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**ORIGINAL RESEARCH**

# Inferior Venacaval Collapsibility Index Guided Volume Preload To Prevent Spinal Hypotension In Lower Abdominal Surgeries

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## ABSTRACT

**Background -**Spinal anaesthesia is widely used for elective lower abdominal surgeries; however, spinal-anaesthesia-induced hypotension remains a common and clinically significant complication due to sympathetic blockade. Conventional fluid preloading strategies are empirical and do not account for individual variations in intravascular volume status. The inferior vena cava collapsibility index (IVCCI), assessed using ultrasound, may help identify patients who benefit from targeted fluid preload.

**Study Objective-**

1. To evaluate the effectiveness of IVCCI-guided fluid preload in reducing the incidence and severity of spinal anesthesia induced hypotension.
2. To compare the total fluid consumption in both the groups.
3. To calculate the dose of phenylephrine required to overcome hypotension .
4. To access other side effect of drugs like nausea,vomiting.
5. Incidence of bradycardia and treatment with atropine.

**Methods and Study Design-**This prospective comparative study included 108 adult patients undergoing elective lower abdominal surgeries under spinal anaesthesia. Preoperative IVCCI was measured using ultrasound. Patients were allocated into two groups: Group P (n = 54) with IVCCI ≥ 43.5%, who received fluid preload, and Group C (n = 54) with IVCCI < 43.5%, who did not receive preload. Demographic variables, hemodynamic parameters, incidence and frequency of hypotension, fluid requirements, vasopressor usage, and adverse events were recorded and analysed. **Principal Results-** Both groups were comparable with respect to age (44.3 ± 9.8 vs 43.7 ± 10.1 years), sex distribution, BMI (24.6 ± 3.1 vs 24.2 ± 3.4 kg/m²), ASA status,and basal hemodynamics. Group P had significantly higher IVCCI (46.8 ± 3.1%) compared with Group C (28.4 ± 4.2%). The incidence of hypotension was significantly lower in Group P (22.2%) than in Group C (57.4%, $p < 0.001$). The mean number of hypotensive episodes were also reduced (0.41 ± 0.68 vs 1.39 ± 1.02). Group P maintained higher systolic blood pressure values during the peri-spinal period. Despite receiving preload (612 ± 74 mL), Group P required lower total fluid volume (1424 ± 167 vs 1536 ± 181 mL) and less phenylephrine (18.5% vs 53.7%, mean dose 58 ± 41 vs 132 ± 78 µg). Nausea and vomiting were significantly less frequent in Group P, while bradycardia and duration of surgery were comparable. **Conclusions-**IVCCI-guided fluid preload using a cut-off value of ≥43.5% significantly reduces spinal-anaesthesia-induced hypotension, improves hemodynamic stability, decreases vasopressor requirement, and optimises fluid administration. IVCCI is a simple, non-invasive, and effective tool for individualized fluid management in patients undergoing spinal anaesthesia.

**Keywords-**Inferior vena cava collapsibility index; Spinal anaesthesia; Hypotension; Fluid preload; Ultrasound; Hemodynamic stability.

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## INTRODUCTION

Spinal anaesthesia is one of the most commonly used neuraxial techniques for lower abdominal, obstetric and lower limb surgeries worldwide because it is simple to administer, has rapid onset and avoids airway manipulation.[1] Despite these advantages, neuraxial anaesthesia–induced hypotension remains a frequent and clinically important adverse effect, with contemporary non-obstetric series reporting incidences in the range of 16–33%. [2] Studies from low- and middle-income settings similarly describe high rates of spinal anaesthesia–induced hypotension

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in lower abdominal and lower limb surgeries, with links to myocardial ischemia, acute kidney injury and increased postoperative morbidity and mortality. [4] Indian data in routine lower abdominal surgery show that hypotension is the commonest complication of spinal anaesthesia and frequently necessitates rescue vasopressors and additional fluid boluses. [5]

Spinal hypotension typically develops within the first 20–30 minutes after intrathecal injection and is driven by sympathectomy-induced venodilation, reduced venous return and a consequent fall in cardiac output. [1] The risk is higher in elderly patients, those with higher ASA physical status, baseline hypertension or cardiovascular disease, and when higher sensory levels or larger intrathecal doses are used. [1] Recent work also highlights the contribution of anthropometric factors such as increased abdominal circumference and body mass index to the occurrence of post-spinal hypotension, especially in abdominal and obstetric surgery. [6] Across Indian operating rooms, conventional preventive strategies including fixed-volume crystalloid preloading, co-loading, elastic wrapping of the lower limbs and prophylactic vasopressors are widely employed but only partially effective in attenuating these hemodynamic changes. [7] Moreover, such one-size-fits-all fluid strategies do not account for inter-individual variability in intravascular volume status, while excessive fluid loading carries risks of pulmonary oedema and tissue oedema in susceptible patients. [8] These limitations have driven interest in bedside,non-invasive tools that can stratify patients by volume responsiveness before spinal anaesthesia and individualise fluid therapy to minimise both hypotension and fluid overload. [9]

