

Multifactorial analysis of postoperative pain following silicone breast augmentation: patient- and procedure-related predictors

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Abstract

Introduction: Postoperative pain after silicone breast augmentation is influenced by multiple patient- and procedure-related factors, yet limited research has directly evaluated these variables. Understanding predictors of pain may improve analgesic strategies and patient outcomes. The aim of this study was to identify patient- and procedure-related predictors of postoperative pain following elective silicone breast augmentation.

Material and methods: This prospective study enrolled 35 women undergoing elective breast augmentation with silicone gel-filled implants; 28 completed the 14-day protocol. Preoperative questionnaires collected data on age, parity, breastfeeding duration, handedness, hormonal contraception use, satisfaction, and physical activity. Implant characteristics (type, shape, volume) and operative parameters were also analyzed. Patients recorded daily pain for each breast using a 10 cm visual analogue scale (VAS).

Results: Mean VAS pain scores decreased from 79 mm on postoperative day 1 to below 15 mm by day 7, remaining near zero thereafter. Larger implant volume was associated with slightly lower pain on days 1–3. Age negatively correlated with pain on days 13–14. No significant associations were observed with parity, breastfeeding duration, hormonal contraception, physical activity (except day 11), surgical duration, or handedness. Anatomical implants were initially associated with higher early pain scores compared with round implants, but mean pain at day 14 did not differ according to implant type, shape, or height profile.

Conclusions: Postoperative pain following breast augmentation is multifactorial. Most patient- and procedure-related variables, including implant type and model, had a limited long-term impact. Detailed pain monitoring may guide individualized analgesic strategies, optimize perioperative care, and support opioid-sparing approaches.

Key words: pain, VAS, implants, breast, postoperative pain, breast augmentation, visual analogue scale, esthetic surgery, pain predictors.

Introduction

Breast augmentation with silicone implants remains one of the most commonly performed esthetic procedures worldwide, with more than

1.8 million procedures in 2023 [1]. As the popularity of breast augmentation continues to grow, postoperative pain has become a relevant clinical and research concern. Postoperative discomfort is not only a determinant of early recovery, patient satisfaction, and return to daily activities, but may also influence the risk of chronic postsurgical pain [2]. It has been suggested that early postoperative pain may be associated with an increased risk of capsular contracture [3–5].

Pain after breast augmentation is multifactorial. Studies emphasize that its intensity is determined both by patient-related characteristics

and procedure-related parameters [6, 7]. Lifestyle factors – including regular physical activity or hormonal contraception – may additionally modulate pain perception through neuromuscular conditioning or hormonal fluctuations [8].

Only limited research has directly examined postoperative pain after silicone breast augmentation in the context of specific patient-related variables – such as prior breastfeeding duration, parity, age, handedness, hormonal contraception use, or regular physical activity – and procedure-related factors including operative time, implant volume, type, model, and manufacturer. Our

