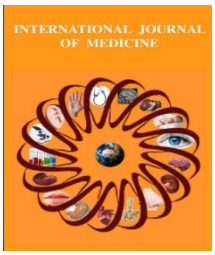

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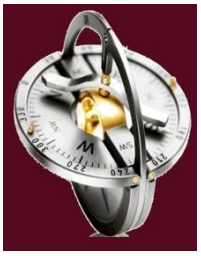

Original Research

Incidence and Predictors of Perioperative Hypotension Among Patients Undergoing Elective Surgery Under Spinal Anaesthesia: A Prospective Observational Study.

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Abstract

Background: Hypotension is a frequent haemodynamic complication of spinal anaesthesia and can compromise perfusion of vital organs, particularly in older patients and those with limited cardiovascular reserve. *Objectives:* To determine the incidence, temporal pattern, and independent predictors of perioperative hypotension among adults undergoing elective surgery under spinal anaesthesia. *Methods:* This prospective observational study included 60 adults undergoing elective lower abdominal, lower-limb orthopaedic, or urological surgery under spinal anaesthesia at VIMS, Ballari, Karnataka, from December 2022 to May 2023. Baseline characteristics, spinal anaesthetic variables, sensory block level, operative duration, blood loss, hypotensive episodes, interventions, and associated adverse events were recorded. Logistic regression was used to identify independent predictors. *Results:* Perioperative hypotension occurred in 24 patients, giving an incidence of 40.0% (95% CI: 27.6-53.5%). Fifteen affected patients (62.5%) developed the first episode within 10 minutes of spinal injection. Hypotensive patients were older, had lower baseline mean arterial pressure, received a higher bupivacaine dose, achieved a higher sensory block, underwent longer surgery, and had greater blood loss. Bradycardia and nausea or vomiting were more frequent in the hypotension group. On multivariable analysis, age ≥60 years (adjusted OR: 3.72; 95% CI: 1.05-13.18), baseline mean arterial pressure <85 mmHg (adjusted OR: 5.46; 95% CI: 1.19-25.02), and sensory block level ≥T6 (adjusted OR: 5.21; 95% CI: 1.42-19.11) independently predicted hypotension. All episodes responded to fluids, vasopressors, or both. *Conclusion:* Perioperative hypotension affected two-fifths of patients and occurred predominantly soon after spinal anaesthesia. Advanced age, lower baseline mean arterial pressure, and a high sensory block identified patients requiring intensified haemodynamic surveillance and prompt preventive or therapeutic intervention.

Keywords: *Blood pressure; haemodynamic instability; hypotension; spinal anaesthesia; sensory block; vasopressors.*

Introduction

Spinal anaesthesia is widely used for lower abdominal, pelvic, urological, and lower-limb procedures because it provides rapid, dense neural blockade while avoiding airway manipulation and reducing systemic exposure to general anaesthetic agents. Its clinical advantages include reliable surgical anaesthesia, effective muscle relaxation, preserved spontaneous ventilation, and favourable postoperative analgesia. Nevertheless, neuraxial sympathetic blockade produces clinically important cardiovascular changes. By blocking preganglionic sympathetic fibres, spinal anaesthesia causes arterial and venous vasodilatation, venous pooling, reduced venous return, and a fall in cardiac output or systemic vascular resistance. The extent and speed of these changes depend on block height, intrathecal dose, patient position, circulating volume, age, and baseline cardiovascular function.[1]

Hypotension is among the most frequent adverse effects of spinal anaesthesia. Reported incidence differs markedly because studies use varying thresholds, including an absolute systolic pressure below 90 or 100 mmHg, a relative reduction from baseline, a low mean arterial pressure, or the requirement for vasopressor treatment.[2-5] In a large prospective investigation, Carpenter et al. identified peak sensory block height, age, and baseline haemodynamic characteristics as important determinants of spinal anaesthesia-related side effects.[2] Hartmann et al. subsequently demonstrated associations with hypertension, body mass index, anaesthetic dose, ASA physical status, and sensory block level, although the reported incidence was lower because a more restrictive definition was applied.[3] These findings indicate that hypotension is not a uniform event; its frequency reflects both patient vulnerability and the operational definition adopted by investigators.

