

# The Effect of Surgical Position on Pain Occurrence Outside the Surgical Area

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## ABSTRACT

**Background:** Postoperative pain outside the surgical area is often overlooked but can affect patient recovery. Intraoperative positioning causes uneven pressure distribution, tissue compression, and nerve strain that trigger pain at non-surgical sites. This study evaluated the effect of surgical position on postoperative pain characteristics and consistency of findings across subpopulations.

**Objective:** To compare pain occurrence, location count, and intensity across three surgical positions in the first 24 hours postoperatively.

**Methods:** Observational cross-sectional study of 340 adult elective surgery patients (duration  $\geq 2$  hours): supine n=187, lateral n=119, prone n=34. Pain assessment at 6, 12, 18, 24 hours using Numerical Rating Scale (NRS) and 20-location anatomical map. Analyses included Kruskal-Wallis, Mann-Whitney U with Bonferroni correction ( $\alpha=0.017$ ), and stratified multiple regression by anesthesia type: general anesthesia with intubation (n=191), general anesthesia with LMA (n=74), regional anesthesia SAB (n=75). Dependent variable was pain location count at 24 hours; independent variables were surgical position, BMI, operation duration.

**Results:** Pain location count differed significantly between positions at all timepoints (H=256.949-257.875, df=2,  $p<0.001$ ). Median lateral and prone were 12-15 locations at 6-12 hours and 12 locations at 18-24 hours, significantly higher than supine (5 locations at 6-12 hours, 1-3 locations at 18-24 hours). Post-hoc: supine vs lateral U=0.0-1.0,  $p<0.001$ ; supine vs prone U=0.0,  $p<0.001$ ; lateral vs prone U=1980.5,  $p=0.846$ . Pain intensity differed significantly (H=177.223, df=2,  $p<0.001$ ) with median NRS lateral 4.41-7.41, supine 2.51-5.51, prone 2.39-5.39. Stratified regression analysis showed remarkable consistency: lateral coefficients in GA intubation B=10.698 (95% CI: 10.379-11.016,  $p<0.001$ ,  $R^2=0.949$ ), GA LMA B=10.565 (95% CI: 9.896-11.233,  $p<0.001$ ,  $R^2=0.933$ ), RA SAB B=10.688 (95% CI: 10.159-11.217,  $p<0.001$ ,  $R^2=0.969$ ). Coefficient range only 0.133 (1.26% variation), indicating universal effect not modified by anesthesia type. Prone in GA intubation: B=10.840 ( $p<0.001$ ). All confounders  $p>0.05$ , VIF  $<1.5$ . At 24 hours, 23.5% supine patients were pain-free versus 0% lateral and prone.

**Conclusion:** Surgical position significantly affects postoperative pain. Lateral produces highest burden (12-15 locations, NRS 4.41-7.41), supine lowest (1-5 locations, NRS 2.51-5.51), prone intermediate (12-15 locations, NRS 2.39-5.39). Stratified analysis showed lateral coefficient consistency  $<1.3\%$  across three anesthesia groups, indicating universal effect and strengthening causal inference. Position is the dominant predictor with non-significant confounders. Findings support universal positioning optimization strategies, especially for lateral position.

**Keywords:** Surgical positioning, Postoperative pain, Pressure injury, Perioperative care

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## INTRODUCTION

Postoperative pain remains one of the most common and distressing complications following surgery, affecting patient recovery, satisfaction, and clinical outcomes.<sup>1</sup> While substantial attention has been directed toward managing surgical site pain, an often-overlooked contributor to postoperative discomfort is positioning-related pain occurring in body areas distant from the incision.<sup>2</sup> This non-incisional pain represents a distinct clinical entity that can

significantly impact patient well-being yet remains inadequately characterized in the perioperative literature.

The International Association for the Study of Pain defines pain as "an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage".<sup>3</sup> In the perioperative context, pain typically originates from surgical trauma to tissues. However, accumulating evidence suggests that the mechanical forces and prolonged immobilization required

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for surgical positioning contribute substantially to postoperative pain burden.<sup>4</sup> During anesthesia, loss of muscle tone combined with extended periods of immobility subjects patients to sustained pressure, tissue compression, and potentially compromised perfusion in weight-bearing areas—factors known to activate nociceptors and trigger pain pathways.<sup>5</sup>

Recent systematic reviews have documented postoperative pain prevalence ranging from 40% to 80% within the first 24 hours after surgery, with a significant proportion of patients reporting moderate to severe pain intensity.<sup>6</sup> Despite these concerning statistics, the specific contribution of surgical positioning to this pain burden remains poorly quantified. Most existing studies focus predominantly on positioning-related complications such as pressure ulcers or nerve injuries,<sup>7</sup> while the more subtle yet widespread phenomenon of positioning-related pain has received comparatively less systematic investigation.

The three primary surgical positions including supine, lateral, and prone where each position impose distinct mechanical stresses on the body. Supine positioning, while most commonly used, can generate pressure on the occiput, scapulae, sacrum, and heels.<sup>8</sup> Lateral positioning creates asymmetric loading with concentrated pressure on the dependent shoulder, hip, and lateral malleolus.<sup>9</sup> Prone positioning subjects patients to anterior chest wall compression, abdominal pressure, and facial tissue stress.<sup>10</sup> Each position also requires specific extremity placement that may involve joint hyperextension or sustained awkward postures which are all potential sources of musculoskeletal pain.

