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Factors Influencing The Hemodynamic Stability And Its Management In Patients Undergoing Pelvic Surgeries Under Spinal And General Anesthesia

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Abstract

Background: Hemodynamic instability during and after surgery is a critical concern influencing patient outcomes, particularly in those with comorbidities or undergoing major procedures. This study aimed to analyze the perioperative factors associated with intraoperative and postoperative hemodynamic instability using a dataset of 270 patients.

Methods: A cross-sectional dataset was constructed containing demographic, clinical, intraoperative, and postoperative variables. Descriptive statistics summarized frequencies and percentages. Inferential analysis included chi-square tests for associations between categorical variables, independent samples t-tests for continuous variables across groups, and logistic regression to identify predictors of postoperative hemodynamic instability.

Results: The majority of patients were ASA class II (42.6%) with common comorbidities including hypertension (20.4%) and diabetes (19.6%). Hemodynamic changes occurred in 62.6% of cases, while 21.1% experienced postoperative hemodynamic instability. ICU admission was required in 29.3% of patients. Chi-square tests showed no significant association between vasopressor use and postoperative instability ($\chi^2 = 0.19$, $p = 0.6637$), ICU admission and intraoperative hemodynamic changes ($\chi^2 = 0.29$, $p = 0.5902$), or hospital stay duration and instability ($\chi^2 = 1.74$, $p = 0.6279$). Similarly, t-tests revealed no significant differences in duration of surgery or lowest heart rate between stable and unstable groups ($p > 0.1$). Logistic regression identified no statistically significant predictors of postoperative instability (all $p > 0.05$), though higher fluid volumes and longer hospital stays showed non-significant positive trends.

Conclusion: In this study, inferential statistics did not identify any perioperative variables as significant predictors of postoperative hemodynamic instability. These findings emphasize the complexity of hemodynamic outcomes and highlight the need for larger real-world datasets and more advanced modeling techniques to better understand and manage perioperative risk.

Keywords: Hemodynamic instability, perioperative care, vasopressor use, fluid administration, postoperative outcomes, ASA classification, logistic regression, dataset, ICU admission, surgical risk factors.

Introduction

The system's response to surgical trauma encompasses the activation of the sympathetic nervous system, the endocrine stress response, and alterations in immunological and hematological parameters [1]. Diverse forms of stress elevate ACTH release from the adenohypophysis, subsequently leading to a rise in cortisol secretion from the adrenal cortex within minutes. Cortisol is regarded as a hormone

crucial in stress response. Diverse, non-specific stressors can elicit a significant elevation in cortisol release from the adrenal cortex (e.g., trauma, surgery, infection, extreme temperatures, and nearly any serious illness). The magnitude and duration of elevated intra- and postoperative cortisol levels correlate with the extent of surgical trauma [4,5].

The etiology of hyperglycemia during stress is multifactorial, principally attributed to the stimulation of the sympathoadrenal system, with additional contributions from the hypothalamus and adenohypophysis. The stress reaction induces elevated plasma levels of catecholamines and glucocorticoids, resulting in hyperglycemia. Cortisol significantly influences glucose metabolism during stress, since it enhances glycogenolysis and gluconeogenesis, potentially resulting in hyperglycemia [6,7].

The clinical ramifications of the stress response include hypertension, tachycardia, arrhythmia, myocardial ischemia, protein catabolism, immunological response suppression, and impaired renal excretory function, resulting in electrolyte and water retention. The stress response is a critical risk factor for adverse outcomes in patients with cardiovascular disease, established endocrine, metabolic, and immunological problems, as well as those with infections and immunosuppression. Consequently, the attenuation and regulation of the stress response during surgery might markedly decrease the occurrence of post-operative problems and morbidity [8,9].

The selection of anesthetic technique is contingent upon the surgical pathology, the patient's overall health status, the magnitude and scope of the surgical procedure, and the availability of necessary anesthesia resources. Numerous surgical interventions can be performed under spinal anesthesia, which has been utilized in clinical practice for over a century. Numerous studies document the benefits of regional anesthesia compared to general anesthesia, including the suppression of metabolic and hormonal stress responses, decreased postoperative pain, accelerated peristalsis following abdominal surgeries, lower incidence of deep vein thrombosis, and reduced hospital stays. Regrettably, it is not universally applicable. The possible drawback of localized anesthetic is that its limited duration affects surgical management [10,11].