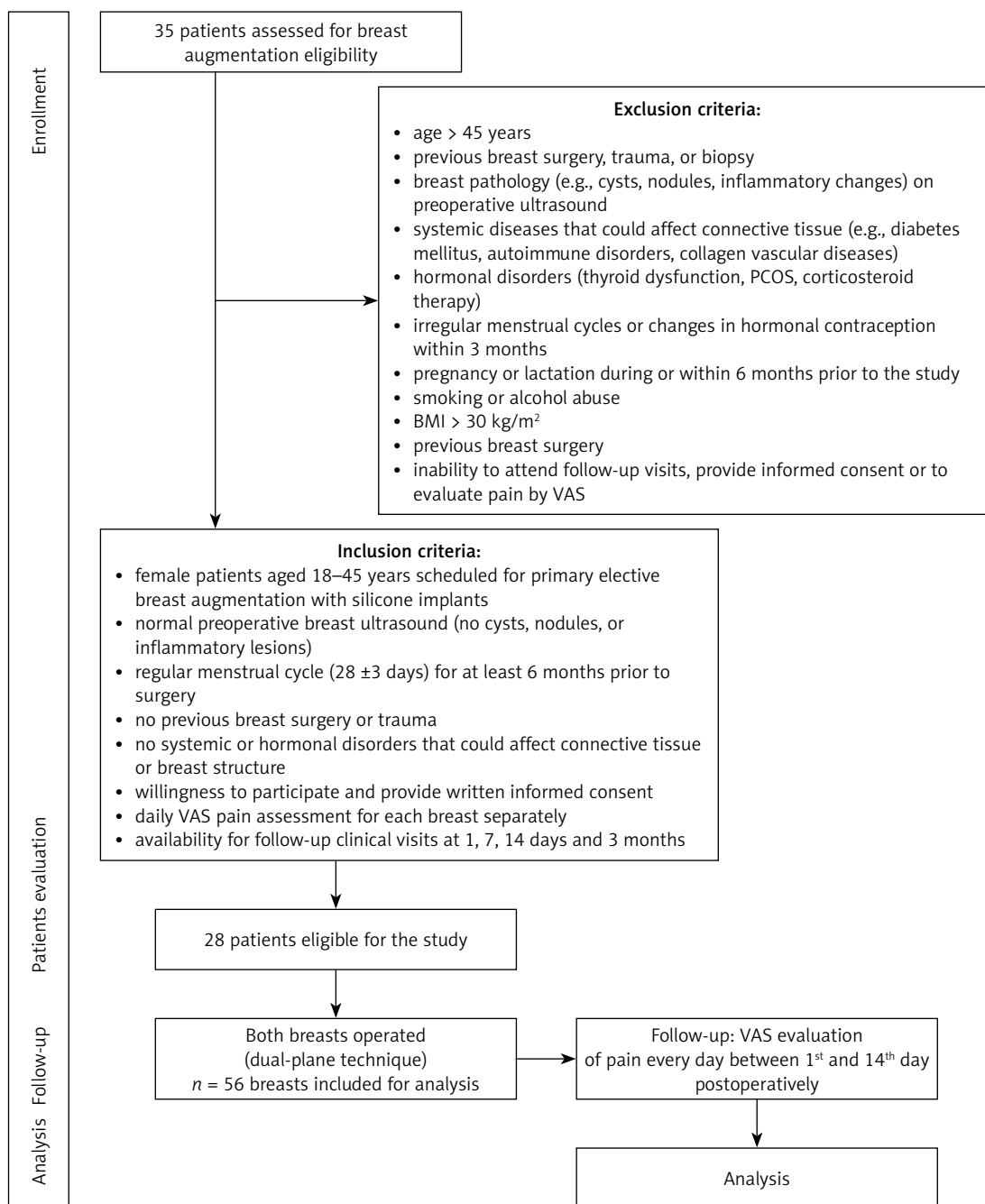


Figure 1. Flowchart of study group

study offers a comprehensive evaluation of potential predictors of postoperative pain that have not been explored in previous studies.

Procedure-specific variables are equally important. Implant pocket, shape and volume influence the degree of intraoperative dissection and subsequent tissue tension [6–8]. Submuscular placement, for example, is consistently associated with higher early postoperative pain due to stretching of the pectoralis major muscle [9, 10] and with lower physical well-being of the chest at 1 year postoperatively on BREAST-Q [11]. Furthermore, surgical technique, duration of the procedure, and the use of perioperative analgesic protocols can significantly affect early postoperative outcomes.

Given the increasing popularity of breast augmentation, the ability to predict postoperative pain based on preoperative characteristics and operative parameters becomes clinically valuable. This study presents an analysis of factors that may influence pain perception following breast implant surgery. Enhanced prediction may support shared decision-making, guide selection of implant type, and allow for individualized perioperative pain management or patient preparation.

Material and methods

The study enrolled 35 women seeking elective breast augmentation with silicone gel-filled implants at a plastic surgery clinic, with 28 participants completing the full study protocol (Figure 1). The mean age of the participants was 31 ±5.0 years (median 31.0; range 21–40 years). Participation was voluntary, and all patients provided written informed consent prior to inclusion. The study protocol received approval from the Bioethics Committee of the Poznan University of Medical Sciences (approval 104 no. 48/16).

All patients completed a preoperative questionnaire, which included questions regarding the number of deliveries, age, duration of breastfeeding, presence of chronic diseases, right- or left-handedness, use of contraceptives, and engagement in sports activities (hours per week). Each patient was also provided with a daily diary to record pain intensity for each breast separately during the postoperative period. Pain was assessed daily each morning upon awakening between 6 and 9 am, before breakfast, prior to taking any analgesics, using the 10 cm visual analogue scale (VAS), from the first postoperative day until day 14 [12]. We chose a 14-day postoperative observation period to capture the full early pain trajectory. Most studies on postoperative pain focus only on the first few days after surgery, whereas clinically relevant pain can persist beyond this period, especially in patients after breast-conserving oncological surgery, highlighting the importance

of extended monitoring [13, 14]. Patients received oral paracetamol 1 g twice a day and oral ibuprofen 400 mg three times a day until day 5 and from day 6 on demand. Our postoperative analgesia protocol was based on our experience and literature [15, 16]. VAS is a reliable tool for pain assessment, extensively validated in the literature, with a simple and well-documented methodology [17–20]. The healing process was assessed by the operating surgeon on days 1, 2, 3, 7, and 14 after the procedure. Overall patient satisfaction was assessed 3 months postoperatively using a 0–10 numeric rating scale, where 0 indicated complete dissatisfaction and 10 indicated complete satisfaction.

