Original Research

COMPARATIVE EVALUATION OF HEMODYNAMIC CHANGES FOLLOWING SPINAL ANAESTHESIA IN CONTROLLED HYPERTENSIVE AND NORMOTENSIVE PATIENTS

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ABSTRACT

Introduction: Spinal anaesthesia commonly causes hypotension due to sympathetic blockade. Controlled hypertensive patients may exhibit altered cardiovascular responses because of vascular and autonomic changes. Evidence comparing hypertensive and normotensive patients remains inconsistent. This study aimed to comparatively evaluate hemodynamic changes following spinal anaesthesia to improve perioperative risk stratification and management.

Material and Method: This comparative observational study included 120 American Society of Anesthesiologists physical status (ASA) I–III patients (40–75 years) undergoing elective infraumbilical surgeries under spinal anaesthesia. Patients were grouped as controlled hypertensive or normotensive. Standardized spinal technique and monitoring were used. Hemodynamic variables were recorded up to 30 minutes. Hypotension was predefined and managed accordingly. Statistical analysis included t-test, ANOVA, Chi-square, and Pearson correlation.

Result: A total of 120 patients undergoing spinal anaesthesia were studied i.e. 60 Controlled hypertensive patients (CHT) and 60 normotensive (NT) with comparable demographics and surgical characteristics. Controlled hypertensive patients had higher baseline mean arterial pressure, systolic and diastolic blood pressure and experienced greater maximum hemodynamic declines. Hypotension (48.3% vs 28.3%) and vasopressor requirement were significantly higher in CHT patients. Advanced age, elevated baseline pressures, higher sensory block, increased body mass index (BMI), and longer surgery predicted hypotension.

Conclusion: Controlled hypertensive patients experience greater hemodynamic instability following spinal anaesthesia compared to normotensive individuals, with higher incidence and earlier onset of hypotension and increased vasopressor requirement. Careful monitoring and individualized perioperative management are essential to improve safety and outcomes.

Keywords: Spinal Anesthesia, Controlled Hypertension, Normotensive Patients, Hemodynamic, Hypotension, Vasopressor Etc.

INTRODUCTION

Spinal anaesthesia is a widely practiced regional anaesthetic technique for infraumbilical and lower limb surgeries due to its rapid onset, effective sensory and motor blockade, reduced stress response, and favourable postoperative analgesia profile. However, it is commonly associated with significant hemodynamic alterations, primarily resulting from sympathetic blockade.

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The interruption of sympathetic outflow leads to vasodilation, decreased systemic vascular resistance, pooling of blood in the venous capacitance vessels, and reduction in venous return, ultimately causing hypotension and occasionally bradycardia [1], [2]. These cardiovascular changes are usually transient but may become clinically significant in patients with altered cardiovascular physiology. Intraoperative hypotension is not a benign event. Several recent studies have demonstrated its association with adverse outcomes including myocardial injury, acute kidney injury, and increased perioperative morbidity [3], [4]. Even short durations of mean arterial pressure below critical thresholds have been linksed with poor

postoperative outcomes [3]. Therefore, understanding patient-related factors that predispose to exaggerated hemodynamic responses following spinal anaesthesia is essential for optimizing perioperative care. Hypertension is one of the most prevalent chronic medical conditions worldwide and is frequently encountered in patients presenting for elective surgery [5]. Although blood pressure may be adequately controlled with antihypertensive therapy, chronic hypertension produces structural and functional vascular changes such as arterial stiffness, impaired baroreceptor sensitivity, and altered autonomic regulation [6]. These changes may influence cardiovascular responses to sympathetic blockade induced by spinal anaesthesia. Furthermore, commonly prescribed antihypertensive medications, including beta-blockers, calcium channel blockers, and renin–angiotensin system inhibitors, may modify compensatory cardiovascular mechanisms during acute reductions in systemic vascular resistance [7]. Previous investigations comparing controlled hypertensive and normotensive patients undergoing spinal anaesthesia have reported variable findings. Some studies have observed a higher incidence and greater magnitude of hypotension among controlled hypertensive patients, along with increased vasopressor requirements [8], [9]. In contrast, other studies have not demonstrated statistically significant differences between the two groups, suggesting that adequate preoperative control of blood pressure may mitigate excessive hemodynamic instability [10]. These inconsistencies highlight the need for further well-designed comparative studies. Given the rising global burden of hypertension and the continued preference for spinal anaesthesia in routine surgical practice, a comparative evaluation of hemodynamic changes in controlled hypertensive and normotensive patients is clinically relevant. Identifying differences in blood pressure trends, heart rate variability, and vasopressor requirements may aid in better perioperative planning, individualized fluid management, and timely pharmacological intervention. Therefore, the present study aims to comparatively evaluate the hemodynamic changes following spinal anaesthesia in controlled hypertensive and normotensive patients to enhance patient safety and improve anaesthetic management strategies.