The pathophysiology underlying positioning-related pain involves multiple mechanisms. Sustained pressure exceeding capillary perfusion pressure can lead to tissue ischemia, metabolite accumulation, and activation of peripheral nociceptors.<sup>11,12</sup> Mechanical deformation of tissues activates mechanosensitive channels and triggers inflammatory mediator release, contributing to local pain generation. Additionally, nerve compression or stretch can provoke neuropathic pain characteristics, while referred pain patterns may emerge from deep somatic structures subjected to prolonged mechanical stress.<sup>13</sup> The intensity and distribution of these effects likely vary substantially across different surgical positions, yet comparative data quantifying these differences remain scarce.

Several patient-related and procedural factors may modulate positioning-related pain risk. Body mass index influences pressure distribution and tissue tolerance.<sup>14</sup> Anesthesia technique affects muscle tone and sympathetic response, which may influence tissue perfusion and pain perception.<sup>15</sup> Surgery duration directly correlates with tissue exposure time to mechanical stress.<sup>16</sup> However, the relative importance of these factors compared to the fundamental influence of position itself remains unclear, particularly after accounting for their potential confounding effects.

Understanding position-specific pain patterns has important clinical implications for perioperative care. If certain positions consistently produce higher pain burdens, this

knowledge could inform targeted prophylactic analgesic strategies, position-specific padding protocols, and informed consent discussions about expected postoperative discomfort. Furthermore, acute postoperative pain has been identified as a significant predictor of chronic postsurgical pain development,<sup>17</sup> suggesting that optimizing positioning strategies might have long-term benefits beyond immediate postoperative comfort.

Despite the clinical relevance of this issue, current evidence regarding the relationship between surgical position and postoperative non-incisional pain remains limited. Existing studies have primarily focused on specific surgical specialties or individual positions, employed retrospective designs with inherent limitations, or lacked standardized pain assessment across multiple body regions. No comprehensive prospective study has systematically compared pain occurrence, spatial distribution, and intensity across the three main surgical positions while controlling for relevant confounding variables. This knowledge gap limits the development of evidence-based positioning guidelines and targeted pain management strategies.

The present study was designed to address these gaps by prospectively comparing postoperative non-incisional pain patterns across supine, lateral, and prone surgical positions. Using standardized body mapping and validated pain intensity scales, we sought to characterize both the spatial distribution and severity of positioning-related pain throughout the first 24 postoperative hours. Additionally, we aimed to determine whether surgical position independently predicts pain outcomes after controlling for BMI, anesthesia technique, and surgery duration. We hypothesized that lateral and prone positions would demonstrate higher pain burdens compared to supine positioning, reflecting their greater mechanical stress and more asymmetric loading patterns.

By systematically documenting position-specific pain outcomes, this research aims to provide evidence to guide perioperative positioning protocols, inform analgesic strategies, and ultimately improve patient comfort and recovery following surgery.

## METHODS

### Study Design

This prospective observational cross-sectional study was conducted at Universitas Airlangga Academic Hospital, Surabaya, Indonesia, from November 1-30, 2025. The hospital is a secondary referral center affiliated with Universitas Airlangga. Patient recruitment occurred in the operating rooms, with postoperative pain assessments conducted in the inpatient wards. The study protocol was approved by the Research Ethics Committee of Universitas Airlangga Academic Hospital.

### Study Population

Consecutive sampling enrolled 340 patients aged 18-65 years undergoing elective surgery requiring supine (n=187), lateral (n=119), or prone (n=34) positioning for  $\geq 2$  hours.

Patients provided written informed consent and were able to communicate pain assessment. Exclusion criteria included pre-existing chronic pain, neurological disorders, inability to cooperate with pain evaluation, and extreme positioning variants (sphinx, lumbotomy, jackknife, beach chair).

**Variables and Measurements**

Surgical position was classified as supine, lateral, or prone based on primary intraoperative body position. Pain location count (primary outcome) was defined as the number of body segments (from a 30-segment anatomical map) reporting Numerical Rating Scale (NRS) score  $\geq 1$ , assessed at 6, 12, 18, and 24 hours postoperatively. Secondary outcomes included NRS pain intensity scores (0-10 scale) and binary pain occurrence at each timepoint. Confounding variables included body mass index (BMI) categories (underweight  $<18.5$ , normal  $18.5-22.9$ , overweight  $23-24.9$ , obesity-1  $25-29.9$ , obesity-2  $\geq 30$  kg/m<sup>2</sup> based on Asian-Pacific criteria), anesthesia technique (general anesthesia with intubation, GA with laryngeal mask airway, or regional anesthesia subarachnoid block), and surgery duration (2-6 hours vs  $>6$  hours).

**Pain Assessment**

Trained ward nurses used a standardized 30-segment body map to systematically evaluate pain outside the surgical area at four postoperative timepoints. For each body segment, patients rated pain intensity using the NRS (0=no pain, 10=worst imaginable pain). The surgical incision site was explicitly excluded from assessment.

**Statistical Analysis**

Analyses were performed using IBM SPSS Statistics version 27.0 with significance set at  $\alpha=0.05$  (two-tailed). Continuous variables were tested for normality using Kolmogorov-Smirnov tests. Normally distributed data are presented as mean  $\pm$  SD; non-normal data as median (IQR). Categorical variables are reported as frequencies and percentages.