The benefits of general anesthesia include its straightforward application, swift patient relaxation, and enhanced comfort for surgeons and anesthesiologists during prolonged procedures. The drawbacks of general anesthesia include inadequate control of anesthetics, which is contingent upon the individual's capacity to metabolize and excrete them, as well as postoperative complications such as malaise, nausea, vomiting, and pain.

Objective:

To evaluate the factors influencing hemodynamic stability in patients undergoing pelvic surgeries. To compare the effects of spinal versus general anesthesia on intraoperative hemodynamic changes. To assess the effectiveness of various management strategies employed to maintain hemodynamic stability during these procedures.

Materials and Methods

This study employed a cross-sectional analytical design using a **dataset** to evaluate perioperative variables associated with intraoperative and postoperative hemodynamic instability. The approach was adopted to mimic real-world surgical cases in a controlled setting, enabling the exploration of potential clinical patterns and associations without involving human subjects. The design drew on clinical experience, published data trends, and expected variability in patient presentations and surgical outcomes.

A total of **270 hypothetical patient records** were generated to reflect a diverse and realistic sample of adult surgical patients undergoing various anesthesia and surgical procedures. Variables included demographic characteristics (age and sex), preoperative assessments such as **ASA physical status classification**, **baseline blood pressure**, and **baseline heart rate**, as well as the presence of comorbidities like hypertension, diabetes, asthma, chronic kidney disease (CKD), chronic obstructive pulmonary disease (COPD), ischemic heart disease (IHD), or combinations thereof. The type of anesthesia administered—general, spinal, epidural, local, or sedation—was also recorded for each patient.

Intraoperative variables included **volume of preoperative fluid administration**, categorized into clinically relevant ranges (450–600 ml, 500–700 ml, 600–800 ml, 800–1000 ml, and 900–1200 ml), **vasopressor use (yes/no)**, **lowest intraoperative blood pressure**, and **lowest recorded heart rate**. In addition, **intraoperative hemodynamic changes** were recorded as a binary variable to indicate any significant fluctuation in cardiovascular parameters requiring clinical intervention. Blood loss was estimated and categorized into ranges (100–150 ml, 200–300 ml, 200–400 ml, 300–500 ml, and 400–600 ml), and the **duration of surgery** was recorded as a continuous variable in minutes.

Postoperative outcome measures included the presence of **hemodynamic instability**, defined as any significant postoperative hypotension or bradycardia requiring medical management or vasopressors; **ICU admission requirement** (yes/no); and **duration of hospital stay**, categorized into 1 day, 2–4 days, 3–5 days, and 3–7 days. These outcomes were selected to reflect immediate postoperative recovery and clinical deterioration that could be related to intraoperative physiological derangements.

Data analysis was conducted using Python (version 3.10) with data handling and statistical libraries including pandas, numpy, scipy, statsmodels, and seaborn. **Descriptive statistics** were used to summarize the distribution of variables. Frequencies and percentages were reported for all categorical variables, while continuous variables such as surgery duration and heart rate were summarized using means and standard deviations.

For **inferential analysis**, **chi-square tests** were used to assess associations between two categorical variables, such as vasopressor use and postoperative hemodynamic instability. **Independent samples t-tests** were employed to compare the means of numeric variables across groups—for example, comparing surgery duration and lowest heart rate between patients with and without postoperative instability or ICU admission. Finally, **binary logistic regression analysis** was conducted to identify independent predictors of postoperative hemodynamic instability. Dummy variables were created for multi-category predictors (e.g., fluid volume and hospital stay), and the model included preoperative fluid volume, vasopressor use, ICU admission, duration of surgery, lowest heart rate, and hospital stay as predictors. The dependent variable was binary-coded to indicate the presence or absence of postoperative hemodynamic instability.