MATERIAL AND METHOD

This comparative observational study was conducted in the Department of Anaesthesiology at Laxmi Chandravansi Medical College and Hospital, Bishrampur, Palamu, after obtaining approval from the Institutional Ethics Committee. The study was carried out over a period of 12 months from November 2024 to November 2025. Informed consent was obtained from all participants prior to enrolment. A total of 120 patients undergoing elective infraumbilical surgeries under spinal anaesthesia were included in the study. Adult patients aged 40–75 years, of either gender, belonging to American Society of Anesthesiologists (ASA) physical status I to III were considered eligible. Patients were categorized into two groups based on their preoperative blood pressure status. Group CHT (Controlled Hypertensive Group) consisted of patients with a documented history of essential hypertension who were on regular antihypertensive therapy and had preoperative blood pressure maintained below 140/90 mmHg. Group NT (Normotensive Group) comprised patients without any history of hypertension and with consistently normal blood pressure recordings during pre-anaesthetic evaluation. Exclusion criteria included uncontrolled or secondary hypertension, coronary artery disease, significant valvular heart disease, cardiac arrhythmias, congestive heart failure, diabetes mellitus with autonomic neuropathy, chronic kidney disease, body mass index greater than 35 kg/m^2, pregnancy, coagulopathy, contraindications to spinal anaesthesia, emergency surgeries, and cases requiring conversion to general anaesthesia.

The sample size was calculated assuming an expected 15% difference in the incidence of post-spinal hypotension between the two groups, with a confidence level of 95% and a study power of 80%. The minimum required sample size was 54 patients per group. To enhance reliability and compensate for possible exclusions, 60 patients were recruited in each group, resulting in a total sample size of 120 participants. All patients followed standard fasting guidelines. Baseline hemodynamic parameters including heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), and peripheral oxygen saturation (SpO_2) were recorded prior to administration of anaesthesia. Intravenous access was established, and patients received crystalloid coloading at 10 ml/kg. Spinal anaesthesia was administered in the sitting position at the L3–L4 interspace using a 25-gauge Quincke needle under strict aseptic precautions. A standardized dose of 3 ml of 0.5% hyperbaric bupivacaine was injected intrathecally. Patients were subsequently placed supine and given supplemental oxygen. Hemodynamic variables were recorded at baseline (pre-spinal), and subsequently at 5, 10, 20, and 30 minutes following administration of spinal anaesthesia. Additional readings were recorded intraoperatively as clinically indicated until completion of surgery. Hypotension was defined as a reduction in SBP greater than 20% from baseline or an absolute SBP below 90 mmHg and was treated with intravenous ephedrine and additional fluids. Severe hypotension was defined as a >30% fall in systolic blood pressure from baseline. Bradycardia (HR <50 beats/min) was managed with

intravenous atropine. Data were compiled in Microsoft Excel and analyzed using SPSS version 25. Continuous variables were expressed as mean ± standard deviation and compared using independent sample t-test and repeated measures ANOVA. Pearson's correlation analysis was done to identify predictors of hypotension following spinal anaesthesia. Categorical variables were analyzed using Chi-square test. A p-value <0.05 was considered statistically significant.