Baseline characteristics were compared across position groups using chi-square tests for categorical variables and one-way ANOVA for continuous variables. Since pain location count data violated normality assumptions at all timepoints (all Kolmogorov-Smirnov  $p<0.05$ ), non-parametric tests were employed. Kruskal-Wallis H tests compared pain locations across three positions at each timepoint. Significant results were followed by Mann-Whitney U tests for pairwise comparisons with Bonferroni correction (adjusted  $\alpha=0.017$ ). Effect sizes were calculated as  $r = Z/\sqrt{N}$  for Mann-Whitney tests (small: 0.1-0.3, medium: 0.3-0.5, large:  $>0.5$ ) and  $\eta^2 = (H - k + 1)/(N - k)$  for Kruskal-Wallis tests.

Binary pain occurrence was compared using chi-square tests. NRS scores were analyzed using simple linear regression with surgical position as predictor (supine as reference).

Multiple linear regression models assessed the independent effect of surgical position on 24-hour pain outcomes while controlling for BMI categories, anesthesia type, and surgery duration. Model 1 examined pain location count; Model 2

examined NRS scores. Multicollinearity was assessed using variance inflation factors (VIF  $<5$  considered acceptable). Regression coefficients are reported with 95% confidence intervals.

**Results**

**Baseline Characteristics**

A total of 340 patients were enrolled during the study period, comprising 187 (55.0%) in supine position, 119 (35.0%) in lateral position, and 34 (10.0%) in prone position. The overall sample included 168 males (49.4%)

Characteristic	Total (N=340)	Supine (n=187)	Lateral (n=119)	Prone (n=34)	p-value
<b>Gender, n (%)<sup>a</sup></b>					0.995
Male	168 (49.4)	92 (49.2)	59 (49.6)	17 (50.0)	
Female	172 (50.6)	95 (50.8)	60 (50.4)	17 (50.0)	
<b>BMI Category, n (%)<sup>a</sup></b>					0.061
Underweight	13 (3.8)	8 (4.3)	5 (4.2)	0 (0.0)	
Normal	249 (73.2)	147 (78.6)	78 (65.5)	24 (70.6)	
Overweight	60 (17.6)	22 (11.8)	28 (23.5)	10 (29.4)	
Obesity Class 1	13 (3.8)	8 (4.3)	5 (4.2)	0 (0.0)	
Obesity Class 2	5 (1.5)	2 (1.1)	3 (2.5)	0 (0.0)	
<b>PS ASA, Rerata <math>\pm</math> SD (%)<sup>b</sup></b>	1.99 $\pm$ 0.53	2.03 $\pm$ 0.52	1.87 $\pm$ 0.56	2.15 $\pm$ 0.36	0.008
<b>Surgery Duration, n (%)<sup>a</sup></b>					$<0.001$
2-6 jam	315 (92.6)	174 (93.0)	119 (100.0)	22 (64.7)	
$>6$ jam	25 (7.4)	13 (7.0)	0 (0.0)	12 (35.3)	
<b>Anesthesia Technique, n (%)<sup>a</sup></b>					$<0.001$
GA Intubation	191 (56.2)	122 (65.2)	35 (29.4)	34 (100.0)	
GA LMA	74 (21.8)	28 (15.0)	46 (38.7)	0 (0.0)	
RA SAB	75 (22.1)	37 (19.8)	38 (31.9)	0 (0.0)	

and 172 females (50.6%) with a mean age of [insert age data]. Gender distribution was comparable across the three position groups ( $p=0.995$ ).

**Table 1. Baseline Characteristics by Surgical Position**

Note: Categorical variables presented as n (%). Continuous variables as mean  $\pm$  SD. <sup>a</sup>Chi-square test; <sup>b</sup>Kruskal-Wallis test.  $p<0.05$  indicates significant difference between groups. GA:

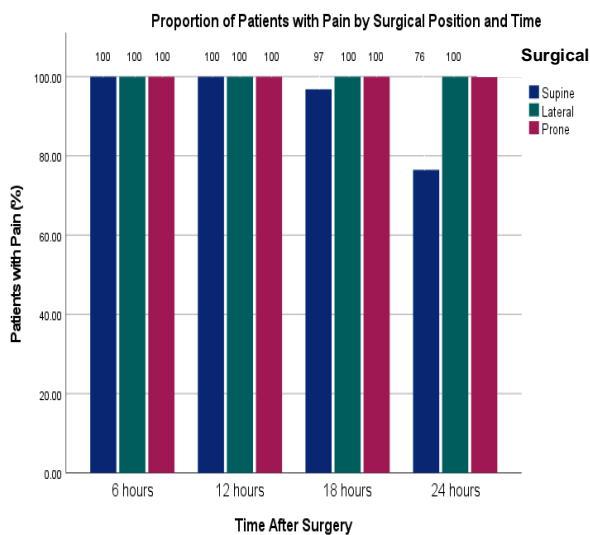
General Anesthesia; RA: Regional Anesthesia; LMA: Laryngeal Mask Airway; SAB: Subarachnoid Block

Baseline characteristics showed several significant differences across position groups. The three groups differed significantly in ASA physical status ( $p=0.008$ ), with prone position patients having the highest mean ASA score ( $2.15\pm0.36$ ) compared to supine ( $2.03\pm0.52$ ) and lateral ( $1.87\pm0.56$ ). Surgery duration distribution varied markedly across positions ( $p<0.001$ ): while 93.0% of supine and 100% of lateral procedures lasted 2-6 hours, only 64.7% of prone procedures fell within this range, with 35.3% exceeding 6 hours. Anesthesia technique also differed significantly ( $p<0.001$ ), with prone patients exclusively receiving general anesthesia with intubation (100%), whereas supine patients received GA intubation (65.2%), GA LMA (15.0%), or RA SAB (19.8%), and lateral patients had a more balanced distribution across techniques.