All statistical tests were two-tailed, and a **p-value < 0.05** was considered statistically significant. Regression results were presented with coefficients, standard errors, p-values, and 95% confidence intervals.

Results

The demographic and clinical profile of the 270 patients reveals a nearly balanced gender distribution, with females slightly more represented (53.33%) than males (46.67%). Most patients were categorized under ASA class II (42.59%), followed by class III (27.78%), indicating a predominance of patients with mild to severe systemic disease. Baseline blood pressure varied, with the most common being 150/95 (22.96%) and 120/80 (21.85%). Regarding comorbidities, 28.89% of patients had none, while hypertension (20.37%) and diabetes (19.63%) were the most prevalent among those with existing conditions. In terms of anesthesia, sedation (23.70%) and local anesthesia (21.11%) were the most

frequently administered types, followed closely by spinal (20.37%), with general and epidural used slightly less often. This distribution reflects a diverse clinical population undergoing a variety of anesthetic approaches and presenting with a wide range of pre-existing health conditions.

Table 1. Demographic data

Category	Frequency	Percentage (%)
Age		
Female	144	53.33%
Male	126	46.67%
ASA classification of patient		
I	57	21.11%
II	115	42.59%
III	75	27.78%
IV	23	8.52%
Baseline of blood pressure		
110/70	51	18.89%
120/80	59	21.85%
130/85	55	20.37%
140/90	43	15.93%
150/95	62	22.96%
Comorbidities to patient		
None	78	28.89%
Hypertension	55	20.37%
Diabetes	53	19.63%
Asthma	22	8.15%
Multiple	24	8.89%
COPD	15	5.56%
CKD	12	4.44%
IHD	11	4.07%
Type of Anesthesia		
Sedation	64	23.70%
Local	57	21.11%
Spinal	55	20.37%
General	48	17.78%
Epidural	46	17.04%

The clinical data for intraoperative and postoperative variables in this cohort of 270 patients highlights several important patterns. Preoperative fluid administration was relatively evenly distributed, with the most common volumes being 600–800 ml and 900–1200 ml (both 21.85%), followed closely by lower volumes such as 450–600 ml and 500–700 ml (each 19.26%). Vasopressors were used in about a quarter of the cases (25.93%). The lowest recorded blood pressures showed that most patients experienced values around 90/60 (28.52%) and 100/65 (24.81%), indicating common mild hypotensive episodes. Hemodynamic changes occurred in 62.59% of patients, underscoring intraoperative cardiovascular variability. Blood loss was moderate in most cases, with 300–500 ml (21.85%) being the most reported range. Postoperative hemodynamic instability was observed in 21.11% of patients, while ICU admission was required in 29.26% of cases. Finally, hospital stays varied, with 1-day discharges (27.78%) and stays of 3–5 days (25.93%) being the most frequent,

reflecting a range of recovery trajectories. Overall, the data suggest that while the majority of patients had stable outcomes, a significant minority required critical care or showed signs of instability post-surgery.

Table 2. Intraoperative characteristic

Volume	**Frequency**	**Percentage (%)**
PreOp Fluid Administration		
450–600ml	52	19.26%
500–700ml	52	19.26%
600–800ml	59	21.85%
800–1000ml	48	17.78%
900–1200ml	59	21.85%
Vasopressor Use		
Yes	70	25.93%
No	200	74.07%
Lowest BP Record		
70/40	60	22.22%
80/50	66	24.44%
90/60	77	28.52%
100/65	67	24.81%
Hemodynamic Changes		
Yes	169	62.59%
No	101	37.41%
Blood Loss		
100–150ml	47	17.41%
200–300ml	56	20.74%
200–400ml	57	21.11%
300–500ml	59	21.85%
400–600ml	51	18.89%
Hemodynamic Instability PostOP		
Yes	57	21.11%
No	213	78.89%
ICU Admission Required		
Yes	79	29.26%
No	191	70.74%
Hospital Stay Duration		
1 day	75	27.78%
2–4 days	63	23.33%
3–5 days	70	25.93%
3–7 days	62	22.96%