RESULT

A total of 120 patients undergoing spinal anaesthesia were included in the study, with 60 patients in the controlled hypertensive (CHT) group and 60 in the normotensive (NT) group. As seen in Table 1, the two groups were comparable with respect to age, sex distribution, body mass index (BMI), duration of surgery, and ASA physical status. The mean age of patients was 58.4 ± 8.2 years in the CHT group and 56.9 ± 7.6 years in the NT group (p = 0.28). The male-to-female ratio was similar between groups (34/26 vs 32/28, p = 0.71). BMI was 27.1 ± 3.4 kg/m² in the CHT group and 26.5 ± 3.1 kg/m² in the NT group (p = 0.32). Mean duration of surgery was also comparable (84.5 ± 21.3 min vs 81.2 ± 19.8 min, p = 0.39), as was the distribution of ASA II and III patients (p = 0.44). The time to reach maximum sensory block was similar in both groups (6.4 ± 1.8 min vs 6.1 ± 1.7 min, p = 0.34). However, the CHT group required significantly higher additional intravenous fluids intraoperatively (412 ± 105 ml vs 338 ± 98 ml, p = 0.001), and hypotension occurred earlier compared to the NT group (8.4 ± 3.1 min vs 10.2 ± 3.8 min, p = 0.004). Regarding recurrent hypotensive episodes, 30% of CHT patients experienced a single episode compared to 20% in the NT group (p = 0.21), while ≥2 episodes occurred in 18.3% of CHT patients versus 8.3% in NT patients (p = 0.09). The maximum sensory block achieved was distributed similarly in both groups, with T4 reached in 33.3% of CHT patients versus 20% of NT patients (p = 0.09), T6 in 46.7% versus 56.7% (p = 0.25), and T8 in 20% versus 23.3% (p = 0.67). Overall, baseline demographic and procedural characteristics were comparable, while CHT patients demonstrated earlier onset of hypotension and greater fluid requirements, suggesting increased hemodynamic susceptibility.

Table 1- Demographic and Clinical Characteristics of the Study Participants

Variable		Group CHT (N=60)	Group NT (N=60)	P-Value
Age in years (Mean ± SD)		58.4 ± 8.2	56.9 ± 7.6	0.28
Male/Female (n)		34/26	32/28	0.71
BMI in kg/m² (Mean ± SD)		27.1 ± 3.4	26.5 ± 3.1	0.32
Duration of Surgery in min (Mean ± SD)		84.5 ± 21.3	81.2 ± 19.8	0.39
ASA II/III (n)		38/22	42/18	0.44
Time to maximum sensory block in min (Mean ± SD)		6.4 ± 1.8	6.1 ± 1.7	0.34
Additional IV fluids required in ml		412 ± 105	338 ± 98	0.001
Time to onset of hypotension in min (Mean ± SD)		8.4 ± 3.1	10.2 ± 3.8	0.004
Recurrent hypotensive episodes n (%)	Single episode	18 (30%)	12 (20%)	0.21
	≥2 episodes	11 (18.3%)	5 (8.3%)	0.09
Maximum sensory block achieved n (%)	T4	20 (33.3%)	12 (20%)	0.09
	T6	28 (46.7%)	34 (56.7%)	0.25
	T8	12 (20%)	14 (23.3%)	0.67

Baseline hemodynamic parameters were recorded prior to spinal anaesthesia in both groups. As clear in Table 2, the mean heart rate was comparable between the controlled hypertensive (CHT) and normotensive (NT) groups (78.6 ± 9.4 vs 76.8 ± 8.7 beats/min, p = 0.29). However, baseline systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) were significantly higher in the CHT group compared to the NT group (SBP: 136.2 ± 8.5 vs 124.6 ± 7.9 mmHg, p < 0.001; DBP: 84.3 ± 6.2 vs 78.1 ± 5.8 mmHg, p < 0.001; MAP: 101.6 ± 7.1 vs 93.6 ± 6.4 mmHg, p < 0.001). Following spinal anaesthesia, the maximum fall in hemodynamic parameters was more pronounced in the CHT group. The mean reduction in heart rate was 9.2 ± 5.1 beats/min in CHT patients compared to 6.8 ± 4.7 beats/min in NT patients (p = 0.01). The mean decrease in SBP was 18.6 ± 7.4 mmHg versus 13.9 ± 6.5 mmHg (p = 0.002), DBP decreased by 23.2 ± 8.1 mmHg versus 17.5 ± 7.2 mmHg (p < 0.001), and MAP decreased by 32.4 ± 10.6 mmHg versus 24.8 ± 9.3 mmHg (p < 0.001) in CHT and NT groups, respectively. These findings indicate that although baseline heart rates were similar, patients with controlled hypertension had significantly higher baseline blood pressures and experienced a greater magnitude of hemodynamic changes following spinal anaesthesia.

