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The Influence of Preoperative Situational Anxiety on Postoperative Pain Sensitivity: Implications for Anesthetic Technique Selection in Laparoscopic Abdominal Surgery

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Research Article

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Abstract

Introduction:

This pilot prospective study aimed to improve the effectiveness of perioperative analgesia in patients undergoing laparoscopic abdominal surgery (LAS) through an individualized choice of anesthetic technique based on preoperative situational anxiety (SA) and pain threshold (PT).

Materials and methods

The study included 120 patients aged 22–82 years (25 men [20.8%] and 95 women [79.2%]) who underwent laparoscopic surgery for abdominal conditions of various localizations. Postoperative hyperalgesia (PH) was assessed using measures of peripheral and central pain sensitization, including changes in PT and the extent of the pain perception zone (PPZ). Preoperative psychometric assessment was combined with quantitative sensory testing using algometry.

Results

In patients with low preoperative anxiety (SA ≤ 44 points), both anesthesia methods (MGA and CA) were reliable in preventing signs of PH. However, highly anxious patients (SA ≥ 45) required combined spinal anesthesia, since the isolated use of multicomponent general anesthesia in laparoscopic abdominal surgical interventions was unable to prevent manifestations of postoperative hyperalgesia.

Conclusions

The findings support an individualized approach to anesthetic selection in patients undergoing LAS. Both the combined anesthesia (CA) and the multicomponent general anesthesia (MGA) may be appropriate for patients with low preoperative SA, whereas CA may be preferable in patients with high SA (≥ 45 points on the Spielberger–Hanin scale). These findings should be interpreted in light of the pilot study design and require confirmation in larger studies.

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Introduction

Inadequate management of acute postoperative pain may contribute to the development of chronic postsurgical pain, which is associated with substantial socioeconomic costs and highlights the need for effective preventive strategies. The incidence of chronic postsurgical pain varies considerably depending on the type of surgical procedure, patient characteristics, and the diagnostic criteria used. Chronic pain is also a major public health concern, and its burden is expected to remain substantial [1, 2, 3]. The economic impact of this condition is considerable: according to estimates published in 2025, the total

economic costs of chronic pain in the United States in 2021 amounted to approximately $722.8 billion, including direct medical expenditures and losses in work productivity [4].

Identifying predictors of postoperative hyperalgesia and risk factors for chronic postsurgical pain is therefore an important objective in contemporary anesthesiology and is consistent with the principles of Enhanced Recovery After Surgery (ERAS).

The combination of minimally invasive surgery and ERAS principles represents a major advance in modern abdominal surgery. The development of laparoscopic techniques, pioneered by Kurt Semm and Philippe Mouret [5, 6], was complemented by the work of Henrik Kehlet and Douglas W. Wilmore, which contributed substantially to the development of modern perioperative care and the ERAS approach [7]. This multifaceted strategy not only enhances the benefits of minimally invasive surgery but also highlights the importance of optimizing anesthetic management, even in procedures associated with relatively limited surgical trauma [8].

Despite the widespread adoption of day-case surgery in Western Europe and North America, effective management of acute postoperative pain remains a challenge [9, 10, 11]. Epidemiological studies have reported moderate-to-severe postoperative pain in 30–75% of patients, while more than 80% report clinically significant pain during the early postoperative period. Approximately half of patients remain dissatisfied with the quality of postoperative analgesia [12, 13, 14].

Recent neurophysiological research on postoperative hyperalgesia and pain sensitization, including studies by Steven E. Harte and Mary M. Volcheck, reflects growing scientific interest in the mechanisms underlying the development and persistence of pathological pain. A better understanding of peripheral and central sensitization provides a rationale for pharmacological and regional interventions targeting different mechanisms involved in postoperative pain amplification [15, 16].

A multimodal approach to perioperative analgesia can reduce the intensity of acute postoperative pain and, in appropriate clinical settings, its duration [17, 18]. However, intraoperative administration of high doses of opioids may contribute to opioid-induced hyperalgesia, potentially complicating postoperative pain management and warranting consideration of strategies to minimize unnecessary opioid exposure [19]. Prevention and management of postoperative hyperalgesia may also benefit from regional anesthesia and analgesia, which can modulate nociceptive transmission at different levels of the nervous system, from peripheral transduction at the site of tissue injury to central processing of nociceptive signals. Procedure-specific recommendations developed by the PROSPECT Working Group support the use of selected regional techniques as components of multimodal analgesia for laparoscopic abdominal procedures, depending on the type of surgery and the patient's risk profile [20].

One possible explanation for the suboptimal prevention of postoperative hyperalgesia in patients undergoing laparoscopic abdominal surgery is the insufficient consideration of individual patient-related risk factors for pain sensitization. Accordingly, objective assessment of preoperative psycho-emotional

status and quantitative evaluation of pain sensitivity may help identify patients at increased risk of adverse postoperative pain outcomes and inform the individualized selection of anesthetic techniques.

Aim of the study

To optimize perioperative analgesia in patients undergoing laparoscopic abdominal surgery through an individualized selection of anesthetic technique based on preoperative situational anxiety and pain sensitivity.

Materials and methods

This pilot prospective study used a paired preoperative–postoperative assessment design. Participants were allocated to four groups according to their preoperative situational anxiety level and the anesthetic technique used: multicomponent general anesthesia or combined anesthesia.

The study included 120 patients (25 men [20.8%] and 95 women [79.2%]), aged 22–82 years, with excess body weight, who underwent abdominal surgery at the clinical sites of the Department of Anesthesiology and Intensive Care of Bogomolets National Medical University between 2020 and 2026.

The distribution of surgical diagnoses is presented in Table 1.

Table 1
Distribution of patients by nosological forms of disease

Nosologies	n (of 120)	Percentage, %	95% CI, %
Chronic cholecystitis	63	52.5	43.63–61.22
Acute cholecystitis	25	20.8	14.53–28.95
Acute appendicitis	21	17.5	11.74–25.28
Chronic appendicitis	4	3.3	1.30–8.26
Umbilical hernia	2	1.7	0.46–5.87
Incisional hernia	1	0.8	0.15–4.57
Inguinal hernia	1	0.8	0.15–4.57
Ovarian cyst rupture	1	0.8	0.15–4.57
Ectopic pregnancy	1	0.8	0.15–4.57
Adhesive disease	1	0.8	0.15–4.57
Total	120	100	

Note: n — absolute number of patients; the proportion was calculated from the total sample (n = 120); the 95% CI was calculated using the Wilson method.

More than 94% of the cases involved gallbladder pathology (73.3%) or acute appendicitis (20.8%). The remaining diagnoses were represented by isolated cases, which should be considered when interpreting the findings and assessing their generalizability.

The study compared four groups defined by the combination of two factors: preoperative psychophysiological status and anesthetic technique. Depending on these factors, the patients were divided into four groups of 30 patients each. At baseline, the groups showed no statistically significant differences in their main demographic, anthropometric, clinical, or medical history characteristics ($p > 0.05$), supporting the comparability of the groups for subsequent intergroup analyses (Table 2).