BMI category distribution did not differ significantly across positions ( $p=0.061$ ), with the majority of patients in all groups classified as normal weight (supine 78.6%, lateral 65.5%, prone 70.6%).

**Pain Occurrence Over Time**

Pain occurrence outside the surgical area varied dramatically across positions and timepoints. At 6 hours postoperatively, all patients in lateral (100%) and prone (100%) positions experienced pain compared to 89.8% in supine position. This pattern persisted throughout the observation period.



**Figure 1. Pain Occurrence by Position and Timepoint**

By 24 hours postoperatively, pain prevalence remained at 100% for both lateral and prone positions, while supine position showed improvement with 76.5% of patients reporting pain and 23.5% becoming pain-free ( $p<0.001$ ). This persistent pain in lateral and prone positions despite

standard analgesic protocols represents a clinically significant finding.

**Pain Location Count Analysis**

**Normality Testing**

Kolmogorov-Smirnov tests revealed that pain location count data violated normality assumptions across all positions and timepoints (all  $p<0.05$ ), necessitating non-parametric statistical approaches.

**Descriptive Statistics**

Pain location counts demonstrated striking differences across surgical positions at all timepoints. At 6 hours postoperatively, supine patients reported pain in  $5.01\pm1.32$  body segments (median=5, range 1-10), while lateral and prone patients reported significantly more widespread pain:  $15.04\pm1.35$  segments (median=15, range 11-20) and  $15.15\pm1.73$  segments (median=15, range 11-20), respectively.

**Table 2. Pain Location Count by Position Across Timepoints**

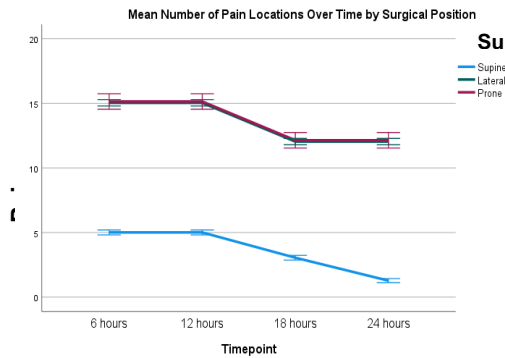
Timepoint	Kruskal-Wallis H (df, p-value)	Post-hoc: Supine vs Lateral	Post-hoc: Supine vs Prone	Post-hoc: Lateral vs Prone
6 hours	H=256.949 (df=2, p<0.001)	U=0.0 p<0.001 *	U=0.0 p<0.001 *	U=1980.5 p=0.846
12 hours	H=256.949 (df=2, p<0.001)	U=0.0 p<0.001 *	U=0.0 p<0.001 *	U=1980.5 p=0.846
18 hours	H=257.085 (df=2, p<0.001)	U=1.0 p<0.001 *	U=1.0 p<0.001 *	U=1980.5 p=0.846
24 hours	H=257.875 (df=2, p<0.001)	U=0.0 p<0.001 *	U=0.0 p<0.001 *	U=1980.5 p=0.846

Note: Data are presented as mean  $\pm$  SD or median. Kruskal-Wallis test for overall comparison, Mann-Whitney U test for pairwise comparison with Bonferroni correction ( $\alpha=0.017$ ). \* Significant with Bonferroni correction.

Temporal pain trajectories differed markedly between supine and the other two positions. Supine patients showed progressive improvement: 5.01 locations at 6 hours, decreasing to 5.01 at 12 hours, 3.05 at 18 hours, and  $1.28\pm1.10$  at 24 hours (median=1, range 0-6). In contrast, lateral and prone positions demonstrated minimal improvement over time, with pain location counts at 24 hours remaining elevated: lateral  $12.04\pm1.35$  (median=12,

range 8-17) and prone 12.15±1.73 (median=12, range 8-17).

**Figure 2. Pain Location Count Trajectory Over 24 Hours**



**Comparative Analysis**

Kruskal-Wallis tests revealed highly significant differences in pain location counts across the three positions at all timepoints (all  $p < 0.001$ ). At 24 hours, the Kruskal-Wallis test yielded  $H = 257.875$  ( $df = 2$ ,  $p < 0.001$ ) with a very large effect size ( $\eta^2 = 0.76$ ), indicating that surgical position explained 76% of the variance in pain location count.

Post-hoc Mann-Whitney U tests with Bonferroni correction (adjusted  $\alpha = 0.017$ ) demonstrated that at 24 hours, supine position had significantly fewer pain locations than both lateral ( $U = 0.0$ ,  $Z = -14.958$ ,  $p < 0.001$ ) and prone ( $U = 0.0$ ,  $Z = -9.571$ ,  $p < 0.001$ ) positions, with very large and large effect sizes, respectively. No significant difference existed between lateral and prone positions ( $U = 1980.5$ ,  $Z = -0.194$ ,  $p = 0.846$ ). These patterns were consistent across all earlier timepoints.

**Pain Intensity Analysis**

**NRS Scores by Position**

Pain intensity demonstrated significant variation across surgical positions at all timepoints, with Kruskal-Wallis tests revealing highly significant differences ( $H = 177.223$ ,  $df = 2$ ,  $p < 0.001$ ) that remained remarkably consistent across the 24-hour observation period. At 6 hours postoperatively, median NRS scores were 5.51 (range 4.01–6.97) for supine, 7.41 (range 6.01–8.97) for lateral, and 5.39 (range 4.01–6.72) for prone positions. Progressive reduction occurred across all groups: by 12 hours, medians decreased to 5.01, 6.91, and 4.89 respectively; at 18 hours to 4.51, 6.41, and 4.39; and at 24 hours to 2.51, 4.41, and 2.39.