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The clinical relevance of perioperative hypotension extends beyond transient discomfort. Reduced arterial pressure can cause nausea, vomiting, dizziness, altered consciousness, bradycardia, and delayed recovery. More sustained or profound hypotension can reduce coronary, cerebral, and renal perfusion. Large noncardiac surgical cohorts have demonstrated graded associations between lower intraoperative mean arterial pressure and myocardial injury, acute kidney injury, major cardiovascular events, and mortality.[10-14] Although most outcome data arise from general anaesthesia, the physiological concern is directly applicable to spinal anaesthesia, in which abrupt sympathectomy can produce a rapid pressure decline. Older adults and patients with hypertension can be particularly susceptible because autonomic compensation, ventricular compliance, and intravascular reserve are often reduced.[6-9]

Early recognition of high-risk patients allows closer monitoring, judicious fluid administration, dose adjustment, limitation of excessive cephalad spread, and timely vasopressor therapy. However, prospective data describing hypotension during routine elective spinal anaesthesia remain limited in many Indian tertiary-care settings. Therefore, the present study aimed to determine the incidence and timing of perioperative hypotension among adults undergoing elective surgery under spinal anaesthesia and to evaluate demographic, clinical, anaesthetic, and operative factors associated with its occurrence. The secondary objectives were to describe the haemodynamic severity, treatment requirements, and associated perioperative adverse events.

METHODOLOGY

Study design and setting: This prospective observational study was conducted in the Department of Anaesthesiology at Vijayanagara Institute of Medical Sciences (VIMS), Ballari (Bellary), Karnataka, India, from December 2022 to May 2023. The study included consecutive adults scheduled for elective lower abdominal, lower-limb orthopaedic, or urological surgery under spinal anaesthesia.

Participants: Patients aged 18–80 years with American Society of Anesthesiologists (ASA) physical status I–III were eligible. Patients were excluded when they declined consent, required emergency surgery, had contraindications to spinal anaesthesia, had severe valvular disease or decompensated cardiac failure, had uncontrolled arrhythmia, were receiving vasopressor support before anaesthesia, or required conversion to general anaesthesia before adequate haemodynamic observation. A sample of 60 was planned using an anticipated hypotension incidence of 40%, 95% confidence level, and absolute precision of 12.5%. Written informed consent was obtained before enrolment.

Anaesthetic procedure and monitoring: Preanaesthetic evaluation included age, sex, body mass index, comorbidities, ASA status, medications, and baseline haemodynamic measurements. In the operating theatre, electrocardiography, pulse oximetry, and non-invasive blood pressure monitoring were instituted. Baseline blood pressure was the mean of two readings obtained after five minutes of rest. An intravenous line was secured, and crystalloid administration was recorded. Spinal anaesthesia was performed under aseptic precautions in the sitting or lateral position at the L3–L4 or L4–L5 interspace using hyperbaric bupivacaine. Intrathecal dose was selected by the attending anaesthesiologist according to patient and surgical requirements. Sensory block was assessed by loss of cold sensation or pinprick, and the highest level was documented.