Table 2
Clinical characteristics of patients.

Parameter	**Group**				**Total**	**p**
	1 (n = 30)	**2 (n = 30)**	**3 (n = 30)**	**4 (n = 30)**	***(n = 120)***	
Sex:	**6**	**6**	**7**	**6**	**25**	
men	**24**	**24**	**23**	**24**	**95**	
women						
Mean age, years	55.83 ± 12.28	52.26 ± 13.69	56.73 ± 15.24	54.90 ± 14.889	54.93 ± 14.00	$p_H >$ 0,05
Body weight, kg	91.13 ± 14.27	82.73 ± 11.01	86.91 ± 13.13	87.10 ± 12.52	86.97 ± 12.97	$p_H >$ 0,05
Body mass index	32.65 ± 4.64	30.48 ± 3.94	31.58 ± 4.38	31.48 ± 3.60	31.55 ± 4.18	$p_H >$ 0,05
ASA	3	9	3	6	21	$p_H >$ 0,05
I	27	21	27	24	99	
II						

Note: p – assessment of the significance of differences using the Kruskal–Wallis H test for quantitative variables and the χ^2 test for categorical variables. Quantitative parameters are presented as M ± SD, categorical ones (sex, ASA class) as the absolute number of patients.

The study included patients with the aforementioned surgical conditions and concomitant diseases in the compensated or subcompensated stage (Table 3). None of the patients required urgent pharmacological intervention or medication administration that could interfere with the planned anesthetic technique.

Table 3
Structure of concomitant pathology and conditions in the study patients

Parameter	Group				Total
	1 (n = 30)	2 (n = 30)	3 (n = 30)	4 (n = 30)	*(n = 120)*
Hypertensive disease	22 (73,33%)	12 (40%)	22 (73,33%)	18 (60%)	74 (61,67%)
Atherosclerotic myocardial fibrosis	7 (23,33%)	7 (23,33%)	7 (23,33%)	11 (36,67%)	32 (26,67%)
Chronic obstructive pulmonary disease	4 (13,3%)	3 (10%)	3 (10%)		10 (8.33%)
Diabetes mellitus type 2	2 (6,67%)		3 (10%)	3 (10%)	8 (6,67%)
Atrial fibrillation (persistent form)	1 (3,33%)		2 (6,67%)	2 (6,67%)	5 (4,17%)
Post-infarction myocardial fibrosis	1 (3,33%)		2 (6,67%)		3 (2,5%)
Sinus tachycardia				3 (10%)	3 (2,5%)
Sinus bradycardia		1 (3,33%)		1 (3,33%)	2 (1.67%)
Chronic pancreatitis			2 (6,67%)		2 (1,67%)
Hypothyroidism				1 (3,33%)	1 (0,83%)
Pregnancy, 5 weeks			1 (3,33%)		1 (0,83%)
Dilated cardiomyopathy			1 (3,37%)		1 (0,83%)

Hypertensive disease (61.67%) and atherosclerotic myocardial fibrosis (26.67%) were the most prevalent comorbid conditions. Intergroup comparisons of the prevalence of hypertension using Fisher's angular transformation (φ* criterion), with adjustment for multiple comparisons using the Hochberg procedure (adjusted p = 0.094), revealed no statistically significant differences. Similarly, no statistically significant between-group differences were found in the prevalence of the other chronic conditions (p = 0.119–1.000).

Patients were excluded from the study if they met any of the following criteria:

- decompensated comorbid conditions or an unstable clinical status that could affect the perioperative course;
- known hypersensitivity or intolerance to amide local anesthetics;
- regular systemic use of medications that could alter psycho-emotional status or pain perception, including opioid analgesics, tranquilizers, antidepressants, antipsychotics, and other psychotropic agents;
- diagnosed psychotic disorders, severe affective disorders, or other mental conditions that could compromise communication with the patient, the reliability of psychometric assessment, or the evaluation of subjective pain measures.
- Before surgery, all participants underwent quantitative assessment of the mechanical pain threshold using a set of von Frey sensory monofilaments in two anatomical sites: the skin of the medial forearm and the nipple areola complex (NAC)[21, 22, 23]. The monofilaments were calibrated according to the force required to bend each filament upon contact with the skin. The applied force was expressed in gram-force (gf).
- Pain threshold values in the forearm region ranged from 26.0 to 100.0 gf, with values of 26.0, 60.0, and 100.0 gf observed in 5.8%, 64.2%, and 30.0% of patients, respectively. In the NAC, the values ranged from 6.0 to 10.0 gf, with values of 6.0, 8.0, and 10.0 gf observed in 22.1%, 61.2%, and 16.7% of patients, respectively.
- Preoperative situational anxiety was assessed using the validated Spielberger–Hanin State-Trait Anxiety Inventory. A score of ≤ 44 points was classified as low situational anxiety, whereas a score of ≥ 45 points was classified as high situational anxiety.

Table 4
Psychophysiological parameters of patients.

Parameter	Group				Total	p
	1 (n = 30)	2 (n = 30)	3 (n = 30)	4 (n = 30)	*(n = 120)*	
State of situational anxiety	37,20 ± 1,73	37,10 ± 2,12	48,23 ± 4,07	47,43 ± 2,81	42,49 ± 6,05	p_{1-3} < 0,001 p_{2-4} < 0,001
Pain threshold level before the intervention (forearm)	80 [60–100]	60 [60–100]	60 [60–100]	60 [60–100]	60 [60–100]	p_H > 0,05
Pain threshold level before the intervention (NAC)	8 [8–10]	8 [8–10]	8 [8–8]	8 [8–8]	8 [8–8]	p_H > 0,05
Pain threshold level after the intervention (forearm)	60 [60–100]	60 [60–90]	60 [60–60]	60 [60–60]	60 [60–60]	p_{1-3} = 0,037
Pain threshold level after the intervention (NAC)	8 [6–8]	8 [6–8]	8 [6–8]	6 [6–8]	8 [6–8]	p_{1-2} = 0,112 p_{3-4} = 0,146

Note: p – assessment of the significance of differences using the Kruskal–Wallis H test. Situational anxiety (SA) values are presented as M ± SD, pain threshold (PT) and pain perception zone values as Me [Q1–Q3] (the distribution differs from normal according to the Lilliefors test).

Parameter	Group				Total	p
	1 (n = 30)	2 (n = 30)	3 (n = 30)	4 (n = 30)	*(n = 120)*	
Expansion of the pain perception zone, cm	2.50 [2.12–3.00]	2.50 [2.50–3.00]	2.50 [2.50–3.50]	3.00 [2.50–3.50]	2.50 [2.50–3.50]	p_{1-2} = 0,618 p_{3-4} = 0,264 p_{1-3} = 0,214 p_{2-4} = 0,053

Note: p – assessment of the significance of differences using the Kruskal–Wallis H test. Situational anxiety (SA) values are presented as M ± SD, pain threshold (PT) and pain perception zone values as Me [Q1–Q3] (the distribution differs from normal according to the Lilliefors test).