All surgeries were conducted under intravenous anesthesia; a small incision was made in the lower areolar region to create a submuscular pocket (dual-plane) for implant placement. This site was irrigated with 10% povidone-iodine (EGIS Pharmaceuticals, Servier, France), and a lateral 12 Fr drain was inserted. The procedure was then mirrored on the opposite side. Before insertion, all implants were immersed in a combined antibiotic solution of 150 mg/ml Dalacin C (Pfizer, Belgium) and 0.5% metronidazole (Polpharma, Poland).

Most participants received anatomical implants (F2, F3, M2, M3, L3), whereas round implants (MP EU; Eurosilicone, GC Aesthetics Cedex, France) were used in 10 cases. The characteristics of the implants used are presented in Table I. Implant volumes ranged from 180 to 500 cm³. Incisions were closed in layered fashion with absorbable sutures. Steri-Strips (3M Company) and dressings were applied, and patients were fitted with a supportive bra and elastic bandage postoperatively. The duration of each surgery was recorded from incision to closure.

Table I. Implant characteristics in the study group

Parameter	n (%)
Type	
Anatomical	46 (80.8)
Round	10 (19.2)
Model	
Anatomical Eurosilicone	
F2	4 (7.1)
F3	4 (7.1)
M2	15 (26.8)
M3	17 (30.4)
L3	6 (10.7)
Round Eurosilicone	
MP EU	10 (17.9)
Volume (cm ³)	329.0 ±71.3 (median 325.0/180.0-500.0)

The obtained results were collected in a calculation form and subsequently stored and analyzed in MS Excel (Microsoft, USA), with additional analyses performed using SigmaPlot 11.0 (Systat Software, San Jose, CA, USA). For cross-validation of analytical formulas (Fisher's z-approximation for detectable correlations and the standardized difference Cohen's *d*), results were checked using G*Power 3.1.9.7 (Heinrich-Heine-Universität Düsseldorf, Germany). Due to the non-Gaussian distribution of the data (as assessed by the Shapiro-Wilk test), use of ordinal-scale variables or unequal group sizes, nonparametric statistical methods were applied.

Given our estimation-focused, hypothesis-generating design, which included daily pre-analgesic VAS measurements over 14 days, repeated-measures data were summarized using the Kish design effect.

$$N_{eff} = \frac{nm}{1 + (m - 1)\rho}$$

Where the *m* stands for the number of clustered measurements (days), and ρ is the interclass correlation coefficient (ICC).

Based on the effective sample size and precision quantified by the *t*-based 95% confidence interval half-width, the cohort of 28 patients was sufficiently large to provide clinically meaningful precision for describing acute postoperative pain trajectories and detecting moderate associations within a standardized single-center protocol (using the appropriate *t*-critical value from the Student's *t*-distribution).

$$half_width_{95\%} = t_{0.975, n-1} * \frac{SD}{\sqrt{n}}$$

Table II. Clinical characteristics of the study group

Parameter	Data
Age [years], mean ± SD (median/min-max)	31.1 ± 5.0 (31.0/21.0-40.0)
Duration of breastfeeding [months], mean ± SD (median/min-max)	6.4 ± 8.2 (3.5/0.0-31.0)
Physical activity [h/week], mean ± SD (median/min-max)	3.6 ± 8.4 (2.0/0.0-44.0)
Number of deliveries, <i>n</i> (%)	
0	6 (21.4)
1	12 (42.9)
2	9 (32.1)
3	1 (3.6)
Use of contraceptives	
Yes (current use)	11 (39.3)
No (minimum 3 months prior to surgery)	17 (60.7)

Differences between two independent groups were evaluated with the Mann-Whitney *U* test, while paired comparisons were analyzed with the Wilcoxon signed-rank test. When the data were normally distributed, Student's *t*-test was used. Multi-subgroup analysis was performed using the Kruskal-Wallis ANOVA. Correlations between two variables were examined using Spearman's rank correlation coefficient. The frequency of categorical variables was compared using chi-square test. Results are presented as mean ± SD if not otherwise specified. Statistical significance was defined as *p* < 0.05. All graphs were generated using GraphPad Prism v5.0 (GraphPad Software, USA) or Ms Excel v 2016 (Microsoft Redmond, WA, USA).

Results

A total of 28 patients (56 breasts were evaluated) with a mean age of 31 ± 5 years completed the study protocol. Reasons for exclusion were: hormonal treatment with contraceptives or hormone replacement therapy within the previous three months, smoking, previous breast surgery, and body mass index (BMI) > 30 kg/m². Most were right-handed (89%, *n* = 24), did not use contraceptives (minimum 3 months prior to surgery), and had given birth at least once. In parous women, the mean duration of breastfeeding was over 6 weeks. Regular physical activity was reported by 60.7% of patients, with an average of more than 3 hours per week. Detailed clinical characteristics are presented in Table II.