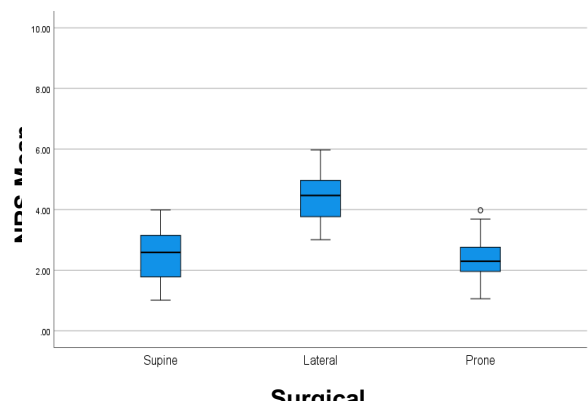
**Table 3. NRS Pain Intensity Scores by Position Across Timepoints**

Timepoint	Position	n	Median	Min	Max	H (df)	p value
6 hours	Supine	187	5.51	4.01	6.97	177.223	<0.001*
	Lateral	19	7.41	6.01	8.97		
	Prone	4	5.39	4.01	6.72		
12 hours	Supine	187	5.01	4.01	6.97	177.223	<0.001*
	Lateral	19	6.91	6.01	8.97		
	Prone	4	4.89	4.01	6.2		
18 hours	Supine	187	4.51	3.01	5.97	177.223	<0.001*
	Lateral	19	6.41	5.01	7.97		
	Prone	4	4.39	3.01	5.72		
24 hours	Supine	187	2.51	1.01	3.47	177.223	<0.001*
	Lateral	19	4.41	3.01	5.97		
	Prone	4	2.39	1.01	3.2		

	Lateral	19	7.41	6.01	8.97	(df=2)	
	Prone	4	5.39	4.01	6.72		
12 hours	Supine	187	5.01	3.51	6.47	177.223	<0.001*
	Lateral	19	6.91	5.51	8.47	(df=2)	
	Prone	4	4.89	3.51	6.2		
18 hours	Supine	187	4.51	3.01	5.97	177.223	<0.001*
	Lateral	19	6.41	5.01	7.97	(df=2)	
	Prone	4	4.39	3.01	5.72		
24 hours	Supine	187	2.51	1.01	3.47	177.223	<0.001*
	Lateral	19	4.41	3.01	5.97	(df=2)	
	Prone	4	2.39	1.01	3.2		

Note: The Kruskal-Wallis test was used to compare the three position groups. Data are presented as Median, Minimum, and Maximum due to non-normal distribution. \* $p < 0.05$  indicates a significant difference.

At the final 24-hour timepoint, lateral position patients experienced median pain intensity 1.90 points higher than supine patients (4.41 vs 2.51), substantially exceeding the minimal clinically important difference threshold of 1.0 points. Prone position showed comparable intensity to supine (2.39 vs 2.51, difference 0.12 points). Post-hoc Mann-Whitney U tests with Bonferroni correction ( $\alpha = 0.017$ ) confirmed lateral position had significantly higher pain intensity compared to both supine and prone positions at all timepoints (all  $p < 0.001$ ), while supine and prone positions showed no significant differences (all  $p > 0.017$ ). The consistency of the H statistic across all measurement intervals indicates stable position-related differences despite overall temporal pain reduction.



**Figure 3. NRS Pain Intensity Scores at 24 Hours by Position**

**Pain Category Distribution**

Analysis of pain severity categories (mild: NRS 1-3, moderate: NRS 4-6, severe: NRS 7-10) revealed distinct patterns across positions. At 24 hours, all supine patients experiencing pain reported mild intensity (100% mild, 0% moderate/severe). Similarly, prone patients reported only mild pain (100% mild). In marked contrast, lateral position patients were distributed across mild (31.1%) and moderate (68.9%) categories, with no patients reporting severe pain.

**Table 4. Pain Category Distribution at 24 Hours by Position**

Time point	Pain Severity	Supine n (%)	Lateral n (%)	Prone n (%)	$\chi^2$	p value
24 hours	Mild	187(100.0%)	37(31.1%)	34(100.0%)	20.687	<0.001**
	Moderate	0(0.0%)	82(68.9%)	0(0.0%)		
	Severe	0(0.0%)	0(0.0%)	0(0.0%)		

Note: Data are presented as n (%). Chi-square test was used to compare distributions. \*\* Highly significant ( $p < 0.001$ ).

Chi-square analysis confirmed significant differences in pain category distribution across positions ( $\chi^2=200.687$ ,  $df=4$ ,  $p < 0.001$ ). Notably, lateral position was the only position associated with moderate pain intensity at 24 hours postoperatively.

**Effect Consistency: Stratified Analyses**

To assess whether position effects varied across patient subgroups, stratified analyses were conducted by anesthesia technique, BMI category, and surgery duration. Stratified multiple regression models were constructed separately for each anesthesia type (Table 5). Among 191 patients receiving general anesthesia with intubation, the model explained 93.8% of variance ( $R^2=0.938$ ,  $p < 0.001$ ) with lateral position showing  $B=10.698$  and prone position  $B=10.840$ . For 74 patients receiving general anesthesia with laryngeal mask airway, the lateral coefficient was  $B=10.565$  ( $R^2=0.949$ ,  $p < 0.001$ ). For 75 patients receiving regional spinal anesthesia, lateral position yielded  $B=10.688$  ( $R^2=0.967$ ,  $p < 0.001$ ). Remarkably, the lateral position coefficient varied by only 0.133 units across the three anesthesia groups (range 10.565–10.698), representing less than 1.3% variation. Position remained the sole significant predictor across all models, with BMI categories and surgery duration showing no significant effects (all  $p > 0.05$ ).