The groups were comparable in terms of preoperative pain threshold (PT) values ($p > 0.05$). Differences in situational anxiety (SA) levels between the groups reflected the study design, as the groups were specifically formed according to this characteristic, and therefore did not indicate unintended sample heterogeneity.

All patients underwent laparoscopic abdominal surgery with carbon dioxide pneumoperitoneum under one of two anesthetic techniques: multicomponent general anesthesia (MGA) or combined anesthesia (CA). MGA involved inhalational anesthesia with sevoflurane or intravenous anesthesia with propofol, together with opioid analgesia using fentanyl and mechanical ventilation (MV). Spinal anesthesia (SpA) was performed using the conventional technique at the L3–L4 interspace, with 7.5–12.5 mg of 0.5% hyperbaric bupivacaine. CA consisted of spinal anesthesia combined with MGA.

According to preoperative SA level and anesthetic technique, the patients were allocated to four groups of 30 patients each:

- Group 1: patients with low SA (≤ 44 points) who received CA.
- Group 2: patients with low SA (≤ 44 points) who received MGA alone.
- Group 3: patients with high SA (≥ 45 points) who received CA.
- Group 4: patients with high SA (≥ 45 points) who received MGA alone.

One hour after emergence from general anesthesia, the mechanical pain threshold was reassessed using von Frey sensory monofilaments at two anatomical sites: the skin of the medial forearm and the NAC [21, 22, 23]. The change in PT was calculated by comparing postoperative and preoperative

measurements. The extent of expansion of the pain perception zone from the surgical wound into surrounding intact tissue was also assessed and measured in centimeters.

A postoperative decrease in PT was considered an indicator consistent with peripheral pain sensitization (PPS). Expansion of the area of increased pain sensitivity beyond the surgical wound was used as a clinical indicator suggestive of central pain sensitization (CPS). These findings were interpreted as clinical manifestations associated with postoperative hyperalgesia rather than as definitive proof of the underlying sensitization mechanisms.

Statistical analyses were performed using IBM SPSS Statistics, version 20.0 (IBM Corp., Armonk, NY, USA). Normality of the data distribution was assessed using the Lilliefors test. Normally distributed quantitative variables were expressed as mean ± standard deviation (M ± SD), whereas non-normally distributed variables were reported as median and interquartile range (Me [Q1–Q3]) [24]. Categorical variables were summarized as frequencies and percentages, with 95% confidence intervals (CIs) calculated using the Wilson method [26, 27, 28].

Between-group comparisons involving two independent groups were performed using the independent-samples Student's t-test or the Mann–Whitney U test, as appropriate. Comparisons across three or more independent groups were performed using the Kruskal–Wallis H test. Preoperative and postoperative PT measurements within the same patients were compared using the Wilcoxon signed-rank test or the sign test, as appropriate. Categorical variables were compared using the chi-square (χ^2) test or Fisher's angular transformation test (φ^* criterion), as appropriate [24, 25]. The primary outcome was the change in PT (ΔPT) from the preoperative to the postoperative assessment. The associations of SA level and anesthetic technique with the study outcomes were examined using prespecified pairwise comparisons. The Bonferroni and Hochberg procedures were applied, as appropriate, to adjust for multiple comparisons. Statistical significance was set at $p < 0.05$. Values between 0.05 and 0.10 were interpreted as suggestive of a possible association and were not considered statistically significant.

Clinical and statistical monitoring of the anesthetic and surgical course was performed throughout the perioperative period (Table 5).

Table 5
Characteristics of perioperative parametric monitoring of patients

Parameter	**Group**				**p**
	1 (n = 30)	**2 (n = 30)**	**3 (n = 30)**	**4 (n = 30)**	
Intraoperative fentanyl consumption, μg	300 [200; 375]	750 [600; 900]	300 [200; 400]	700 [600; 900]	p_{1-2} < 0,0001 p_{3-4} < *0,0001*
Postoperative fentanyl use, doses	0 [0; 0]	0 [0; 0]	0 [0; 1]	1 [0; 1]	p_{1-3} = 0,0056 p_{2-4} = *0,0016*
Duration of surgical intervention, hours	1.00 [0.77; 1.29]	1.23 [1.00; 1.67]	1.10 [0.83; 1.58]	1.25 [0.93; 1.77]	p > 0,05
Volume of intravenous infusion during anesthesia, liters	1.25 [1.20; 1.60]	1.20 [0.80; 1.20]	1.25 [1.20; 1.60]	0.80 [0.80; 1.20]	p_{1-2} = 0,0013 p_{3-4} < *0,0001*
Length of stay in the intensive care unit, hours	4.00 [2.22; 5.45]	4.13 [3.17; 5.40]	4.10 [3.32; 8.85]	4.30 [3.20; 13.65]	p_H > 0,05
Duration of the postoperative period, days	3 [2; 4]	5 [4; 6]	3 [2; 3]	5 [4; 6]	p_{1-2} < 0,0001 p_{3-4} < *0,0001*

Note: p – *assessment of the significance of differences using the Kruskal–Wallis H test.*

Intraoperative fentanyl consumption differed significantly according to the anesthetic technique, with higher doses administered to patients in groups 2 and 4, who received multicomponent general anesthesia (MGA) alone (Bonferroni-adjusted $p < 0.0001$). Analysis of postoperative patient-controlled fentanyl use revealed a significant effect of situational anxiety (SA) level, with differences observed between groups 1 and 3 ($p = 0.0056$) and between groups 2 and 4 ($p = 0.0016$).

Intravenous fluid volumes were significantly higher in the combined anesthesia (CA) groups than in the corresponding MGA groups (group 1 vs. group 2, $p = 0.0013$; group 3 vs. group 4, $p < 0.0001$). The duration of the postoperative period was significantly longer in the MGA groups (Bonferroni-adjusted $p < 0.0001$).

No statistically significant between-group differences were observed in the duration of surgery or the length of stay in the intensive care unit (ICU) ($p > 0.05$). Intraoperative monitoring included heart rate (HR) and mean arterial pressure (MAP).

Hemodynamic changes across all study groups were generally consistent with the expected physiological responses during laparoscopic abdominal surgery. However, patients in the multicomponent general anesthesia (MGA) groups (groups 2 and 4) showed a tendency toward increased mean arterial pressure (MAP). Between the second and third intraoperative assessment time points, increases in MAP were observed in these groups, reaching statistical significance in group 4 ($p < 0.01$). In contrast, patients in the combined anesthesia (CA) groups (groups 1 and 3) exhibited significant decreases in heart rate (HR) and MAP during the same period ($p < 0.001$).