Table 2- Baseline Hemodynamic Parameters and Maximum Fall In Hemodynamic Parameters Following Spinal Anaesthesia

Parameter		Group CHT (Mean ± SD)	Group NT (Mean ± SD)	P-Value
Baseline hemodynamic parameters	Heart Rate (beats/min)	78.6 ± 9.4	76.8 ± 8.7	0.29
	SBP (mmHg)	136.2 ± 8.5	124.6 ± 7.9	<0.001
	DBP (mmHg)	84.3 ± 6.2	78.1 ± 5.8	<0.001
	MAP (mmHg)	101.6 ± 7.1	93.6 ± 6.4	<0.001
Maximum fall in hemodynamic parameters following spinal anaesthesia	HR (beats/min)	9.2 ± 5.1	6.8 ± 4.7	0.01
	SBP (mmHg)	18.6 ± 7.4	13.9 ± 6.5	0.002
	DBP (mmHg)	23.2 ± 8.1	17.5 ± 7.2	<0.001
	MAP (mmHg)	32.4 ± 10.6	24.8 ± 9.3	<0.001

The incidence of hemodynamic complications following spinal anaesthesia is summarized in Figure 1. Hypotension occurred significantly more often in the controlled hypertensive (CHT) group compared to the normotensive (NT) group (29 [48.3%] vs 17 [28.3%], p = 0.02). Severe hypotension, defined as a >30% fall in systolic blood pressure, was observed in 11 (18.3%) CHT patients and 5 (8.3%) NT patients, though this difference did not reach statistical significance (p = 0.09). Bradycardia (heart rate <50 bpm) occurred in 11 (18.3%) CHT patients versus 6 (10%) NT patients (p = 0.19). Reflex tachycardia (HR >100 bpm) was noted in 8 (13.3%) CHT patients and 5 (8.3%) NT patients (p = 0.36). Postoperative nausea and vomiting occurred in 14 (23.3%) CHT patients and 8 (13.3%) NT patients (p = 0.15). Vasopressor requirement was significantly higher in the CHT group, with 26 (43.3%) patients requiring ephedrine versus 14 (23.3%) in the NT group (p = 0.01). Overall, controlled hypertensive patients were more prone to hypotension and required more vasopressor support, although other complications did not differ significantly between the groups.

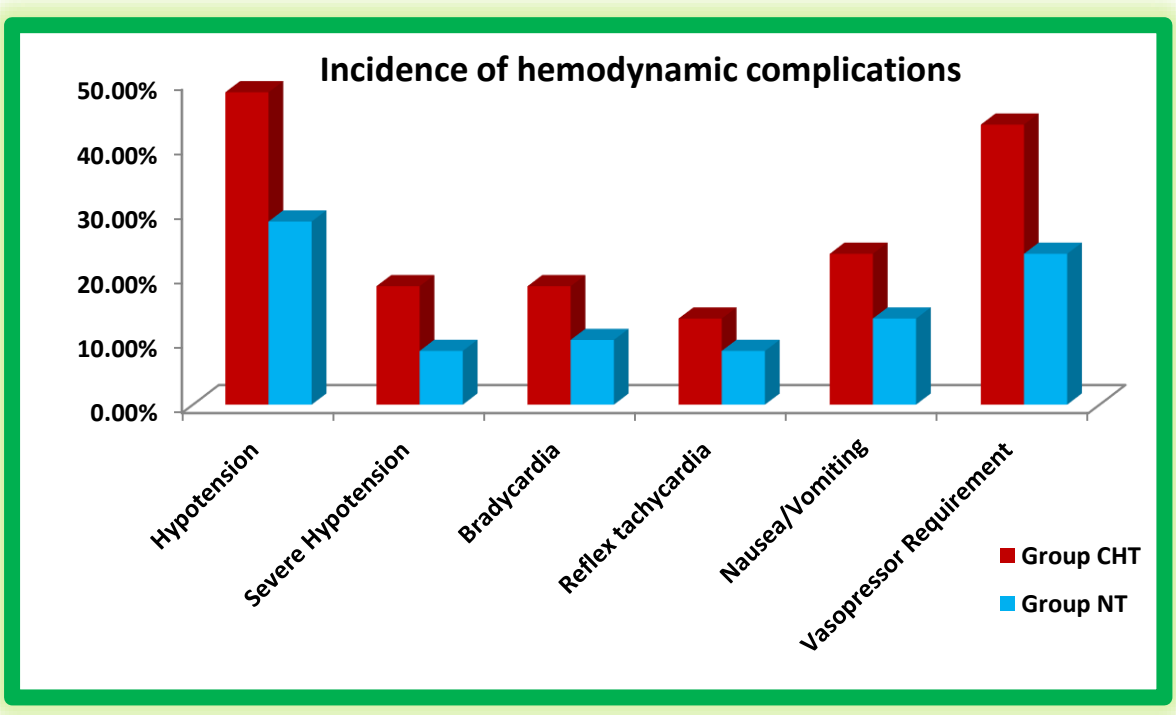

Figure 1- Comparison of Incidence of Hemodynamic Complications among Both the Groups