Outcome assessment: Perioperative hypotension was defined as systolic blood pressure <90 mmHg or a reduction of at least 20% from baseline, or mean arterial pressure <65 mmHg, from spinal injection until completion of immediate postoperative observation.[4,5] Blood pressure and heart rate were recorded at short intervals after spinal injection and throughout surgery. The time, number, nadir pressure, percentage systolic reduction, fluid bolus, vasopressor use, bradycardia, nausea, vomiting, blood loss, surgery duration, and conversion to general anaesthesia were documented. Bradycardia was defined as heart rate <50 beats/min. Hypotension was managed according to routine departmental practice with intravenous crystalloid, mephentermine, phenylephrine, or combined therapy.[9]

Statistical analysis and ethics: Continuous variables were summarised as mean ± standard deviation or median with interquartile range and compared using the independent-samples t test or a non-parametric test, as appropriate. Categorical variables were expressed as frequency and percentage and compared using the chi-square or Fisher exact test. Variables with $p<0.10$ on univariate analysis were entered into an exploratory multivariable logistic regression model. Odds ratios with 95% confidence intervals were reported. Model discrimination was assessed using the receiver operating characteristic curve and calibration with the Hosmer–Lemeshow test. A two-sided $p<0.05$ was considered statistically significant. Necessary Permissions were obtained before starting the study

Results

Participant recruitment and incidence

During the study period, 66 patients scheduled for elective surgery under spinal anaesthesia were assessed for eligibility. Six patients were excluded: four did not meet the eligibility criteria and two declined participation. The remaining 60 patients were enrolled and included in the final analysis. Complete perioperative haemodynamic and clinical outcome data were available for all participants. Perioperative hypotension occurred in 24 of the 60 patients, corresponding to an overall incidence of 40.0% (95% confidence interval [CI]: 27.6–53.5%). The remaining 36 patients (60.0%) maintained stable blood pressure throughout the perioperative observation period.

Baseline demographic and clinical characteristics

The mean age of the study population was 51.7 ± 13.6 years, with a range of 22–76 years. Thirty-three (55.0%) participants were males and 27 (45.0%) were females. The mean body mass index was 25.8 ± 3.9 kg/m². Hypertension was present in 20 (33.3%) patients, diabetes mellitus in 12 (20.0%), and ischaemic heart disease in 4 (6.7%). Twenty-five (41.7%) patients belonged to ASA physical status I, 27 (45.0%) to ASA II, and 8 (13.3%) to ASA III. Patients who developed hypotension were significantly older than haemodynamically stable patients (58.5 ± 10.7 versus 47.1 ± 13.5 years; $p=0.001$). Age ≥60 years, hypertension, ASA physical status II–III, lower baseline diastolic pressure, lower baseline mean arterial pressure, and baseline mean arterial pressure <85 mmHg were significantly associated with hypotension. Sex, body mass index, diabetes mellitus, and baseline heart rate did not differ significantly between groups (Table 1).

Table 1. Baseline characteristics according to the occurrence of perioperative hypotension

Characteristic	Total, n=60	Hypotension, n=24	No hypotension, n=36	p value
Age, years, mean ± SD	51.7 ± 13.6	58.5 ± 10.7	47.1 ± 13.5	**0.001**
Age ≥60 years	19 (31.7)	12 (50.0)	7 (19.4)	**0.012**
Male sex	33 (55.0)	12 (50.0)	21 (58.3)	0.526
Female sex	27 (45.0)	12 (50.0)	15 (41.7)	–
BMI, kg/m², mean ± SD	25.8 ± 3.9	26.7 ± 4.1	25.2 ± 3.6	0.138
BMI ≥25 kg/m²	34 (56.7)	16 (66.7)	18 (50.0)	0.201
Hypertension	20 (33.3)	12 (50.0)	8 (22.2)	**0.025**
Diabetes mellitus	12 (20.0)	6 (25.0)	6 (16.7)	0.430
Ischaemic heart disease	4 (6.7)	3 (12.5)	1 (2.8)	0.143
ASA physical status II–III	34 (56.7)	18 (75.0)	16 (44.4)	**0.019**
Baseline heart rate, beats/min	78.5 ± 10.8	80.4 ± 11.7	77.2 ± 10.1	0.265
Baseline SBP, mmHg	132.6 ± 15.9	128.3 ± 16.8	135.5 ± 14.8	0.083
Baseline DBP, mmHg	78.4 ± 10.2	74.6 ± 10.0	80.9 ± 9.7	**0.018**
Baseline MAP, mmHg	96.5 ± 11.1	90.9 ± 10.2	100.2 ± 10.2	**0.001**
Baseline MAP <85 mmHg	12 (20.0)	9 (37.5)	3 (8.3)	**0.005**

Values are presented as n (%) unless otherwise specified. BMI: body mass index; ASA: American Society of Anesthesiologists; SBP: systolic blood pressure; DBP: diastolic blood pressure; MAP: mean arterial pressure; SD: standard deviation.