Comparison of intraoperative hemodynamic changes revealed differences between the two anesthetic techniques—multicomponent general anesthesia (MGA) and combined anesthesia (CA)—in their effects on hemodynamic stability, particularly during carbon dioxide pneumoperitoneum. Statistically significant between-group differences in mean arterial pressure (MAP) were observed in the corresponding comparisons (group 1 vs. group 2 and group 3 vs. group 4).

MAP values were higher in the MGA groups (groups 2 and 4) at the 20th minute after induction of anesthesia (group 1 vs. group 2, $p = 0.045$), at the initial establishment of carbon dioxide pneumoperitoneum ($p < 0.001$), and at the 30th minute of pneumoperitoneum maintenance ($p < 0.05$). No statistically significant between-group differences in MAP were detected at the other intraoperative assessment time points ($p > 0.05$).

Results

1. Homogeneity of samples

Statistical analyses using the chi-square (χ^2) test, Fisher's angular transformation (φ^* criterion), and the Kruskal–Wallis H test revealed no statistically significant between-group differences ($p > 0.05$) in the key baseline characteristics, including sex, age, body weight, and preoperative pain threshold, or in the duration of surgery. These findings support the comparability of the groups with respect to the assessed variables.

2. Intergroup comparisons

Table 6
Characteristics of intergroup changes in pain threshold level

Study area	Group	p_z	p_w
Forearm	Gr.1 (low SA, CA)	0.2500	0.0833
	Gr.2 (low SA, MGA)	0.1250	0.0633
	Gr.3 (high SA, CA)	**0.0039**	**0.0062**
	Gr.4 (high SA, MGA)	**0.0005**	**0.0016**
NAC	Gr.1 (low SA, CA)	**0.0005**	**0.0005**
	Gr.2 (low SA, MGA)	**0.0001**	**0.0001**
	Gr.3 (high SA, CA)	**0.0001**	**0.0001**
	Gr.4 (high SA, MGA)	**0.0001**	**0.0001**

Note: p_z *– sign test*, p_w*– Wilcoxon signed-rank test.*

Among patients with low situational anxiety (SA) (groups 1 and 2), postoperative pain threshold (PT) values at the forearm site did not change significantly ($p > 0.05$). In contrast, patients with high SA (groups 3 and 4) exhibited a statistically significant postoperative decrease in PT ($p < 0.05$). At the NAC site, a significant postoperative decrease in PT was observed in all four groups ($p < 0.001$).

The sign test and Wilcoxon signed-rank test revealed statistically significant preoperative-to-postoperative changes in PT in groups 1 and 3 (Table 6). However, differences in the statistical significance of within-group changes do not, in themselves, establish statistically significant differences in the magnitude of these changes between groups. Direct between-group comparisons of ΔPT are therefore required to determine whether the anesthetic technique was associated with different postoperative changes in pain sensitivity.

Overall, postoperative PT dynamics varied according to the patients' preoperative SA level, the anesthetic technique used, and the anatomical site of assessment.

3. Influence of situational anxiety and anesthesia method on postoperative pain threshold parameters

The influence of the baseline SA level was assessed by pairwise comparison of postoperative changes in pain threshold level between groups 1–3 and 2–4 (Table 7).

Table 7
Characteristics of intergroup comparison of changes in pain threshold level

Stude area	Parameter	Comparison	p	p_1
Forearm	Before surgery	Gr.1–Gr.2	0.1972	0.7886
		Gr.2–Gr.4	0.7902	1.0000
		Gr.1–Gr.3	0.1189	0.4758
		Gr.3–Gr.4	1.0000	1.0000
	After surgery	Gr.1–Gr.2	0.1736	0.6945
		Gr.2–Gr.4	0.0532	0.2129
		Gr.1–Gr.3	0.0093	0.0373
		Gr.3–Gr.4	0.5174	1.0000
	Delta (before − after)	Gr.1–Gr.2	0.7602	1.0000
		Gr.2–Gr.4	0.0250	0.1001
		Gr.1–Gr.3	0.0820	0.3281
		Gr.3–Gr.4	0.4519	1.0000
NAC	Before surgery	Gr.1–Gr.2	0.7902	1.0000
		Gr.2–Gr.4	0.2299	0.9196
		Gr.1–Gr.3	0.0709	0.2837
		Gr.3–Gr.4	0.7289	1.0000
	After surgery	Gr.1–Gr.2	0.1120	0.4480
		Gr.2–Gr.4	0.2459	0.9837
		Gr.1–Gr.3	0.1126	0.4505
		Gr.3–Gr.4	0.1459	0.5837
	Delta (before − after)	Gr.1–Gr.2	0.0613	0.2453
		Gr.2–Gr.4	0.5458	1.0000
		Gr.1–Gr.3	0.4452	1.0000
		Gr.3–Gr.4	0.0666	0.2664

Note: **p** *– за критерієм Mann–Whitney U test*, p_1 *– with Bonferroni correction for multiple coparisons (k = 4). The absence of preoperative differences in all pairs (p > 0,05) confirms the baseline comparability of the groups.*

The most pronounced difference in postoperative pain threshold (PT) at the forearm site was observed between the combined anesthesia groups (groups 1 and 3; $p = 0.0093$). In the multicomponent general anesthesia (MGA) groups (groups 2 and 4), the between-group difference approached, but did not reach, statistical significance ($p = 0.053$).

Analysis of changes in PT (ΔPT) showed a greater postoperative decrease in patients with high situational anxiety (SA), although the difference was statistically significant only in the MGA groups (groups 2 and 4; $p = 0.025$), whereas the corresponding comparison between the combined anesthesia groups (groups 1 and 3) did not reach statistical significance ($p = 0.082$). At the NAC site, no statistically significant differences in either absolute PT values or the magnitude of their changes were found between patients with different SA levels ($p > 0.05$).

The effects of anesthetic technique were compared between groups 1 and 2 and between groups 3 and 4. At the forearm site, no statistically significant between-group differences were found in either absolute PT values or their postoperative changes ($p > 0.05$). At the NAC site, postoperative PT values did not differ significantly between the anesthetic techniques ($p > 0.05$). However, the analysis of ΔPT showed trends toward a smaller magnitude of postoperative PT change with combined anesthesia in both patients with low SA (groups 1 and 2; $p = 0.061$) and those with high SA (groups 3 and 4; $p = 0.067$).

To further evaluate the associations of SA level and anesthetic technique with postoperative pain sensitivity, pooled groups were analyzed according to SA level (groups 1 and 2 vs groups 3 and 4) and anesthetic technique (groups 1 and 3 vs groups 2 and 4). At the forearm site, postoperative PT was significantly higher in patients with low SA than in those with high SA ($p = 0.001$). The magnitude of the postoperative PT decrease was also greater in patients with high SA ($p = 0.005$). At the NAC site, patients receiving MGA had significantly lower postoperative PT values ($p = 0.035$) and a greater magnitude of PT decrease ($p = 0.008$) than those receiving combined anesthesia.