The serial changes in mean arterial pressure (MAP) following spinal anaesthesia are presented in Table 3. At baseline, the MAP was significantly higher in the controlled hypertensive (CHT) group compared to the normotensive (NT) group (101.6 ± 7.1 mmHg vs 93.6 ± 6.4 mmHg, p < 0.001). At 5 minutes post-spinal, MAP decreased in both groups (85.4 ± 9.2 mmHg in CHT vs 82.8 ± 8.7 mmHg in NT), with no statistically significant difference (p = 0.11). At 10 minutes, the MAP reached its lowest values (78.3 ± 10.1 mmHg in CHT vs 80.6 ± 9.4 mmHg in NT, p = 0.18). By 20 minutes, MAP began to recover, but

was significantly lower in the CHT group compared to the NT group (81.2 ± 8.7 mmHg vs 84.9 ± 8.2 mmHg, p = 0.02). At 30 minutes, MAP continued to stabilize (84.6 ± 7.9 mmHg in CHT vs 87.1 ± 7.5 mmHg in NT, p = 0.07). Overall, although the initial fall in MAP was similar between groups, hypertensive patients demonstrated a slower recovery and slightly lower MAP at 20 minutes, indicating increased hemodynamic susceptibility following spinal anaesthesia.

Table 3- Serial Changes in Mean Arterial Pressure (MAP)

Time Interval	Group Cht (Mean ± Sd)	Group Nt (Mean ± Sd)	P-Value
Baseline	101.6 ± 7.1	93.6 ± 6.4	<0.001
5 minutes	85.4 ± 9.2	82.8 ± 8.7	0.11
10 minutes	78.3 ± 10.1	80.6 ± 9.4	0.18
20 minutes	81.2 ± 8.7	84.9 ± 8.2	0.02
30 minutes	84.6 ± 7.9	87.1 ± 7.5	0.07

Correlation analysis was performed to identify factors associated with hypotension following spinal anaesthesia. As shown in Table 4, age greater than 60 years was positively correlated with hypotension (r = 0.28, p = 0.004), indicating that older patients were more prone to hemodynamic instability. Baseline MAP greater than 100 mmHg and baseline SBP greater than 140 mmHg showed significant positive correlations with hypotension (r = 0.37, p < 0.001 and r = 0.35, p < 0.001, respectively), suggesting that patients with higher preoperative blood pressures were at increased risk of larger blood pressure drops. BMI greater than 27 kg/m² was moderately correlated with hypotension (r = 0.22, p = 0.02), while maximum sensory block at or above T6 was also significantly associated with hypotension (r = 0.31, p = 0.001). Duration of surgery exceeding 90 minutes had a weaker but statistically significant correlation with hypotension (r = 0.19, p = 0.04). Overall, these findings indicate that advanced age, elevated baseline blood pressures, higher BMI, higher spinal block levels, and longer surgeries are important predictors of hypotension following spinal anaesthesia in both controlled hypertensive and normotensive patients. This analysis can help guide risk stratification and intraoperative monitoring.

Table 4- Correlation Analysis for Predictors of Hypotension

Predictor	Correlation With Hypotension (R)	P-Value
Age (>60 years)	0.28	0.004
Baseline MAP (>100 mmHg)	0.37	<0.001
Baseline SBP (> 140 mmHg)	0.35	<0.001
BMI (>27 kg/m²)	0.22	0.02
Maximum sensory block ≥ T6 n (%)	0.31	0.001
Duration of surgery (>90 minutes)	0.19	0.04