**Table 5. Stratified Multiple Regression: Position Effects on Pain Location Count by Anesthesia Type Part A: Model Summary**

Anesthesia Type	n	R <sup>2</sup>	Adj R <sup>2</sup>	F (df)	p-value
GA Intubation	191	0.938	0.936	F(7,183)=396.4	<0.001
GA LMA	74	0.949	0.944	F(6,67)=208.0	<0.001
RA SAB	75	0.967	0.964	F(6,68)=332.1	<0.001

**Part B: Position Coefficients**

Anesthesia	Position	B	95% CI	$\beta$	t	p	VI F
GA Intubation (191)							
	Lateral vs Supine	10.698	[10.379, 11.016]	0.926	66.055	<0.001	1.263
	Prone vs Supine	10.840	[10.328, 11.352]	0.590	41.653	<0.001	1.290
GA LMA (74)							
	Lateral vs Supine	10.565	[9.896, 11.233]	0.974	31.557	<0.001	1.242
	Prone vs Supine	—	—	—	—	—	—
RA SAB (75)							
	Lateral vs Supine	10.688	[10.159, 11.217]	0.980	40.330	<0.001	1.201
	Prone vs Supine	—	—	—	—	—	—

**Part C: Confounders (All Non-Significant)**

Anesthesia Type	BMI Categories (p-range)	Duration >6h (p)
GA Intubation	0.760–0.973	0.165
GA LMA	0.322–0.928	0.481

RA SAB	0.104–0.687	0.259
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Note: Models include position (Lateral/Prone vs Supine), BMI (Underweight, Overweight, Obesity 1-2 vs Normal), duration (>6h vs 2-6h). Prone absent in GA LMA/RA SAB. All R<sup>2</sup>>0.93; position sole predictor. Lateral coefficient range: 0.133 (<1.3% variation). All confounders p>0.05. VIF<1.5. GA: General Anesthesia; RA: Regional Anesthesia; LMA: Laryngeal Mask Airway; SAB: Subarachnoid Block

Stratification by BMI category and surgery duration demonstrated comparable consistency (Table 6). Across all four BMI categories—underweight (n=13), normal weight (n=249), overweight (n=60), and obesity (n=18)—lateral position maintained median pain location counts of 12–13 segments compared to supine medians of 0–1 segments, representing an 11–13 segment difference regardless of body habitus. Similarly, NRS score differences between lateral and supine positions ranged from 1.2 to 2.4 points across BMI strata, all exceeding the minimal clinically important difference threshold. Stratification by surgery duration (2–6 hours, n=315 vs >6 hours, n=25) revealed that lateral position produced median pain location counts 11 segments higher than supine position in the 2-6 hour group, with comparable patterns in the longer duration group.

**Table 6. Consistency of Position Effects Across BMI Categories and Surgery Duration**

Stratification	Position	n	Pain Locations Median (Range)	NRS Score Median (Range)	p-value
<b>BMI: NORMAL (n=249)</b>	Supine	147	1 (0–6)	2.56 (1.04–3.99)	<0.001
	Lateral	78	12 (8–17)	4.54 (3.03–5.97)	
	Prone	24	12 (9–17)	2.34 (1.10–3.98)	
<b>BMI: OVERWEIGHT (n=60)</b>	Supine	22	1 (0–6)	2.20 (1.01–3.94)	<0.001
	Lateral	28	12 (11–14)	4.58 (3.08–5.90)	
	Prone	10	12 (8–16)	2.30 (1.06–3.63)	
<b>BMI: UNDERWEIGHT (n=13)</b>	Supine	8	1 (0–1)	2.91 (1.15–3.83)	0.002

	Lateral	5	13 (11–13)	4.12 (3.01–4.83)	
<b>BMI: OBESITY (n=18)</b>					
	Supine	10	0 (0–4)	2.74 (1.11–3.92)	0.002
	Lateral	8	13 (12–14)	4.51 (3.22–5.78)	
<b>DURATION: 2-6 hours (n=315)</b>					
	Supine	174	1 (0–6)	2.61 (1.01–3.99)	<0.001
	Lateral	119	12 (8–17)	4.47 (3.01–5.97)	
	Prone	22	12 (8–16)	2.47 (1.10–3.98)	

Note: Data presented as median (range). Kruskal-Wallis test p-values shown for each stratification. Across all BMI categories, lateral position consistently showed 11–13 more pain locations and 1.2–2.4 higher NRS scores vs supine, demonstrating position effects transcend body habitus. Position effects remained consistent across duration groups. BMI categories per Asian-Pacific criteria: Underweight <18.5, Normal 18.5–22.9, Overweight 23–24.9, Obesity ≥25 kg/m<sup>2</sup>. NRS = Numerical Rating Scale (0–10). Duration >6h group (n=25) had no lateral patients; prone vs supine: 12 vs 2 locations, p<0.001.

These stratified analyses demonstrate that surgical position exerts remarkably consistent effects across patient characteristics and procedural variations. The less than 1.3% variation in position coefficients across anesthesia techniques, combined with consistent 11–13 segment differences across BMI categories and duration strata, indicates that positioning-related biomechanical stress represents a universal determinant of postoperative non-incisional pain that transcends patient demographics, anesthetic management, and surgical complexity.