To assess factors associated with the postoperative expansion of the pain perception zone (PPZ), the pooled groups were compared using the Mann–Whitney U test. Patients with high preoperative SA (≥ 45 points) exhibited significantly greater PPZ expansion after surgery than those with low SA (≤ 44 points; $p = 0.027$). This finding suggests an association between higher preoperative anxiety and more pronounced postoperative expansion of the pain perception zone. No statistically significant differences in PPZ expansion were found between the combined anesthesia and MGA groups ($p > 0.05$).

Overall, the pooled-group analysis revealed site-dependent differences in postoperative PT changes. Higher preoperative SA was associated with a greater reduction in PT at the forearm site and greater postoperative PPZ expansion, whereas MGA was associated with a greater reduction in PT at the NAC site. No statistically significant difference in PPZ expansion was detected between anesthetic techniques.

4. Intergroup comparisons by qualitative variables.

Analysis using the odds ratio (OR) indicated an association between preoperative situational anxiety (SA) and postoperative pain threshold (PT). OR values below 1 in comparisons between patients with low and high SA (groups 1 vs. 3 and groups 2 vs. 4) suggest lower odds of a higher postoperative PT in patients with high SA (Fig. 3).

Among patients with high preoperative situational anxiety (SA), those receiving multicomponent general anesthesia (MGA; group 4) had 4.3-fold higher odds of a postoperative decrease in pain threshold (PT) at the forearm site than patients with low SA receiving the same anesthetic technique (group 2) (OR = 0.231; 95% CI: 0.064–0.831; Fisher's exact test, p = 0.0391). The comparison between patients receiving combined anesthesia (CA) showed a similar direction of association: the odds of a postoperative PT decrease were approximately 3.9-fold higher in patients with high SA (group 3) than in those with low SA (group 1), although the result did not reach statistical significance (OR = 0.259; 95% CI: 0.062–1.079; Fisher's exact test, p = 0.1042). No statistically significant associations between SA level and postoperative PT changes were observed at the NAC site in either the MGA groups (groups 2 vs. 4) or the CA groups (groups 1 vs. 3; $p > 0.05$).

The analysis also suggested a possible association between anesthetic technique and postoperative PT changes. Among patients with low preoperative SA, the odds of a postoperative PT decrease were higher with MGA than with CA (group 2 vs. group 1); however, the difference did not reach statistical significance (OR = 2.591; 95% CI: 0.914–7.342; χ^2 test, p = 0.0705). A similar trend was observed among patients with high SA, in whom the odds of a postoperative PT decrease were approximately 2.8 times higher with MGA than with CA (group 4 vs. group 3; OR = 2.750; 95% CI: 0.934–8.100; χ^2 test, p = 0.0631). These findings suggest a potential association between anesthetic technique and postoperative changes in pain sensitivity, but the differences did not reach the conventional threshold for statistical significance.

Pairwise comparisons of algometric parameters at the forearm site did not reveal statistically significant differences attributable to the anesthetic technique ($p > 0.05$; Fig. 4). After adjustment for multiple comparisons, the analysis of postoperative changes in pain threshold (PT) identified a trend toward a between-group difference only in the comparison of groups 2 and 4 (Table 8).

Overall, the findings suggest that preoperative situational anxiety (SA) is associated with postoperative pain sensitivity, whereas the potential contribution of anesthetic technique remains uncertain. The observed between-group differences that approached statistical significance should be interpreted cautiously and do not establish a corrective or protective effect of either anesthetic technique.

The findings from the analysis of categorical variables were further examined in pooled samples (n = 60 per pooled group). As in the quantitative analysis, patients were pooled according to preoperative SA level (groups 1 and 2 vs. groups 3 and 4) and anesthetic technique (groups 1 and 3 vs. groups 2 and 4).

Table 8
Indicators of postoperative changes in pain threshold level

Stude area	Comparison	p	p_{Bonf}
Forearm	Group 2 – Group 4	0.0195	0.0781
	Group 1 – Group 3	0.0528	0.2112
	Group 2 – Group 1	0.6876	1.0000
	Group 4 – Group 3	0.4168	1.0000
Peri-incisional skin	Group 2 – Group 4	0.4051	1.0000
	Group 1 – Group 3	0.4363	1.0000
	Group 2 – Group 1	0.0705	0.2822
	Group 4 – Group 3	0.0631	0.2523

Note: **p** – *χ² test;* p_{Bonf} – *with Bonferroni correction for multiple coparisons (k = 4).*

The findings from the analysis of categorical variables were further evaluated in pooled patient samples (n = 60 per pooled group). As in the quantitative analysis, patients were grouped according to preoperative situational anxiety (SA) level (groups 1 and 2 vs. groups 3 and 4) and anesthetic technique (groups 1 and 3 vs. groups 2 and 4).

Pairwise analysis of pooled data (n = 60 per pooled group) on postoperative algometric parameters at the forearm site demonstrated an association between preoperative situational anxiety (SA) and postoperative changes in pain sensitivity. Patients with high SA (groups 3 and 4) had significantly higher odds of a postoperative decrease in pain threshold (PT) than patients with low SA (groups 1 and 2) (OR = 0.25; 95% CI: 0.09–0.63; χ² test, p = 0.0025). In contrast, no statistically significant association was found between anesthetic technique (multicomponent general anesthesia vs. combined anesthesia) and postoperative PT changes at this site (OR = 1.45; 95% CI: 0.62–3.33; χ² test, p = 0.3880).

At the NAC site, pooled analysis revealed a statistically significant association between anesthetic technique and postoperative PT changes. Patients receiving MGA (groups 2 and 4) had higher odds of a postoperative decrease in PT than those receiving CA (groups 1 and 3) (OR = 2.64; 95% CI: 1.25–5.55; χ² test, p = 0.0099). No statistically significant association was found between preoperative SA level and postoperative PT changes at this site (OR = 0.66; 95% CI: 0.33–1.37; χ² test, p = 0.2690; Fig. 5).

Taken together, these findings suggest that the associations of preoperative SA and anesthetic technique with postoperative pain sensitivity differed between the anatomical sites assessed. Higher SA was associated with an increased likelihood of a postoperative PT decrease at the forearm site, whereas MGA was associated with higher odds of a PT decrease at the NAC site. These findings are consistent with differences in postoperative pain sensitivity according to psychological status, anesthetic

technique, and measurement site; however, a decrease in PT alone does not establish the presence of postoperative hyperalgesia or distinguish peripheral from central sensitization.

The present results do not establish that either anesthetic technique provides equivalent prevention of postoperative hyperalgesia in patients with low SA or that CA significantly reduces peripheral and central sensitization in patients with high SA. Such conclusions would require direct statistical comparisons of clinically defined outcomes, including pain perception zone expansion, with effect estimates and confidence intervals.