Mean duration of the surgical procedure was 66.2 ± 8.9 minutes. As expected, a gradual decrease in pain intensity was observed over the subsequent postoperative days (Figure 2). Mean VAS pain scores decreased from approximately 79 mm on postoperative day 1 to 40 mm on day 4 and below 15 mm by day 7. From day 8 onward, pain scores remained close to zero.

Implant volume had a statistically significant but moderate impact on pain levels only on postoperative days 1–3, with larger implants associated

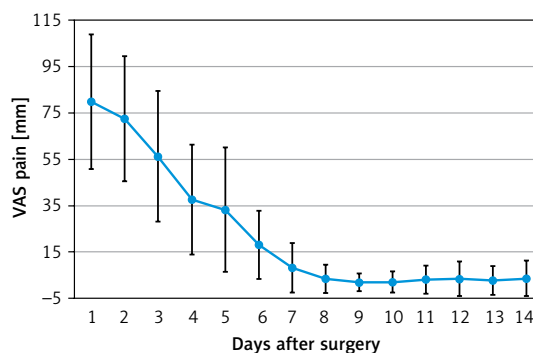


Figure 2. Postoperative breast pain assessed by visual analogue scale (VAS) from day 1 to day 14 after augmentation

Table III. Correlation between daily visual analogue scale (VAS) assessments and selected parameters. Statistically significant correlations are highlighted

Day	Age [years]		Deliveries, <i>n</i>		Lactation [months]		Sport [h/week]		Implant volume [cm ³]		Surgery time [min]	
	<i>R</i> _s	<i>p</i>	<i>R</i> _s	<i>p</i>	<i>R</i> _s	<i>p</i>	<i>R</i> _s	<i>p</i>	<i>R</i> _s	<i>p</i>	<i>R</i> _s	<i>p</i>
VAS1	-0.029	0.833	-0.100	0.463	-0.050	0.713	0.002	0.990	-0.327	0.014	-0.125	0.358
VAS2	0.098	0.471	0.032	0.813	0.051	0.708	-0.136	0.315	-0.224	0.046	0.099	0.465
VAS3	0.098	0.471	0.008	0.953	0.044	0.746	-0.095	0.483	-0.282	0.035	-0.044	0.744
VAS4	0.139	0.305	-0.057	0.673	-0.064	0.637	-0.012	0.930	-0.104	0.443	0.023	0.866
VAS5	0.154	0.255	-0.038	0.778	-0.014	0.920	0.079	0.560	-0.094	0.488	0.100	0.463
VAS6	0.141	0.298	-0.051	0.710	-0.064	0.639	0.061	0.653	-0.035	0.795	0.093	0.495
VAS7	-0.035	0.799	-0.156	0.250	-0.239	0.076	-0.034	0.801	-0.178	0.190	-0.179	0.186
VAS8	0.079	0.564	-0.057	0.677	-0.093	0.495	-0.004	0.979	-0.106	0.434	-0.231	0.087
VAS9	0.187	0.167	0.055	0.685	0.066	0.630	0.017	0.903	-0.092	0.499	-0.185	0.170
VAS10	0.053	0.699	0.002	0.989	0.017	0.904	0.131	0.334	-0.080	0.554	-0.120	0.375
VAS11	-0.011	0.933	0.052	0.700	0.011	0.934	0.284	0.034	0.022	0.870	-0.065	0.632
VAS12	-0.171	0.206	0.051	0.709	-0.002	0.989	0.197	0.146	-0.023	0.865	-0.122	0.370
VAS13	-0.264	0.050	0.098	0.472	0.021	0.879	0.080	0.555	-0.027	0.841	-0.124	0.359
VAS14	-0.310	0.020	-0.070	0.607	-0.125	0.357	0.162	0.231	-0.045	0.741	-0.144	0.287
VAS mean	0.113	0.407	-0.085	0.533	-0.077	0.574	0.044	0.749	-0.172	0.204	-0.047	0.730

with lower pain (Table III). Statistically significant negative correlations were observed between age and pain levels on postoperative days 13 and 14. All detailed correlations are presented in Table III.

The mean satisfaction score was 9.4 ±1.2, and 91.3% of patients reported the highest possible satisfaction level (score 10). Satisfaction was not significantly associated with pain intensity at any postoperative interval except on day 14, when a negative correlation was observed (*R*_s = -0.34, *p* < 0.05).

No significant associations were found between postoperative pain and any of the following factors: frequency of exercise (except a single incidental correlation on day 11), duration of surgery, parity, or breastfeeding duration (Spearman's *R*_s). Mean pain levels calculated from individual postoperative days (1–14) did not differ significantly across these variables (Spearman's *R*_s, *p* > 0.05 for all comparisons). No adverse events related to pain management occurred in our cohort. We did not observe any healing disturbance during this period except one patient who was diagnosed with peri-implant effusion with spontaneous resolution.