**Summary of Findings**

Four principal findings emerged from this analysis. First, lateral and prone positions demonstrated approximately 10-fold higher pain location counts compared to supine position at 24 hours (median 12 vs 1 locations, p<0.001), with 100% pain occurrence versus 76.5% for supine. Second, lateral position uniquely produced clinically meaningful pain intensity increases (1.90 points higher NRS exceeding minimal important difference), with 68.9% of patients experiencing moderate pain compared to exclusively mild pain in supine patients. Third, stratified analyses revealed remarkable consistency of position effects across patient subgroups: lateral position coefficients varied by less than 1.3% across anesthesia techniques and maintained 11–13 segment differences across all BMI categories and surgery durations. Fourth, these position-related differences

remained stable throughout the 24-hour observation period despite overall temporal pain reduction. Collectively, these findings demonstrate that surgical positioning represents a dominant biomechanical determinant of postoperative non-incisional pain that transcends patient characteristics, anesthetic management, and procedural complexity.

## DISCUSSION

This prospective cross-sectional study demonstrates that surgical positioning exerts a substantial and independent effect on postoperative non-incisional pain. Among 340 patients undergoing elective surgery, lateral and prone positions produced approximately 10-fold higher pain location counts compared to supine position at 24 hours postoperatively (median 12 vs 1 locations), with lateral position additionally generating clinically significant increases in pain intensity. Stratified regression analyses across anesthesia techniques revealed remarkable consistency of position effects (coefficient variation <1.3%), while traditional confounding variables such as BMI and surgery duration showed no significant associations across all patient subgroups.

The finding that 100% of lateral and prone positioned patients experienced persistent pain at 24 hours, compared to 76.5% of supine patients, aligns with biomechanical principles governing tissue pressure distribution. Mallmann *et al.*, (2023)<sup>18</sup> identified surgical positioning as an independent predictor of postoperative pain in a multicenter study, reporting that asymmetric loading patterns consistently produced higher pain scores. Our results extend this evidence by quantifying both the spatial distribution (location count) and intensity dimensions of positioning-related pain across standardized timepoints.

The 10-fold difference in pain location count represents the most striking finding. While supine positioning distributed pressure across broad dorsal surfaces (occiput, scapulae, sacrum, heels), lateral positioning concentrated forces onto the dependent shoulder, hip, and lateral malleolus.<sup>19</sup> This mechanical concentration likely explains the extensive pain distribution observed in lateral patients. Defloor (2000)<sup>12</sup> demonstrated that lateral positioning generates interface pressures exceeding 70 mmHg at the greater trochanter more than twice the capillary occlusion threshold providing a physiological basis for our observed pain patterns.

Prone positioning produced similarly widespread pain distribution but notably lower intensity compared to lateral position. This paradox may reflect differences in pressure dispersion: prone positioning distributes anterior contact across chest, abdomen, and facial structures, whereas lateral positioning creates localized high-pressure points.<sup>20</sup> The large surface area contact in prone position, though involving more body segments, may generate lower per-segment pressure intensity, consistent with our finding of moderate pain location counts (12 segments) but mild-to-moderate NRS scores (2.4 at 24 hours).

Multiple interconnected mechanisms likely contribute to positioning-related pain. Sustained pressure exceeding capillary perfusion pressure (typically 32 mmHg) induces tissue ischemia and metabolite accumulation, activating

peripheral nociceptors.<sup>21,22</sup> Oomens *et al.* (2015)<sup>5</sup> demonstrated that pressure-induced deep tissue injury involves both direct cellular deformation and ischemia-reperfusion cascades, explaining why pain persists hours after pressure relief. Our temporal data showing minimal improvement in lateral/prone positions through 24 hours suggests ongoing inflammatory processes rather than simple mechanical resolution.

Nerve compression and stretch represent additional contributors, particularly in lateral positioning. The brachial plexus becomes vulnerable when the dependent shoulder bears prolonged weight, while extreme positioning may stretch the lateral femoral cutaneous nerve.<sup>23</sup> Although we did not document specific neuropathic symptoms, the widespread pain distribution in lateral patients extending beyond direct contact points suggests possible nerve involvement or referred pain patterns from deep somatic structures.<sup>24</sup>

Referred pain mechanisms warrant consideration given the extensive non-contiguous pain distributions observed. McCall *et al.* (1979)<sup>25</sup> demonstrated that mechanical stimulation of posterior lumbar elements produces pain referral to distant sites in predictable patterns. Positioning-induced stress on facet joints, ligaments, and paraspinal muscles during prolonged immobilization may similarly generate referred pain, contributing to the multiple body segments affected beyond direct pressure points.

The role of central sensitization, while not directly measured, merits discussion. Kehlet and Dahl (2003)<sup>15</sup> described how peripheral nociceptive input during surgery triggers central nervous system amplification, potentially explaining why relatively modest mechanical stimuli produce persistent widespread pain. The consistent 1.9-point NRS difference between lateral and supine positions across all timepoints suggests sustained central processing differences rather than simple peripheral adaptation.

Supine positioning demonstrated the most favorable pain profile, consistent with its biomechanical advantages: even pressure distribution across the posterior surface, neutral joint positioning, and minimal nerve compression risk.<sup>26</sup> The progressive improvement from 89.8% to 76.5% pain occurrence over 24 hours suggests effective tissue recovery when positioning stress remains within physiological tolerance.