Anaesthetic and operative characteristics

Hyperbaric bupivacaine was used in all patients. The mean intrathecal dose was 13.1 ± 1.4 mg, and the mean preoperative crystalloid volume was 493 ± 156 mL. A sensory block level of T6 or above was achieved in 21 (35.0%) patients. Patients who developed hypotension received a higher bupivacaine dose and more frequently achieved a block at or above T6. The mean preoperative crystalloid volume was lower in the hypotension group, but this difference was not statistically significant.

The mean duration of surgery was 87.6 ± 28.7 minutes. Hypotension was associated with longer surgery, surgical duration >90 minutes, greater estimated blood loss, and blood loss ≥300 mL. The distribution of lower abdominal, lower-limb orthopaedic, and urological procedures was comparable between groups (Table 2). No patient had major haemorrhage requiring massive transfusion or conversion to general anaesthesia.

Table 2. Anaesthetic and operative variables according to hypotension status

Variable	Total, n=60	Hypotension, n=24	No hypotension, n=36	p value
Bupivacaine dose, mg	13.1 ± 1.4	13.7 ± 1.3	12.7 ± 1.3	**0.006**
Bupivacaine dose ≥13.5 mg	26 (43.3)	15 (62.5)	11 (30.6)	**0.015**
Preoperative crystalloid, mL	493 ± 156	454 ± 139	519 ± 163	0.115
Preoperative crystalloid <500 mL	27 (45.0)	14 (58.3)	13 (36.1)	0.091
Sensory block level ≥T6	21 (35.0)	14 (58.3)	7 (19.4)	**0.002**
Duration of surgery, minutes	87.6 ± 28.7	99.4 ± 30.1	79.7 ± 25.1	**0.008**
Surgical duration >90 minutes	25 (41.7)	14 (58.3)	11 (30.6)	**0.033**
Estimated blood loss, mL	236 ± 118	284 ± 126	205 ± 103	**0.010**
Blood loss ≥300 mL	16 (26.7)	10 (41.7)	6 (16.7)	**0.031**
Lower abdominal surgery	24 (40.0)	8 (33.3)	16 (44.4)	0.390
Lower-limb orthopaedic surgery	20 (33.3)	9 (37.5)	11 (30.6)	0.577
Urological surgery	16 (26.7)	7 (29.2)	9 (25.0)	0.720

Values are presented as mean ± SD or n (%). SD: standard deviation.

Pattern, severity, and management of hypotension

Among the 24 patients who developed hypotension, 15 (62.5%) experienced the first episode within 10 minutes after spinal anaesthesia, 6 (25.0%) between 11 and 30 minutes, and 3 (12.5%) after 30 minutes. A single episode occurred in 15 (62.5%) patients, two episodes in 7 (29.2%), and three or more episodes in 2 (8.3%). The median time to the first episode was 8 minutes (interquartile range: 5-16 minutes). The mean lowest systolic blood pressure was 82.6 ± 8.7 mmHg, the mean lowest mean arterial pressure was 61.9 ± 6.5 mmHg, and the mean maximum systolic reduction from baseline was 31.4 ± 8.9%.

All hypotensive episodes were successfully managed. Rapid crystalloid administration was required in 22 (91.7%) affected patients, mephentermine in 17 (70.8%), and phenylephrine in 5 (20.8%); two patients responded to fluids alone. Atropine was administered to four patients. The timing, recurrence, severity, and treatment of hypotension are summarised in Table 3.