The use of hormonal contraceptives did not influence mean postoperative pain assessed with the VAS score (days 1–14). The difference in average pain calculated from days 1–14 between users and non-users was not statistically significant according to Student's *t*-test (26.7 ±11.4 vs. 25.3 ±11.6; *p* = 0.677). Similarly, the changes in VAS pain evaluation scores over the follow-up period did not differ between the groups (Figure 3).

The mean pain VAS scores for the dominant hand side were 25.1 ±11.1, compared with 26.3 ±11.6 for the non-dominant side (*p* = 0.762, Mann-Whitney test). No differences were observed in daily pain scores throughout the 14 postoperative days, or in the average pain over the entire 14-day period, between breasts on the dominant versus non-dominant hand side (Figure 4). Daily left–right breast VAS pain score differences during the 14-day follow-up, along with the overall mean across all days and individuals, are summarized in Table IV [15].

The type of implant influenced postoperative pain. Patients receiving anatomical implants reported higher VAS scores, which decreased more rapidly over time compared to those with round

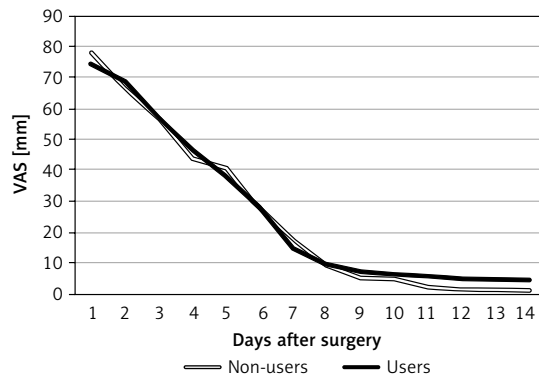


Figure 3. Changes in pain during over 14 days of follow-up in relation to hormonal contraceptive use (*p*-values for each day: 0.55, 0.827, 0.973, 0.529, 0.993, 0.980, 0.993, 0.950, 0.553, 0.640, 0.678, 0.706, 0.777, and 0.227)

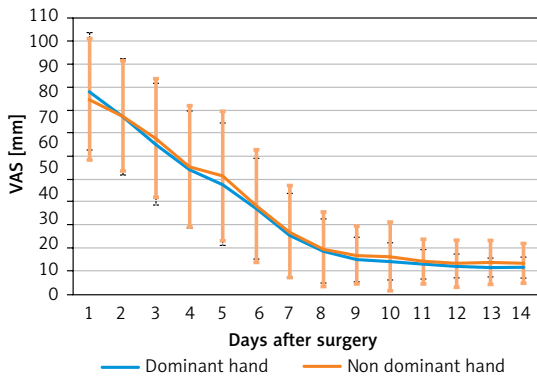


Figure 4. Mean pain scores between breasts on the dominant versus non-dominant hand side; differences not significant

implants. Nevertheless, the mean pain at 14 days postoperatively did not differ between the two implant types (Figure 5).

There were no statistically significant differences between implant models, shapes, height profiles, or implant types (Figure 6). Analysis of the overall VAS score showed that implants tended to be associated with slightly higher pain levels compared with anatomical implants, although the difference was not statistically significant ($p = 0.160$) (Table V).

Discussion

The visual analogue scale is a validated and reliable tool that allows for the assessment of post-

Table IV. Individual left/right VAS pain score analysis presented as differences scored by each patient during 14 days of follow-up (VAS1-14) and overall mean (\pm SD)

Day	Mean	SD	Min	Max
VAS1	6.679	9.456	0.000	46.000
VAS2	9.214	10.082	0.000	41.000
VAS3	10.107	11.226	0.000	39.000
VAS4	11.393	12.931	0.000	40.000
VAS5	12.250	14.196	0.000	41.000
VAS6	12.893	14.266	0.000	42.000
VAS7	9.714	13.106	0.000	49.000
VAS8	7.214	11.865	0.000	54.000
VAS9	5.071	11.099	0.000	55.000
VAS10	6.536	14.713	0.000	57.000
VAS11	3.250	9.423	0.000	47.000
VAS12	3.464	9.106	0.000	44.000
VAS13	2.857	8.497	0.000	42.000
VAS14	2.679	6.639	0.000	27.000
Mean VAS1-14	6.279	8.185	0.000	37.400