DISCUSSION

The present study comparatively evaluated hemodynamic changes following spinal anaesthesia in controlled hypertensive (CHT) and normotensive (NT) patients undergoing infraumbilical surgeries. Although demographic characteristics and surgical duration were comparable between groups, CHT patients demonstrated significantly greater blood pressure reductions, earlier onset of hypotension, higher incidence of hypotension, and increased vasopressor requirement. Baseline SBP, DBP, and MAP were significantly higher in the CHT group, reflecting persistent vascular tone alterations despite blood pressure control. More importantly, the magnitude of maximum fall in SBP, DBP, and MAP after spinal anaesthesia was significantly greater in CHT patients. Our findings are supported by Singh et al. (2018) [11], who reported exaggerated hemodynamic fluctuations in hypertensive individuals following sympathetic blockade. Similar results were observed by Kim et al. (2019) [12], who demonstrated increased blood pressure variability in patients with pre-existing hypertension undergoing neuraxial anaesthesia. The enhanced decline in blood pressure in hypertensive patients may be attributed to impaired baroreceptor reflex sensitivity and reduced vascular compliance. In the present study, the incidence of hypotension was significantly higher in the CHT group (48.3% vs 28.3%), and vasopressor requirement was also markedly increased. These findings are supported by Tadesse et al. (2020) [13], who identified pre-existing hypertension as a significant predictor of spinal anaesthesia-induced hypotension. Furthermore, a prospective observational study by Wang et al. (2022) [14] demonstrated that higher baseline MAP was independently associated with greater risk of post-spinal hypotension. However, our findings are in contrast with the study by Kaur et al. (2017) [15], who reported no statistically significant difference in hypotension incidence between controlled hypertensive and normotensive

patients, possibly due to differences in antihypertensive therapy profiles and perioperative fluid protocols.

Serial MAP analysis in our study showed a significant intergroup difference at baseline and at 20 minutes, indicating delayed hemodynamic recovery in CHT patients. This observation is supported by Park et al. (2020) [16], who described prolonged hemodynamic instability in patients with chronic hypertension following neuraxial blockade. In contrast, Li et al. (2021) [17] reported comparable recovery trends between groups, which may reflect variations in intraoperative vasopressor strategies. Correlation analysis in our study identified age >60 years, baseline MAP >100 mmHg, SBP >140 mmHg, BMI >27 kg/m², higher sensory block (≥T6), and prolonged surgery (>90 minutes) as significant predictors of hypotension. These findings are consistent with the results of Sun et al. (2019) [18], who found advanced age and elevated baseline pressures to be strong predictors of post-spinal hypotension. Additionally, a multivariate analysis by Zhou et al. (2023) [19] demonstrated that higher block height and increased BMI significantly increased the likelihood of hypotensive episodes. Our results are therefore in agreement with contemporary predictive models emphasizing multifactorial risk assessment. Although bradycardia and other complications were more frequent in the CHT group, the differences were not statistically significant. Similar findings were reported by Ahmed et al. (2024) [20], suggesting that blood pressure changes may be more pronounced than heart rate alterations in hypertensive patients. Overall, the present study confirms that even well-controlled hypertensive patients exhibit greater hemodynamic susceptibility following spinal anaesthesia. Identification of high-risk characteristics such as advanced age, elevated baseline blood pressure, and higher sensory block levels may aid in tailoring perioperative management strategies to minimize complications and improve patient safety.

CONCLUSION

The present study demonstrates that patients with controlled hypertension exhibit greater hemodynamic vulnerability following spinal anaesthesia compared to normotensive individuals. Although baseline demographic and operative variables were comparable, controlled hypertensive patients showed significantly higher baseline blood pressure values, greater maximum reductions in SBP, DBP, and MAP, earlier onset of hypotension, and increased vasopressor requirement. The incidence of hypotension was also significantly higher in this group. Furthermore, factors such as advanced age, elevated baseline MAP and SBP, higher sensory block level, increased BMI, and prolonged duration of surgery were significantly correlated with hypotensive episodes. These findings highlight that even well-controlled hypertensive patients remain physiologically predisposed to exaggerated responses following sympathetic blockade. The clinical implication of this study is the need for meticulous preoperative risk stratification, vigilant intraoperative monitoring, and readiness for prompt hemodynamic intervention in hypertensive patients undergoing spinal anaesthesia. Individualized fluid management and early vasopressor use may help reduce perioperative complications. Overall, this study reinforces the importance of tailored anaesthetic planning to enhance perioperative safety and optimize outcomes in this high-risk population.

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Conflict of Interest- None

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