Table 3. Characteristics and management of hypotensive episodes

Variable	Value, n=24
First episode within 10 minutes	15 (62.5)
First episode at 11-30 minutes	6 (25.0)
First episode after 30 minutes	3 (12.5)
One hypotensive episode	15 (62.5)
Two hypotensive episodes	7 (29.2)
Three or more episodes	2 (8.3)
Lowest SBP, mmHg, mean ± SD	82.6 ± 8.7
Lowest MAP, mmHg, mean ± SD	61.9 ± 6.5
Maximum reduction in SBP, %	31.4 ± 8.9
Rapid intravenous crystalloid administration	22 (91.7)
Mephentermine administration	17 (70.8)
Phenylephrine administration	5 (20.8)
Atropine administration	4 (16.7)
Associated bradycardia	6 (25.0)
Associated nausea or vomiting	6 (25.0)

Values are presented as n (%) unless otherwise specified. SBP: systolic blood pressure; MAP: mean arterial pressure; SD: standard deviation.

Bradycardia occurred in 8 (13.3%) participants and was more frequent in the hypotension group than in the non-hypotension group (25.0% versus 5.6%; p=0.028). Nausea or vomiting occurred in 7 (11.7%) patients, including 6 (25.0%) with hypotension and 1 (2.8%) without hypotension (p=0.008). No patient developed cardiac arrest, persistent arrhythmia, myocardial ischaemia, neurological complications, or mortality.

Predictors of perioperative hypotension

On univariate logistic regression, age ≥60 years, pre-existing hypertension, ASA physical status II-III, baseline mean arterial pressure <85 mmHg, bupivacaine dose ≥13.5 mg, sensory block level ≥T6, surgical duration >90 minutes, and blood loss ≥300 mL were associated with perioperative hypotension. Sensory block level ≥T6 showed the strongest unadjusted association (OR: 5.80; 95% CI: 1.79-18.77; p=0.003). After adjustment, age ≥60 years (adjusted OR [aOR]: 3.72; 95% CI: 1.05-13.18; p=0.042), baseline mean arterial pressure <85 mmHg (aOR: 5.46; 95% CI: 1.19-25.02; p=0.029), and sensory block level ≥T6 (aOR: 5.21; 95% CI: 1.42-19.11; p=0.013) remained independent predictors. Hypertension, ASA status, higher bupivacaine dose, prolonged surgery, and greater blood loss did not retain statistical significance (Table 4). The model showed acceptable discrimination, with an area under the receiver operating characteristic curve of 0.81 (95% CI: 0.70-0.92), and satisfactory calibration by the Hosmer-Lemeshow test (p=0.684).

Table 4. Logistic regression analysis of predictors of perioperative hypotension

Predictor	Unadjusted OR (95% CI)	p value	Adjusted OR (95% CI)	p value
Age ≥60 years	4.14 (1.31-13.09)	0.016	3.72 (1.05-13.18)	**0.042**
Hypertension	3.50 (1.13-10.82)	0.030	1.76 (0.45-6.88)	0.417
ASA physical status II-III	3.75 (1.20-11.71)	0.023	1.64 (0.40-6.76)	0.495
Baseline MAP <85 mmHg	6.60 (1.59-27.46)	0.009	5.46 (1.19-25.02)	**0.029**
Bupivacaine dose ≥13.5 mg	3.79 (1.27-11.32)	0.017	2.03 (0.55-7.50)	0.287
Sensory block level ≥T6	5.80 (1.79-18.77)	0.003	5.21 (1.42-19.11)	**0.013**
Surgical duration >90 minutes	3.18 (1.07-9.41)	0.037	1.69 (0.44-6.50)	0.447
Estimated blood loss ≥300 mL	3.57 (1.06-12.06)	0.040	1.52 (0.35-6.61)	0.576

OR: odds ratio; CI: confidence interval; ASA: American Society of Anesthesiologists; MAP: mean arterial pressure.

