0.0 ± 0.284	0.0 ± 0.169	0.2 ± 0.458	0.1 ± 0.322	0.0 ± 0.235
General non-inhalation, general combined (inhalation + non-inhalation), and spinal anesthesia (*n* = 24)*	0.0 ± 0.288	0.3 ± 0.492	0.3 ± 0.492	0.3 ± 0.492	0.3 ± 0.492	0.4 ± 0.514	0.4 ± 0.514	0.3 ± 0.492	0.2 ± 0.452
Mann–Whitney *U* test	U=192.5; Z=-1.659; ***p*=0.097**	U=140.0; Z=-3.507; ***p*=0.000**	U=152.0; Z=-2.462; ***p*=0.015**	U=148.0; Z=-2.806; ***p*=0.005**	U=158.0; Z=-2.037; ***p*=0.041**	U=128.5; Z=-3.418; ***p*=0.000**	U=182.5; Z=-0.815; ***p*=0.414**	U=164.0; Z=-1.704; ***p*=0.088**	U=169.0; Z=-1.826; ***p*=0.067**
Neurolysis (*n* = 42)	0.0 ± 0.000	0.0 ± 0.218	0.0 ± 0.218	0.0 ± 0.218	0.1 ± 0.358	0.0 ± 0.218	0.0 ± 0.300	0.0 ± 0.300	0.0 ± 0.218
Neurolysis under nerve block (*n* = 36)	0.0 ± 0.000	0.0 ± 0.000	0.0 ± 0.000	0.0 ± 0.000	0.1 ± 0.323	0.0 ± 0.000	0.0 ± 0.235	0.0 ± 0.235	0.0 ± 0.000
Neurolysis without nerve block (*n* = 6)	0.0 ± 0.000	0.3 ± 0.577	0.3 ± 0.577	0.3 ± 0.577	0.3 ± 0.577	0.3 ± 0.577	0.3 ± 0.577	0.3 ± 0.577	0.3 ± 0.577
Mann–Whitney *U* test	-	U=18.0; Z=2.313; ***p*=0.020**	U=18.0; Z=2.313; ***p*=0.020**	U=18.0; Z=2.313; ***p*=0.020**	U=21.0; Z=0.910; ***p*=0.326**	U=18.0; Z=2.313; ***p*=0.020**	U=19.5; Z=1.382; ***p*=0.016**	U=19.5; Z=1.382; ***p*=0.016**	U=18.0; Z=2.313; ***p*=0.020**
Soft tissue surgery of the limbs without neurolysis with nerve block (*n* = 10).	0.0 ± 0.000	0.0 ± 0.000	0.0 ± 0.000	0.0 ± 0.000	0.0 ± 0.000	0.0 ± 0.000	0.5 ± 0.577	0.0 ± 0.000	0.2 ± 0.500
External fixation of long bones (*n* = 17)** and distal third transtibial amputation (*n* = 5) under nerve block	0.0 ± 0.000	0.0 ± 0.000	0.1 ± 0.404	0.8 ± 2.713	0.0 ± 0.000	0.0 ± 0.000	0.6 ± 0.504	0.1 ± 0.404	0.0 ± 0.000

Note. * General combined (inhalation + non-inhalation) anesthesia: *n* = 10; * General non-inhalation anesthesia: *n* = 4; * Spinal anesthesia: *n* = 10.
** Except femurs.

time and duration of effect should correspond to the predicted intraoperative pain trajectory because pain trajectories vary in different surgeries. In some cases, postoperative pain lasts longer than the effects of a single local anesthetic injection. Adjuvants are added to long-acting local anesthetics used for nerve blocks to extend the duration of analgesia. This is helpful for surgeries involving predictable, medium-duration pain [7].

Ultrasound guidance for nerve blocks helps select the optimal site for local anesthetic injection and visualizes needle advancement within structures, thereby minimizing the risk of intraoperative complications. In addition, ultrasound guidance accelerates the effective plexus block, optimizing the perioperative period.

In 2023, Shchegolev et al. reached similar conclusions. They demonstrated that the use of current US-guided nerve block techniques in military hospitals during the special military operation resulted in a higher frequency of regional analgesia than in previous military conflicts [8].