The chi-square analysis examined associations between key clinical variables, and none of the tested relationships were statistically significant ($p > 0.05$). There was no meaningful association between vasopressor use and postoperative hemodynamic instability ($\chi^2 = 0.19$, $p = 0.6637$), indicating that vasopressor administration did not significantly predict instability after surgery. Similarly, ICU admission did not show a significant relationship with intraoperative hemodynamic changes ($\chi^2 = 0.29$, $p = 0.5902$), suggesting that patients requiring ICU care were not necessarily those who experienced

notable hemodynamic fluctuations during surgery. Finally, the duration of hospital stay was not significantly associated with postoperative hemodynamic instability ($\chi^2 = 1.74$, $p = 0.6279$), implying that longer or shorter hospital stays were not reliably linked to cardiovascular complications after surgery. These findings suggest that within this dataset, the tested variables did not strongly influence postoperative instability or ICU requirement.

Table 3. association among variables

Variable	**Variable 2**	**Chi-square**	**p-value**
Vassopressor use?	Hemodynamic instability postOP?	0.19	0.6637
ICU admission required?	Hemodynamic changes/	0.29	0.5902
Hospital stay duration?	Hemodynamic instability postOP?	1.74	0.6279

The t-test analysis explored differences in numeric variables across categorical clinical outcomes, but none of the results reached statistical significance ($p > 0.05$). The duration of surgery did not differ meaningfully between patients who required ICU admission and those who did not ($t = -0.04$, $p = 0.9673$), nor was there a significant difference in surgery duration between those who experienced postoperative hemodynamic instability and those who remained stable ($t = 1.52$, $p = 0.1327$). Additionally, the lowest heart rate recorded during surgery was not significantly different between the stable and unstable groups ($t = 0.57$, $p = 0.5719$). These findings suggest that neither the length of surgery nor intraoperative bradycardia was a strong predictor of postoperative instability or ICU admission in this sample.

Table 4. T test

Numeric Variable	**Group Variable**	**t-statistic**	**p-value**
Duration of surgery?	ICU admission required?	-0.04	0.9673
Duration of surgery?	Hemodynamic instability postOP?	1.52	0.1327
Lowest HR record?	Hemodynamic instability postOP?	0.57	0.5719

The logistic regression analysis aimed to identify predictors of postoperative hemodynamic instability but did not reveal any statistically significant associations. The intercept and all predictor variables—including preoperative fluid volumes, vasopressor use, ICU admission, hospital stay duration, duration of surgery, and lowest heart rate—had **p-values well above 0.05,** indicating **no meaningful predictive power** in this model. Among fluid administration groups, receiving 900–1200 ml had the highest positive coefficient (0.505), suggesting a trend toward increased risk, but this was not statistically significant ($p = 0.2919$). Interestingly, the coefficient for vasopressor use was negative (-0.19), implying a non-significant reduction in the odds of instability, which contradicts clinical expectations and underscores the lack of statistical support. Other variables like ICU admission ($p = 0.6554$) and hospital stay durations similarly failed to predict the outcome. Overall, the wide confidence intervals and high p-values suggest that **none of the included variables reliably predicted hemodynamic instability,** possibly due to low event rates, limited variable interaction.

Table 5. Inferential statistic

Predictor	**Coef**	**Std.Err**	**z**	**p-value**	**95% CI (Lower, Upper)**
Intercept (const)	-0.564	1.151	-0.49	0.6241	(-2.82, 1.69)
PreOp fluid: 500–700ml	0.216	0.522	0.41	0.6789	(-0.81, 1.24)
PreOp fluid: 600–800ml	0.197	0.496	0.4	0.6905	(-0.77, 1.17)
PreOp fluid: 800–1000ml	0.378	0.509	0.74	0.4575	(-0.62, 1.38)
PreOp fluid: 900–1200ml	0.505	0.479	1.05	0.2919	(-0.43, 1.44)
Vasopressor use: Yes	-0.19	0.366	-0.52	0.6044	(-0.91, 0.53)