Discussion

The present study found that perioperative hypotension occurred in 40.0% of adults undergoing elective surgery under spinal anaesthesia. The observed frequency is close to the incidence reported in the classic prospective study by Carpenter et al., but it is higher than that reported by Hartmann et al.[2,3] This difference is clinically plausible because incidence is strongly influenced by the definition used, the frequency of blood pressure measurement, patient characteristics, and the type and dose of intrathecal local anaesthetic. Bijker et al. demonstrated that applying different published definitions to the same population produced strikingly different hypotension rates.[4] The composite threshold used in the present study was intended to detect both absolute and clinically relevant relative reductions.

Most first episodes developed within 10 minutes of spinal injection. This early clustering reflects the rapid onset of sympathetic blockade, venous pooling, and reduced preload after intrathecal anaesthesia.[1,9] Prompt blood pressure measurement during this interval is therefore essential. Bradycardia and nausea or vomiting were also more frequent among hypotensive patients, consistent with reduced venous return, vagal predominance, and impaired cerebral or gastrointestinal perfusion. All episodes were corrected with fluids, mephentermine, phenylephrine, or combined therapy, and no major adverse outcome occurred. The absence of organ injury should be interpreted cautiously because the cohort was small and was not designed to detect uncommon postoperative events.

Age ≥60 years independently predicted hypotension. Ageing is accompanied by reduced baroreflex responsiveness, decreased cardiac reserve, altered ventricular compliance, and greater sensitivity to abrupt changes in preload. Studies in elderly surgical patients have shown substantial reductions in arterial pressure and stroke volume following spinal anaesthesia, while titrated or lower-dose techniques can improve haemodynamic stability.[6-8] A baseline mean arterial pressure below 85 mmHg was another independent predictor. This finding suggests that patients starting with limited perfusion pressure have less physiological margin before crossing clinically important thresholds.

A sensory block at or above T6 showed the strongest independent association. Higher cephalad spread blocks a greater proportion of the sympathetic outflow, producing more extensive vasodilatation and venous capacitance. This finding agrees with Carpenter et al. and Hartmann et al., who identified block height as a central determinant of hypotension.[2,3] Higher bupivacaine dose, hypertension, prolonged surgery, and blood loss were significant in univariate analysis but lost significance after adjustment, suggesting overlap with age, baseline pressure, and block extent.

The findings have practical relevance because perioperative hypotension is associated with renal, myocardial, and cardiovascular complications in large noncardiac surgical cohorts.[10-14] Preoperative risk recognition, conservative intrathecal dosing, avoidance of unnecessarily high blocks, frequent early monitoring, and immediate treatment are reasonable strategies. The regression results are exploratory, yet they identify a simple bedside risk profile that can guide vigilance in routine elective practice.

LIMITATIONS

This single-centre study included only 60 patients and 24 hypotensive events, limiting precision and increasing the risk of overfitting in the multivariable model. Surgical procedures and intrathecal bupivacaine doses were heterogeneous, and blood pressure was measured non-invasively at intervals rather than continuously. Immediate perioperative events were assessed, but postoperative renal, myocardial, neurological, and longer-term outcomes after hospital discharge were not systematically evaluated.

Conclusion

Perioperative hypotension was observed in 40.0% of adults undergoing elective surgery under spinal anaesthesia, with nearly two-thirds of first episodes occurring within 10 minutes of intrathecal injection. Age of 60 years or above, baseline mean arterial pressure below 85 mmHg, and sensory block at or above T6 were independent predictors. These findings support structured preanaesthetic risk assessment and intensified haemodynamic monitoring during the early post-spinal period. Careful selection of intrathecal dose, avoidance of excessive cephalad block, appropriate fluid management, and immediate access to vasopressors can improve circulatory stability. Larger multicentre studies with continuous blood pressure monitoring and postoperative organ-outcome assessment are required to validate this predictive profile across surgical populations.

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