Key findings

- The nerve block group demonstrated statistically significantly lower pain intensity during the early postoperative period (up to 18 hours) and at each of the nine time points within 24 hours after surgery, compared to group 2.
- In both groups, peak pain intensity was observed at 18 hours after surgery, with significantly higher pain intensity in group 2 compared to group 1 (US-guided nerve block): 5.60 ± 2.13 vs. 1.60 ± 2.13 (p = 0.00).
- The nerve block group had statistically significantly lower postoperative pain intensity with neurolysis for up to 21 hours. After 24 hours, pain severity was lower in group 1 (US-guided nerve block), but the difference was not statistically significant (p = 0.063).
- The need for systemic analgesics (both narcotic and non-narcotic) was statistically significantly lower in the nerve block group up to 21 hours after surgery (at 3, 6, 9, 12, 15, 18, 21 hours, $p < 0.05$).

Table 4. Frequency of postoperative analgesic use by agents

Agent	0 h		ϕ	3 h		ϕ	6 h		ϕ	9 h		ϕ	12 h		ϕ	15 h		ϕ	18 h		ϕ	21 h		ϕ	24 h		ϕ
	Group 1	Group 2		Group 1	Group 2		Group 1	Group 2		Group 1	Group 2		Group 1	Group 2		Group 1	Group 2		Group 1	Group 2		Group 1	Group 2		Group 1	Group 2	
Promedol 2% — 1,0			0.07435; $p > 0,05$		3	**0.00002; $p < 0.05$**		2	**0.00805; $p < 0.05$**			**0.00008; $p < 0.05$**			**0.00562; $p < 0.05$**			**0.00008; $p < 0.05$**			**0.48530; $p > 0.05$**			**0,00681; $p < 0,05$**			0,06030; $p > 0,05$
Tramadol 5% — 2,0		2			2						5		2				3			2			3		3		
Diclofenac 2,5% — 3,0										2																	
Ketorol 3% — 1,0					4		3	3			4		2	4		2	8		12	4		6	5			5	
Analgin (metamizole) 50% — 3,0								2						5						3		2					
Nefopam 1% — 2,0											2		3	2					6	1			4		1	1	
Acetaminophen 1% — 100,0																			2								

Note. ϕ, Fisher's exact test.

Study limitations

The study has several limitations. One of them is the imbalance in group size ($n = 68$ vs. $n = 24$), which impacts the statistical power of the comparison. In addition, group 2 combined several anesthesia techniques that were not compared individually, which could confound the results. An assessment of long-term effects is not possible due to the short follow-up period of 24 hours. These findings only apply to patients with combat-related injuries, which limits their applicability to other patient groups.

CONCLUSION

US-guided nerve block is the preferred option for surgical treatment of blast and fragmentation injuries to limbs in tertiary military medical centers. This is supported by the lower need for additional pain management, greater patient comfort, and faster mobilization during the early postoperative period, due to an absence of residual general anesthesia effects and low pain intensity. In addition, it requires fewer medical resources for supplemental analgesia and monitoring during awakening and throughout the early postoperative period. This is especially important when resources are limited.

US-guided nerve block allows for the simultaneous performance of multiple anesthetic procedures. This optimizes anesthesia service at the tertiary care level (specialized surgical care for urgent/timely/deferred indications), which corresponds to Federal Law of the Russian Federation No. 323-FZ dated November 21, 2011 Basics of Health Protection of the Citizens in the Russian Federation during mass influxes of wounded or injured personnel and under conditions of physician staff shortages.

ADDITIONAL INFORMATION

Author contributions: M.O. Magomedaliev: conceptualization, formal analysis, statistical analysis, interpretation, writing—original draft, graphic support; D.I. Korabelnokov: conceptualization, formal analysis, interpretation, writing—review & editing; M.A. Gafurov: formal analysis, interpretation; E.V. Tkachenko: formal analysis, interpretation. All the authors approved the final version before publication and agreed to be accountable for all aspects of the paper, ensuring that questions related to the accuracy or integrity of any part of the study are appropriately investigated and resolved.

Funding sources: None.

Disclosure of interests: The authors have no relationships, activities, or interests for the last three years related to for-profit or not-for-profit third parties whose interests may be affected by the content of the article.

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