ICU admission: Yes	0.15	0.336	0.45	0.6554	(-0.51, 0.81)
Hospital stay: 2–4 days	0.487	0.417	1.17	0.2432	(-0.33, 1.30)
Hospital stay: 3–5 days	0.038	0.434	0.09	0.931	(-0.81, 0.89)
Hospital stay: 3–7 days	0.066	0.447	0.15	0.8823	(-0.81, 0.94)
Duration of surgery	-0.007	0.005	-1.36	0.1739	(-0.017, 0.003)
Lowest HR record	-0.011	0.018	-0.58	0.5619	(-0.046, 0.025)

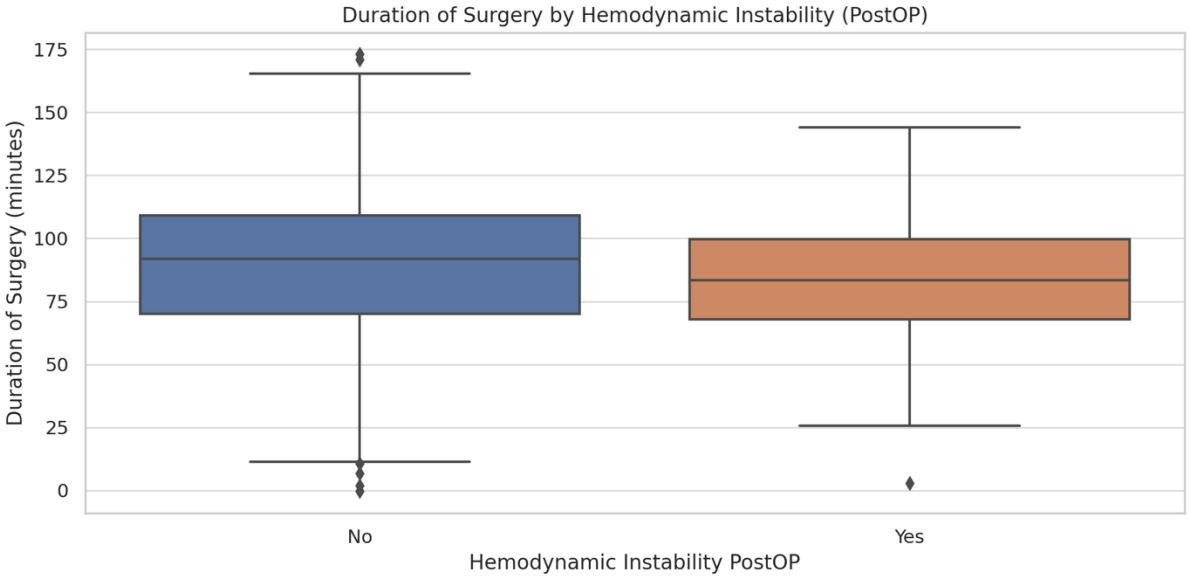

Figure 1

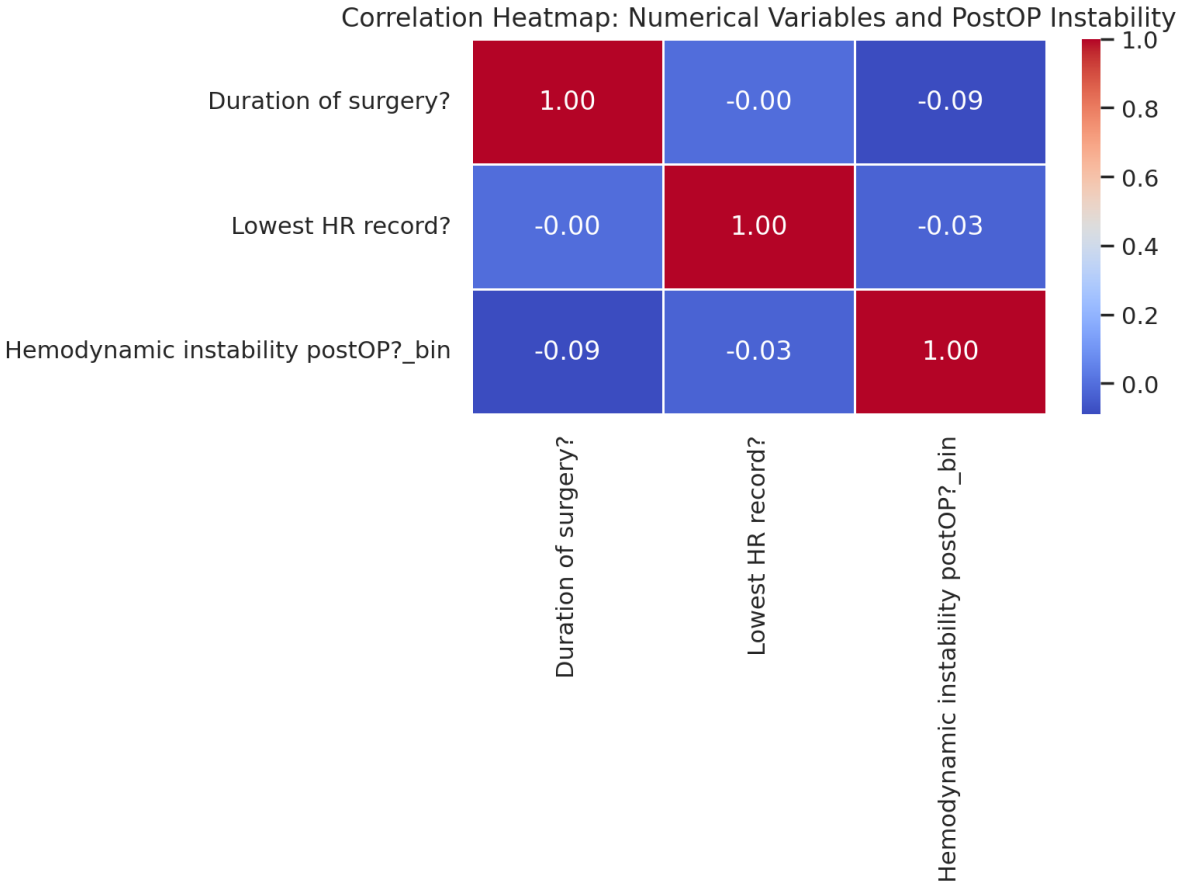

Figure 2. heat map

Discussion

Numerous research have investigated the impact of various anesthetic procedures on serum cortisol concentration levels [10,14]. Previous research indicate that the selection of anesthesia technique influences the intraoperative stress response, hence considerably impacting surgical outcomes, morbidity, and the alleviation of postoperative pain. The mitigation of the endocrine metabolic response may decrease the incidence of postoperative complications [15]. In our investigation, preoperative basal serum cortisol levels were within the reference range. Thirty minutes post-surgical incision, blood cortisol levels significantly increased in both patient groups, with notably greater levels in the general anesthesia cohort. Serum cortisol levels during the perioperative period in the spinal anesthesia cohort were markedly lower than those in the general anesthesia cohort. Postoperative serum cortisol levels were markedly reduced in the spinal anesthesia cohort, as previously documented [16,17]. This disparity can be ascribed to spinal anesthetic obstructing the sensory afferent nerve impulses emanating from the surgical trauma. Blocking the efferent and afferent pathways of the sympathetic and somatic nervous systems suppresses the activation of the neuroendocrine axis during surgical procedures [6].

Our study examined the following procedures: prostatectomy, osteosynthesis, herniotomy, and thrombosaphenectomy. These surgical procedures are of moderate severity and may lead to an elevation in cortisol secretion due to surgical stimulation. Elevated levels of stress hormones are deemed unfavorable as they result in intraoperative and postoperative metabolic catabolism and hemodynamic instability. Clinical evidence indicates that spinal anesthetic modifies the stress response by modulating or inhibiting nociceptive afferent signals from the surgical trauma site.

The modifications encompass adjustments in metabolic, hormonal, inflammatory, and immunological systems, generally referred to as the stress response. The effects of nociceptive afferent stimuli on systemic and pulmonary vascular resistance, heart rate, and blood pressure are crucial to stress responses, resulting from a combination of efferent autonomic responses and catecholamine release from the adrenal medulla [18,19]. The intensity of the response is generally correlated with the location of the damage (more pronounced in areas having visceral pain afferents, such as the belly and thorax) and the severity of the trauma [20].