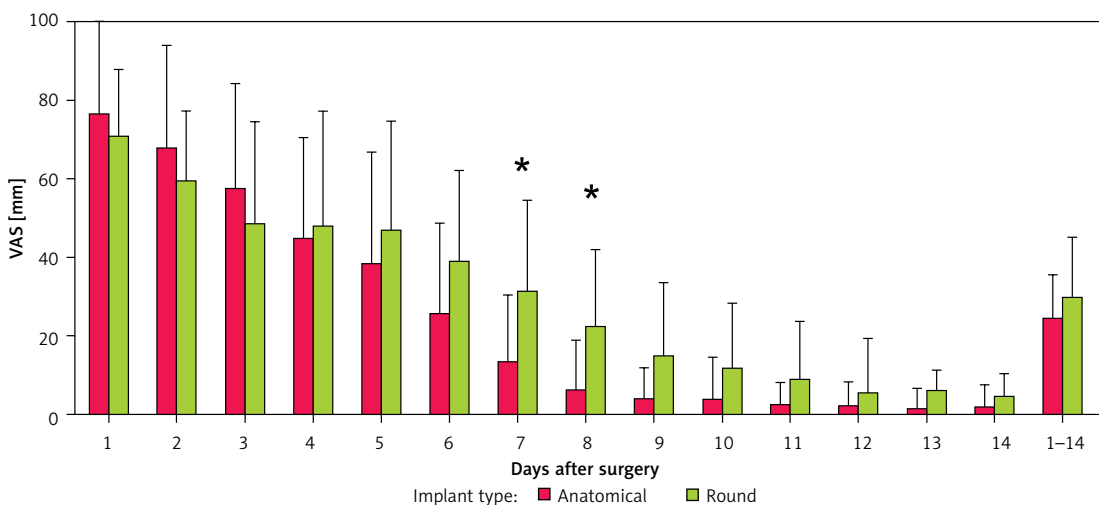


Figure 5. Pain level (mean \pm SD) during the first 14 postoperative days depending on the shape of the implant used. The last bars represent the mean visual analogue scale (VAS) score between days 1 and 14

*Statistically significant difference between anatomical and round implants (Mann-Whitney test, $p < 0.05$).

operative pain intensity and the monitoring of analgesic efficacy. The scale consists of a 100 mm line, ranging from 0 (no pain) to 100 (the worst imaginable pain). Due to its simplicity, reliability, and reproducibility (up to 0.94 depending on the study and context), the VAS is the most widely used method for pain assessment [12, 17–21]. According to the literature, VAS scores of approximately 30, 70, and 100 mm represent the upper boundaries of mild, moderate, and severe pain, respectively. Current guidelines recommend titrating analgesia to achieve a VAS score ≤ 40 mm, with an optimal target of around 33 mm, and a reduction in pain intensity of about 30–40% is required to reflect clinically meaningful improvement [12, 22, 23].

Our results demonstrate that the mean VAS score on postoperative day 1 was approximately 79 mm, corresponding to moderate-to-severe pain. A steady decline in pain intensity was observed over the following days, reaching approximately 40 mm by day 4, which falls within the mild pain range. By day 7, VAS scores dropped below 10 mm, and from day 8 onward, pain levels remained close to zero, indicating near-complete resolution of pain symptoms. The relatively large error bars during the first few days suggest considerable interindividual variability in pain perception and response to analgesic treatment. These findings confirm the effectiveness of the analgesic regimen used, as the therapeutic goal (VAS ≤ 40 mm) was achieved within the first 4 postoperative days. Moreover, the reduction in pain

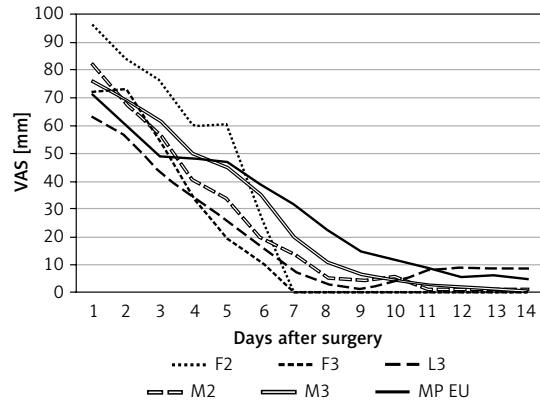


Figure 6. Mean visual analogue scale (VAS) pain scoring of different types of silicone implant – observation between days 1 and 14

during this period exceeded 40%, meeting the criteria for clinically significant improvement. The rapid decline in VAS scores to minimal levels within one week may reflect both optimal pain management and an uncomplicated healing process.