Discussion

The effective management of acute postoperative pain remains a major challenge in contemporary anesthesiology. Identifying reliable predictors of postoperative hyperalgesia (PH) is important for improving perioperative analgesia and potentially reducing the risk of persistent postsurgical pain. Particular attention has been directed toward patients' preoperative psycho-emotional status. Tai A.L. et al. reported associations between acute pain intensity and anxiety, optimism, and pain catastrophizing [29]. Von Korn K. et al. highlighted the potential for modifying subjective pain perception through the reduction of preoperative anxiety [30]. Furthermore, demographic and psychological variables, including age, sex, body mass index (BMI), anxiety, and negative cognitive appraisal of pain, were incorporated into the postoperative pain prediction scale (POPS) developed by Liu R. et al. [13, 14, 31].

Quantitative sensory testing (QST) is widely used to characterize changes in pain sensitivity in clinical research [32, 33]. In the present study, preoperative psychometric assessment was combined with quantitative algometric measurements to investigate the associations of situational anxiety (SA) and anesthetic technique with postoperative pain sensitivity.

The aim of this study was to optimize perioperative analgesia in patients undergoing laparoscopic abdominal surgery through a differentiated selection of anesthetic technique based on preoperative situational anxiety and pain threshold (PT).

The findings revealed site-dependent patterns of postoperative changes in PT. At the second anatomical site, postoperative PT decreased significantly in all four study groups ($p < 0.001$). At the forearm site, a significant postoperative decrease was observed only in patients with high preoperative SA (groups 3 and 4). This pattern suggests that preoperative psychological status may be associated with changes in pain sensitivity at sites remote from the surgical field.

Analysis using the sign test and the Wilcoxon signed-rank test indicated statistically significant preoperative-to-postoperative changes in PT in selected groups. However, differences in within-group statistical significance do not, by themselves, establish differences in the magnitude of change between anesthetic techniques. Direct between-group comparisons of PT changes are required to determine whether one technique is associated with a smaller postoperative decrease in PT.

Although pairwise comparisons of the individual groups (n = 30 per group), with adjustment for multiple testing using the Bonferroni procedure, did not consistently identify statistically significant differences, pooled analyses (n = 60 per pooled group) revealed associations between preoperative SA and postoperative pain sensitivity. SA level was associated with the magnitude of PT reduction at the forearm site (p = 0.001) and with postoperative expansion of the pain perception zone (PPZ; p = 0.027). PPZ expansion may be consistent with altered pain processing, although this measure alone does not establish the underlying mechanism of central sensitization.

The pooled analysis also identified an association between anesthetic technique and algometric outcomes at the NAC site. Compared with patients receiving combined anesthesia (CA; multicomponent general anesthesia [MGA] plus spinal anesthesia), those receiving MGA alone had significantly lower postoperative PT values (p = 0.035) and a greater magnitude of PT reduction (p = 0.008).

Categorical analysis using odds ratios (ORs) further supported an association between high preoperative SA and postoperative PT reduction at the forearm site. Among patients receiving MGA, high SA was associated with higher odds of a postoperative PT decrease than low SA (OR = 0.231; 95% CI: 0.064–0.831; p = 0.0391, as reported). In the CA groups, the corresponding association did not reach statistical significance (OR = 0.259; 95% CI: 0.062–1.079; p = 0.1042). No statistically significant association between SA level and categorical PT changes was identified at the NAC site in the CA groups (OR = 0.667; 95% CI: 0.240–1.854; p = 0.6042).

These findings may have practical implications for individualized perioperative pain management, particularly when preoperative anxiety is considered alongside other clinical factors. In patients with high SA receiving MGA, the reported OR corresponds to an approximately 4.3-fold difference in odds in the reciprocal direction. Pooled analysis also showed that MGA was associated with higher odds of a postoperative PT decrease at the NAC site than CA (OR = 2.64; 95% CI: 1.25–5.55; p = 0.0099).

Taken together, the results suggest that preoperative SA and anesthetic technique may be associated with postoperative pain sensitivity, with the observed associations differing by anatomical site. However, the study does not establish that CA prevents postoperative hyperalgesia or central sensitization, nor does it demonstrate that MGA causes these outcomes. Further studies with adequately powered between-group and interaction analyses are needed to determine whether anesthetic technique modifies the association between preoperative anxiety and postoperative pain-related outcomes.

Conclusions

1. Preoperative situational anxiety (SA) was associated with postoperative changes in pain threshold (PT) and expansion of the pain perception zone (PPZ). These findings suggest that SA may be a clinically relevant factor associated with postoperative pain sensitivity and altered pain processing; however, PT and PPZ changes alone do not establish peripheral or central sensitization.
2. Patients with high preoperative SA (≥ 45 points) demonstrated a significant postoperative decrease in PT at the forearm following multicomponent general anesthesia (MGA) during laparoscopic

abdominal surgery. This finding suggests a possible association between high SA and increased postoperative pain sensitivity, although the magnitude of this effect should be confirmed by direct between-group comparisons.

3. In patients with low preoperative SA, no significant postoperative decrease in forearm PT was observed with either MGA or combined anesthesia (CA; MGA plus spinal anesthesia). In patients with high SA, CA was associated with more favorable postoperative algometric findings at the second anatomical site than MGA alone. These results support further investigation of anxiety-informed anesthetic selection but do not establish that CA prevents postoperative hyperalgesia or reduces its risk.

Declarations

Conflict of interest. The authors declare no conflict of interest and no financial interest in the preparation of this article.

Funding information. The study has no external sources of funding.

Ethical standards. All procedures during the study complied with the institutional standards of clinical practice, the 1964 Declaration of Helsinki and its amendments, and the Universal Declaration on Bioethics and Human Rights (UNESCO). The research direction was approved by the Commission on Bioethical Expertise and Research Ethics of O.O. Bogomolets NMU (protocol No. 204 dated 23.03.2026).

Informed consent. Written informed consent was obtained from each patient.