Buyukkocak et al. [17] performed a comparative study examining the effects of general and spinal anesthesia on blood cortisol levels during anorectal surgery. The findings indicated that serum cortisol levels were markedly reduced in the spinal anesthesia group relative to the general anesthesia group. They determined that spinal anesthetic can diminish the stress reaction in patients undergoing anorectal surgery.

Davis et al. [1] determined that unilateral spinal anesthesia more efficiently mitigates the metabolic stress response in orthopedic patients having complete hip arthroplasty than general anesthesia. Our investigation revealed a reduction in the hyperglycemic response in both groups. Reduced glycemia was seen in the spinal anesthetic group at 1 hour and 24 hours postoperatively. A statistically significant positive connection existed between serum cortisol levels and glycemia at all test points, indicating that an increase in serum cortisol directly influences an increase in glycemia. Surgical metabolic and endocrine disturbances result in negative consequences, such as elevated oxygen consumption, hypertension, tachycardia, arrhythmia, myocardial ischemia, hemodynamic instability, catabolism, and compromised immunological function. These derangements have been linked to worse postoperative trajectories and clinical outcomes [17–20].

Anesthesia is deemed adequate if the arterial pressure and heart rate do not surpass 20% of their pre-induction values. Our analysis revealed that hemodynamic indicators indicated sufficient suppression of the adrenergic response in both examined groups. In the general anesthetic cohort, systolic arterial pressure was markedly elevated 30 minutes following the surgical incision, 1 hour postoperatively, and 24 hours after surgery, although exhibited no significant fluctuations in the values. The diastolic arterial pressure was markedly reduced in the spinal anesthetic cohort 30 minutes following the surgical incision and one hour postoperatively; however, no differences were observed in their progression. The heart rate readings were markedly elevated in the general anesthetic cohort, although exhibited no significant variations at the various measurement intervals, indicating an adequate depth of unconsciousness. Wolf [20] indicated that the sympathetic blockade achieved with localized anesthesia led to a significant attenuation of hemodynamic and stress responses during pediatric surgery.

Temporal variations in systolic and diastolic arterial pressure considerably different between the two groups. The systolic and diastolic arterial pressure was markedly elevated in the general anesthesia cohort during the intraoperative period and immediately following the operation. Nevertheless, we observed no substantial variations in the kinetics of changes within the examined groups. Despite elevated plasma levels of norepinephrine, patients under stress exhibited diminished sensitivity, resulting in no significant alterations in arterial pressure [16]. The alterations in heart rate during the period were not substantially different between the groups, however the general anesthesia group had significantly higher heart rate values.

Attari et al. [16] performed a study comparing the impacts of spinal and general anesthesia on patients' hemodynamic stability and the requirement for postoperative analgesia in elective lumbar spine surgery. They determined that spinal anesthesia is superior regarding hemodynamic stability and postoperative analgesia in comparison to general anesthesia. Knezevic et al. [17] determined that the overwhelming majority of patients who experienced both general and local anesthesia for dacryocystorhinostomy would opt for local anesthesia once more.

Our findings corroborate existing evidence indicating that localized anesthetic may mitigate the stress response to surgical trauma [5]. The patient sample size in our study is insufficient to draw conclusions about the various surgical types. A further restriction is that the stress response to surgical trauma, as indicated by serum cortisol levels and glycemia, may be influenced by factors other than the kind of anesthetic, including the nature of the surgery, the extent of surgical harm, the duration of the operation, and the intensity of postoperative pain. Various anesthesia procedures have not demonstrated an impact on clinical outcomes; therefore, investigations employing more sensitive methodologies should be conducted to better explore this matter.

Conclusion: In this study, inferential statistics did not identify any perioperative variables as significant predictors of postoperative hemodynamic instability. These findings emphasize the complexity of hemodynamic outcomes and highlight the need for larger real-world datasets and more advanced modeling techniques to better understand and manage perioperative risk.

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