In our study, physical activity (PA) before breast augmentation had mostly no significant impact on pain levels during the first two postoperative weeks. Although a weak correlation was noted on postoperative day 11 ($R_s = 0.284, p = 0.034$), this isolated finding is likely incidental, given the absence of significant associations on other days. Early postoperative pain is mainly determined by surgical factors – such as the surgical technique, implant shape, and manufacturer – as well as individual pain sensitivity, rather than by preoperative

Table V. Mean visual analogue scale (VAS) scores calculated across the overall postoperative observation period (days 1–14) stratified by implant model, implant shape, height profile, and implant type

Parameter	n	Mean VAS (1–14)	SD	P-value
Implant model				
F2	4	28.9	6.6	Kruskal-Wallis ANOVA $p = 0.239$
F3	4	18.9	3.0	
L3	6	20.6	10.9	
M2	15	23.8	6.1	
M3	17	27.6	12.8	
MP EU	10	30.0	14.4	
Implant shape				
Anatomical	46	24.8	10.1	Student's <i>t</i> -test, $p = 0.160$
Round	10	29.9	14.3	
Implant height profile				
Lower profile (F2 + M2 + MP EU)	29	26.6	10.2	Student's <i>t</i> -test, $p = 0.941$
Higher profile (F3 + M3 + L3)	27	27.5	12.8	
Implant type				
F-type	8	23.9	7.1	Kruskal-Wallis ANOVA $p = 0.634$
L-type	6	20.6	10.8	
M-type	32	25.8	10.3	

PA. Nilsson *et al.* reported that preoperative PA was associated with faster physical recovery after breast cancer surgery, although their outcome was self-assessed recovery at 3 and 6 weeks postoperatively and not related to pain [24]. Preoperative PA may not reduce pain in the immediate postoperative period, but more physically active patients might be able to resume physical activity sooner after surgery.

The inverse relationship between age and postoperative pain intensity on days 13 and 14 may reflect a blunted inflammatory response or age-related changes in nociceptive processing, including degeneration of small fibers and higher pain thresholds, which can diminish pain perception [25–27]. This timing coincides with the transition from the acute inflammatory phase to the resolution phase, when pro-inflammatory mediators decline and neuroimmune sensitization begins to subside, leading to a marked reduction in pain intensity [26]. Our findings are consistent with previous research reporting that older patients tend to report less pain [7]. In our study, no significant correlation was found between parity and postoperative pain intensity; however, previous research has suggested otherwise. A 2008 study reported that patients with children experienced lower mean 24-hour pain scores [7], indicating that parity might modulate early postoperative pain perception. The discrepancy between these findings may reflect differences in study design, surgical technique, pain-assessment timing, or sample characteristics.

There are many studies regarding the lactation success following breast augmentation [28–30], but none have specifically investigated the impact of previous breastfeeding duration on postoperative pain. In our study, no significant associations were found between breastfeeding history and either daily or 14-day average postoperative pain, suggesting that previous breastfeeding does not influence pain levels. Prolonged breastfeeding appears to promote long-term breast tissue remodeling [31–33], potentially impacting both esthetic outcomes and pain perception after breast surgery.

No significant associations were found between length of surgery and the mean 24-hour pain scores in our cohort, which aligns with the findings of Pacik *et al.*, indicating that operative time does not appear to be a major determinant of postoperative pain intensity [7]. To our knowledge, postoperative pain after breast augmentation has not been systematically evaluated in relation to implant characteristics. Although implant surface properties have been associated with complications such as the double capsule phenomenon, pain outcomes were not assessed [34,

35]. Similarly, studies focusing on intraoperative 3D morphology of implant shape [36] or submuscular versus subglandular positioning [37] did not include postoperative pain as an outcome.

Interestingly, larger implant volumes in our study were associated with slightly lower pain on postoperative days 8–10. This may be related to gradual nerve stretching, which can modulate action potential generation and reduce nerve excitability [38]. Another study in animals showed that stretching of nerve membranes can activate mechanosensitive two-pore-domain potassium channels (TREK-1/TRAAK), resulting in increased leak currents, leading to hyperpolarization and reduced neuronal excitability [39]. In this context, larger implants might induce slower, more uniform tissue expansion, potentially attenuating nociceptive signaling and explaining the moderate reduction in pain observed. Our finding contrasts with Pacik *et al.*, who reported that patients with asymmetrical implants tended to experience slightly more pain on the side with the larger implant, although the difference was minor and not statistically significant [7]. We found a correlation between implant volume and VAS score only on the first, second, and third postoperative days, while in our previous study this relationship was limited to the first two postoperative days and disappeared from day 3 onward [3].

Although our study examined a broad spectrum of factors potentially predicting or mitigating postoperative pain – including both patient-related characteristics and implant-related or surgical parameters – other research has explored additional strategies for pain modulation and reduction. This indicates that postoperative pain is a multifactorial phenomenon, shaped not only by individual patient profiles and surgical choices but also by a variety of adjunctive interventions described in the literature. Psychosocial factors such as preoperative anxiety, depression, and pain catastrophizing are known contributors to postoperative pain severity, as demonstrated in studies showing their association with both short- and mid-term pain outcomes after breast surgery. Although these findings derive mainly from oncologic reconstruction cohorts, similar elevations in anxiety and depression have also been reported among breast augmentation patients, suggesting that psychological status may influence postoperative pain across different breast surgery populations [40].