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Figures

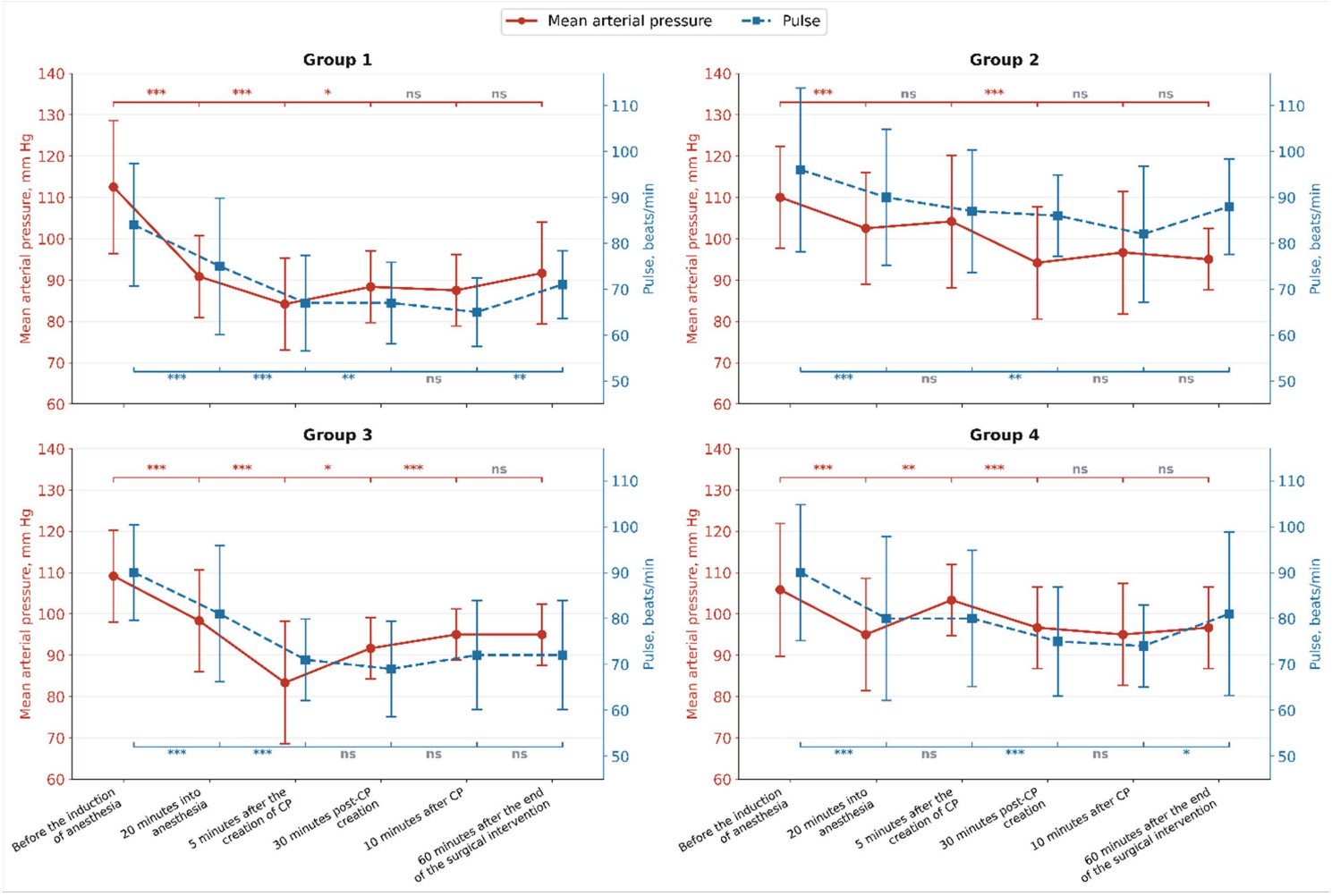


Figure 1

Intraoperative hemodynamic profile of patients

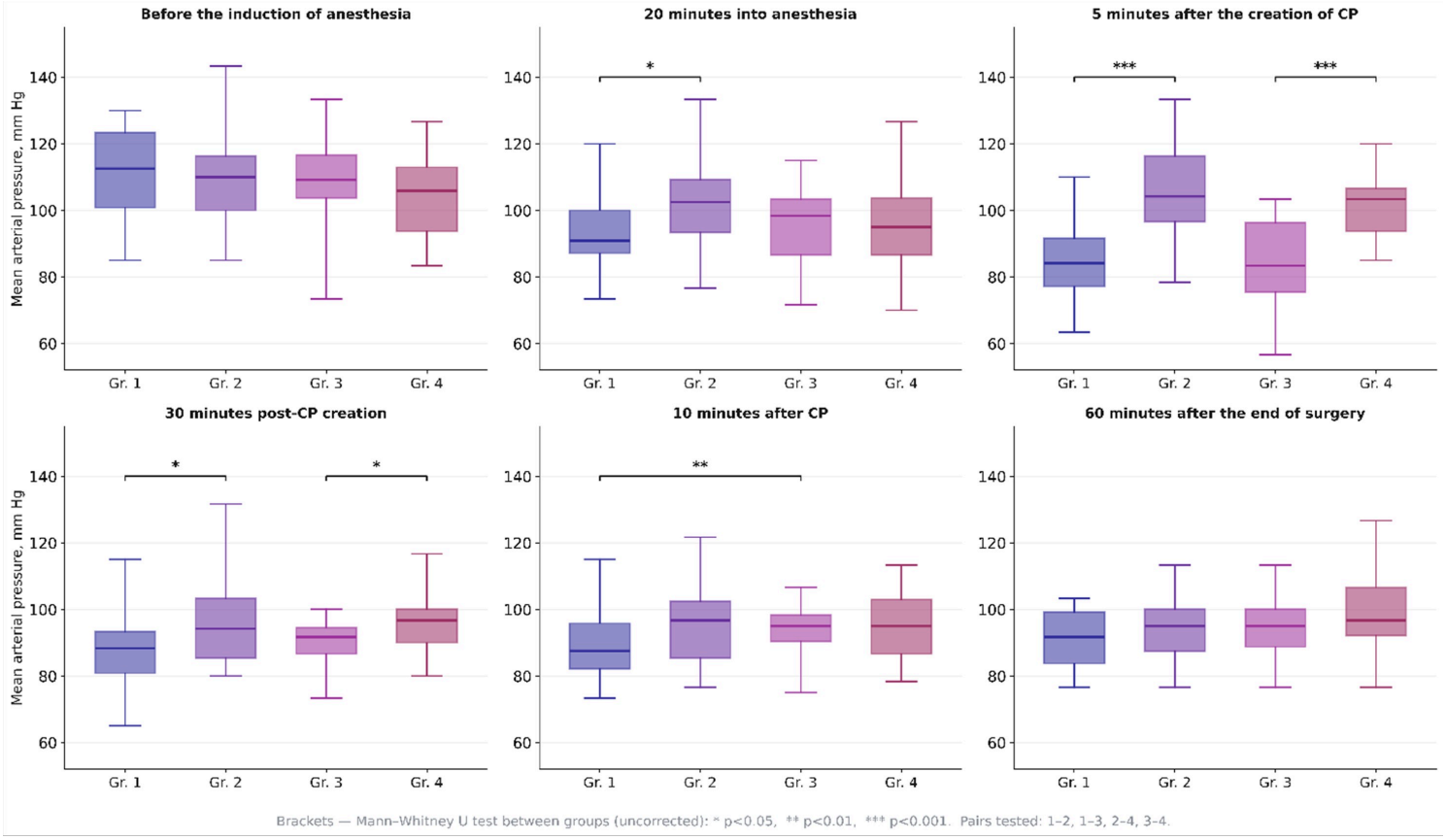


Figure 2

Intergroup differences in parameters MAP during surgical interventios

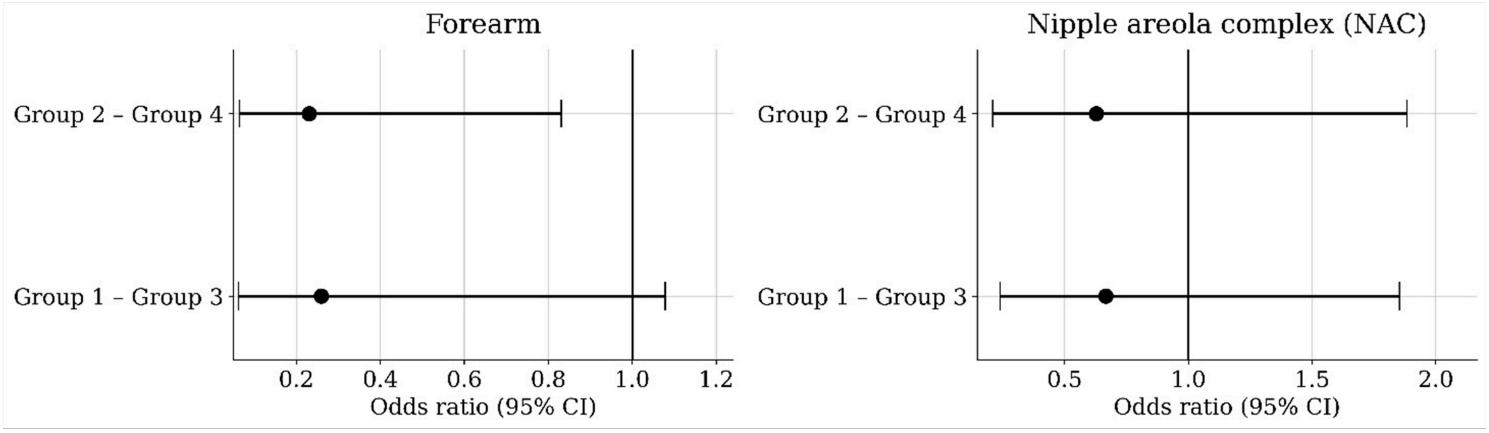


Figure 3

Odds ratios (OR) and 95% confidence intervals for postoperative pain threshold changes depending on the preoperative level of situational anxiety.