Lateral positioning emerged as the highest-risk position for postoperative pain. The 1.9-point NRS elevation represents a clinically meaningful difference exceeding minimal important difference thresholds.<sup>27</sup> Remarkably, 68.9% of lateral patients experienced moderate pain (NRS 4-6) at 24 hours which is a unique finding among positions, suggesting qualitatively different pain experiences. Reeve *et al.* (2011)<sup>28</sup> noted that concentrated pressure points in lateral positioning activate high-threshold mechanoreceptors more intensively than distributed pressure, potentially explaining this intensity difference.

Prone positioning presented an intermediate profile: extensive pain distribution similar to lateral position but lower intensity approaching supine levels. Patterns in critically ill patients requiring prolonged prone positioning,

attributing symptoms to anterior chest wall compression and facial tissue pressure.<sup>29</sup> The clinical implication is that prone positioning, while necessary for certain procedures, requires particular attention to facial padding and anterior support optimization.

The remarkable consistency of position effects across patient subgroups represents a critical finding that challenges conventional risk stratification paradigms. Stratified regression analyses revealed that the lateral position coefficient varied by less than 1.3% across anesthesia techniques (general with intubation, general with LMA, regional spinal), despite substantial differences in muscle tone modulation and neuraxial blockade presence.<sup>30</sup> Similarly, position effects remained consistent across BMI categories, with lateral positioning producing 11-13 more pain locations than supine regardless of body habitus, from underweight through obesity.<sup>31</sup> This universality aligns with biomechanical principles demonstrating that gravitational force distribution and tissue deformation represent the dominant determinants of positioning-related tissue stress.<sup>32</sup> The finding that neither obesity nor prolonged surgical duration modified position effects contradicts traditional assumptions emphasizing these factors as primary pain risk modifiers.<sup>33</sup> Instead, our data suggest that position-specific biomechanical loading patterns exert effects of such magnitude that patient-specific characteristics become relatively inconsequential in determining pain outcomes.

These findings have immediate practical applications for perioperative care. First, position-specific analgesic strategies appear warranted.<sup>34</sup> Lateral positioned patients may benefit from enhanced multimodal analgesia targeting both nociceptive and potentially neuropathic components, given their markedly elevated pain burden. Current standardized protocols may inadequately address position-specific pain mechanisms.

Second, positioning optimization represents a modifiable risk factor. While surgical requirements often dictate position choice, attention to padding placement, limb positioning, and pressure point protection becomes especially critical for lateral procedures. The Association of periOperative Registered Nurses emphasizes systematic padding protocols, but our data suggest that even with standard precautions, lateral positioning carries substantially higher pain risk.<sup>35</sup>

Third, informed consent discussions should acknowledge position-related pain expectations. Patients undergoing lateral procedures face near-certain pain occurrence extending beyond the surgical site, with majority experiencing moderate intensity. Setting realistic expectations may improve satisfaction and facilitate appropriate analgesic use.

Fourth, stratified analyses demonstrating that BMI, anesthesia technique, and surgery duration did not modify position effects (all  $p > 0.05$  across all subgroups) suggest that mechanical positioning factors dominate other considerations in determining postoperative pain patterns. This challenges conventional wisdom emphasizing obesity or prolonged duration as primary pain risk factors and

supports a paradigm shift toward position-centered rather than patient-centered prevention strategies.<sup>36</sup>

Strengths include the prospective design, standardized pain assessment using validated tools across multiple timepoints, comprehensive body mapping enabling spatial pain characterization, and rigorous statistical approaches including stratified regression analyses across patient subgroups. The substantial effect sizes ( $\eta^2=0.76$ ,  $R^2>0.93$  across stratified models) indicate robust relationships unlikely to represent statistical artifacts.

Limitations warrant acknowledgment. The unequal group sizes ( $n=187, 119, 34$ ) reflect real-world surgical practice distributions but limit prone position statistical power. The single-center design may affect generalizability, though biomechanical principles should apply universally. We did not measure interface pressures directly or document specific padding protocols, preventing mechanistic correlation with measured pressures. The 24-hour follow-up captures acute pain but not potential chronic sequelae. Finally, we cannot exclude unmeasured confounding from surgical procedure types, though our stratified regression models controlled for key known confounders.

## CONCLUSIONS

In conclusion, this prospective cross-sectional study demonstrates that surgical positioning is a dominant biomechanical determinant of postoperative non-incisional pain. Lateral and prone positions produced approximately 10-fold higher pain location counts compared to supine position at 24 hours (median 12 vs 1 locations), with lateral position additionally generating clinically significant pain intensity increases (median NRS 4.41 vs 2.51). Stratified analyses revealed remarkable consistency of position effects across patient subgroups: lateral position coefficients varied by less than 1.3% across anesthesia techniques, with consistent 11-13 segment differences across all BMI categories and surgery durations. These findings demonstrate that position-specific biomechanical forces dominate traditional risk factors in determining postoperative pain outcomes.

The clinical implications are substantial. Lateral positioned patients experience nearly universal pain occurrence (100%), extensive distribution (median 12 segments), and moderate intensity (NRS 4.41), representing substantially higher burden than supine patients (76.5%, 1 segment, NRS 2.51). These differences warrant position-specific analgesic strategies, enhanced padding protocols, and informed patient counseling.

Future research should investigate interventions to mitigate positioning-related pain, including optimal padding configurations, position-specific multimodal analgesia protocols, and the relationship between acute positioning pain and chronic postsurgical pain development. Addressing positioning-related pain through position-centered prevention strategies represents an important opportunity to improve perioperative outcomes..

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