Pain control after breast augmentation can be achieved through various methods, although not all of them are necessary or safe [41–43]. Excessive opioid prescribing remains a concern [44], as many patients after breast augmentation require fewer tablets than prescribed [45], and long-term

use may worsen pain and functional outcomes by increasing pain sensitivity [42, 46]. Large observational studies have shown that patients on chronic opioids are less likely to experience improvement in pain and function [46] and report higher postoperative pain scores compared with non-opioid users [47]. Opioid prescribing for non-cancer pain is more common among patients with depression and among postmenopausal women and is associated with substantial morbidity and mortality [45, 46]. According to the American Society of Plastic Surgeons, NSAIDs are recommended as part of postoperative analgesia after breast surgery and reduce opioid requirements [48, 49]. In our study, postoperative analgesia was provided using NSAIDs at manufacturer-approved doses, achieving similar or better pain control compared to opioids [45]. Pain intensity decreased over time, with a mean value of 3.7 mm (0.37 cm) on the VAS on postoperative day 14. In other studies, pain assessed even 1 year after surgery persisted in some patients [50].

In a retrospective study, the relatively short-lasting effects of bupivacaine irrigation of the breast pockets were compared with the administration of 0.75% ropivacaine combined with PF72 gel, which allowed slow release of the anesthetic and prolonged postoperative analgesia [43, 51]. Pain scores during the first three days were consistently lower in the PF72 group [43]. A systematic review and meta-analysis indicated that irrigation with bupivacaine, alone or combined with ketorolac, reduces postoperative pain primarily in the first five days [52]. These findings support the role of local anesthetic irrigation in reducing early postoperative discomfort, although effects may vary depending on the formulation and adjuncts used. In our study, postoperative analgesia was provided exclusively with NSAIDs, allowing assessment of the natural course of postoperative pain over 14 days, offering a longer-term perspective on postoperative discomfort and patient-related predictors compared with studies limited to the first 3–5 days. Pectoral nerve block may reduce postoperative pain in the first 1–6 hours after breast augmentation, but evidence is limited. A meta-analysis by Liang and Xu including only five small randomized controlled trials (RCTs) reported very high heterogeneity ($I^2 = 92\text{--}93\%$) [41]. It has been suggested that intercostal nerves may contribute to postoperative pain, but preoperative intercostal nerve blocks do not appear to significantly reduce pain after surgery [53].

Other factors influencing pain after breast augmentation are included in widely accepted Enhanced Recovery After Surgery (ERAS) protocols [44, 54–56]. In one study, patients in the ERAS group, who received shorter preoperative fasting

and prophylactic oral analgesia, reported significantly lower pain levels and opioid use during the first three postoperative days compared with the non-ERAS group [44]. These results emphasize the potential benefits of multimodal perioperative strategies for minimizing postoperative pain, complementing the patient-focused factors we specifically examined, although the contribution of individual ERAS components to pain reduction remains unclear.

Among other co-factors, higher BMI (≥ 25) is associated with increased postoperative pain and reduced physical functioning following breast augmentation [46]. Because BMI also affects implant size, careful preoperative planning and involving the patient in decision-making may help improve outcomes and reduce pain [57]. Mateja *et al.* developed a calculator to estimate implant volume based on five variables including BMI [58]. Recent machine-learning models have predicted implant size with high accuracy (89%) [59]. Selecting a more suitable implant volume may potentially reduce postoperative pain. In our study, implant volume significantly affected pain intensity only on the first and third postoperative days, with larger implants associated with lower pain. However, no correlation was observed with mean pain level across the 14-day postoperative period. This suggests that implant size has a limited long-term impact on pain levels, highlighting the importance of multifactorial causes. We intentionally adopted a multifactorial design because postoperative pain after breast augmentation arises from interacting determinants rather than a single driver. Robust evidence shows that implant attributes and the placement plane influence early pain and capsular contracture risk; activity level (ERAS) modulates analgesic requirements and recovery; and hormonal contraception and parity (breast tissue biology) are clinically relevant covariates that can confound pain trajectories if ignored [32, 40]. This holistic approach enhances translational value and supports personalized perioperative care, addressing gaps where prior studies often examined these factors in isolation.

The study has several limitations, including the small sample size, single-center design, and voluntary patient selection, which may reduce generalizability and introduce study bias. Additionally, pain assessment reliant on subjective VAS diaries, and the lack of a control group or alternative analgesic strategies are other limitations to consider, although we tried to maintain a highly homogeneous group of patients for a high-quality data set. To the best of our knowledge, this study represents the first multifactorial evaluation of postoperative pain over a two-week period following breast augmentation surgery. Further investiga-

tions, particularly multicenter studies with larger patient populations, are needed to confirm and extend these findings.

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Ethical approval

The study protocol received approval from the Bioethics Committee of the Poznan University of Medical Sciences (approval 104 no. 48/16).

Conflict of interest

The authors declare no conflict of interest.

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