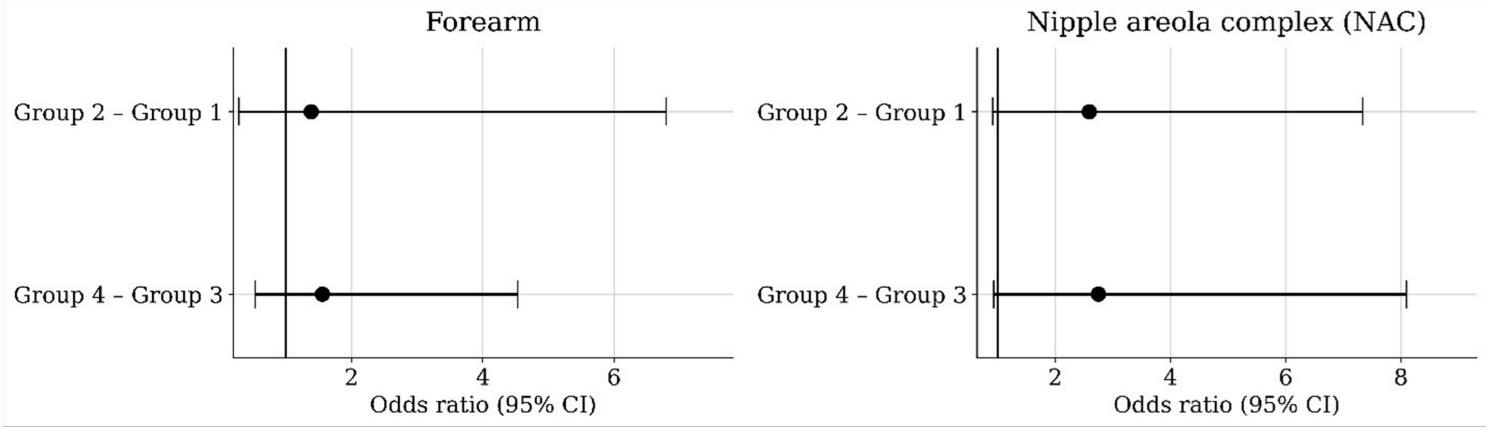


Figure 4

Odds ratios (OR) and 95% confidence intervals for postoperative pain threshold changes depending on the anesthesia method.

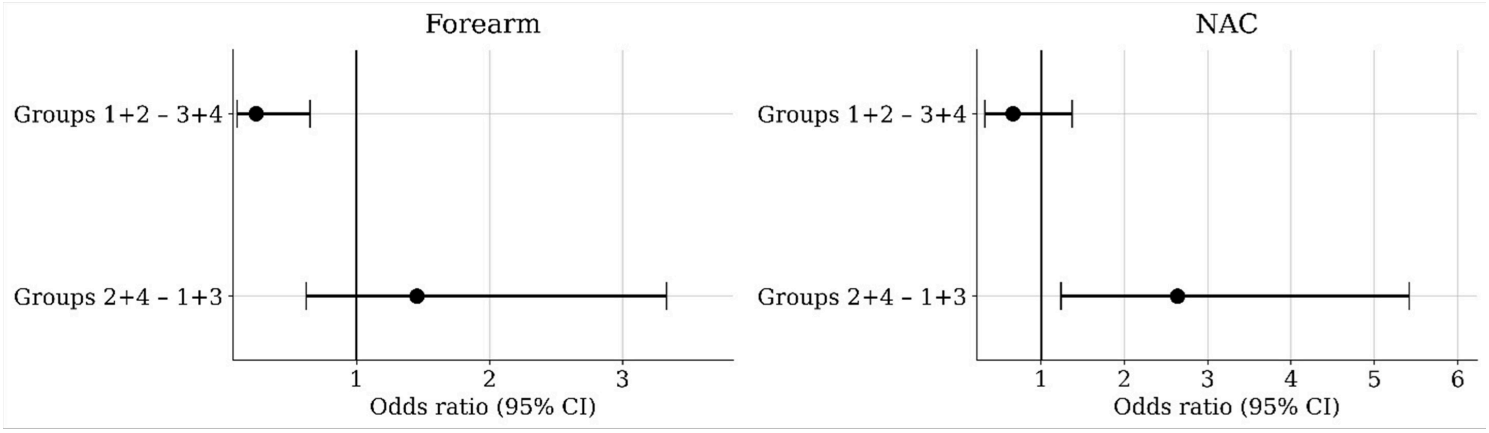


Figure 5

Odds ratios (OR) and 95% confidence intervals for postoperative pain threshold changes in pooled patient samples (n = 60) depending on the preoperative level of situational anxiety.