Ultrasound assessment of the inferior vena cava collapsibility index (IVCCI) has emerged as a promising substitute of preload and fluid responsiveness in spontaneously breathing patients. [10] Prospective trials show that higher pre-spinal IVCCI values are associated with subsequent development of hypotension after spinal anaesthesia, with cut-off values in the range of 40–43% demonstrating good sensitivity and specificity for predicting events and guiding fluid management. [11] In an Indian observational study, preoperative IVCCI and carotid peak systolic velocity variation predicted post-spinal hypotension in spontaneously breathing adults, supporting the feasibility of this modality in routine clinical practice in our population. [12] Randomised work using inferior vena cava ultrasound to guide pre-spinal fluid administration has shown reduced incidence of arterial hypotension compared with standard care, suggesting that ultrasound-guided optimisation of intravascular volume is superior to empirical fluid dosing. [13] However, most published trials involve mixed surgical cohorts or obstetric populations, and there is a paucity of controlled Indian data focusing specifically on IVCCI-guided preloading in elective lower abdominal surgeries under spinal anaesthesia. [14] Clarifying whether IVCCI-guided fluid preloading can safely reduce the incidence of spinal hypotension and vasopressor requirements in this common surgical group would directly inform perioperative protocols in tertiary centers in Karnataka and similar resource-constrained settings. [11]

Point-of-care ultrasound devices have become increasingly available in anaesthesia departments, and structured training initiatives have expanded perioperative ultrasound competence among anaesthesiologists in India . Against this background, the present study proposes to use ultrasound-derived IVCCI to stratify patients undergoing elective lower abdominal surgery under spinal anaesthesia as fluid responders or non-responders, administer a standardised crystalloid preload only to those above a predefined collapsibility cut-off, and compare hemodynamic outcomes, intraoperative fluid consumption and vasopressor requirements between groups. [11] By integrating IVCCI-guided preloading into routine pre-spinal assessment, the work aims to generate context-specific evidence on an accessible, bedside tool that could refine fluid management algorithms, reduce the burden of spinal hypotension and enhance perioperative safety in lower abdominal surgeries in a tertiary teaching hospital setting. [10]

## MATERIALS AND METHODOLOGY

### Study Design and Setting

This prospective, comparative clinical study conducted in the Department of Anaesthesiology,The study included adult patients undergoing elective lower abdominal surgeries under spinal anaesthesia in a tertiary teaching hospital operating theatre complex where neuraxial techniques are routinely used for infra-umbilical procedures after obtaining written informed consent from all participants prior to enrolment in study.

### Study Population

The study population consisted of 108 adult patients posted for elective lower abdominal surgeries (e.g. hernia repair, gynaecological and other infra-umbilical procedures) planned under spinal anaesthesia. Eligible patients were evaluated during the pre-anaesthetic check-up clinic and again on the day of surgery.

### Inclusion Criteria

1. Age 20 to 65 years.
2. Either sex.
3. American Society of Anesthesiologists (ASA) physical status I–II.
4. Body mass index (BMI) <35 kg/m² to allow reliable subcostal ultrasound imaging of the IVC and minimise confounding from morbid obesity.
5. Elective lower abdominal surgery expected to last less than 2 hours under spinal anaesthesia



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**Exclusion Criteria**

1. Pregnant women (obstetric patients) because pregnancy-related aortocaval compression and altered venous capacitance significantly modify IVC dynamics and hypotension risk.
2. Patients with significant cardio-pulmonary disease (e.g. heart failure, severe valvular lesions, significant arrhythmias, severe chronic obstructive pulmonary disease) that independently alter preload and hemodynamic responses.
3. Patients with significant hepatic or renal dysfunction, which may affect fluid handling and vasopressor response.
4. Patients on anticoagulant therapy, those with coagulation disorders, local sepsis at puncture site or other contraindications to neuraxial anaesthesia.
5. Patients in whom adequate IVC visualisation is not possible due to poor acoustic window, previous upper abdominal surgery or excessive bowel gas.

**Randomization and Group Allocation**

Pre-operatively, all 108 patients underwent IVC ultrasound to calculate IVCCI, and then stratified into two groups according to a predefined collapsibility cut-off derived from previous prospective studies.

**Group P (Preload / Fluid responder group)**: patients with IVCCI ≥43.5%, considered at higher risk of post-spinal hypotension and likely fluid responsive.

**Group C (Control / Non-preload group)**: patients with IVCCI <43.5%, considered less collapsible and less likely to benefit from preloading.

All other aspects of anaesthetic management apart from the pre-spinal preload will be standardised across both groups to minimise confounding.

**Ultrasound assessment of inferior vena cava collapsibility index**

In the preoperative holding area, with the patient in the supine position and after confirming adequate fasting status, an intravenous line was secured and baseline blood pressure and heart rate documented IVC ultrasound was performed using a curvilinear probe (2–6 MHz) placed in the subcostal region to obtain a long-axis view of the IVC entering the right atrium, following established point-of-care ultrasound protocols.M-mode is used 2–3 cm caudal to the cavo-atrial junction to measure the maximum IVC diameter during expiration (IVCmax) and minimum diameter during inspiration (IVCmin) over several respiratory cycles in quietly breathing patients.

IVCCI is calculated using the standard formula:

IVCCI = (IVCmax − IVCmin) / IVCmax × 100. Based on previous prospective data, a value ≥43.5% is considered indicative of increased collapsibility and higher risk of spinal-anaesthesia-induced hypotension. The ultrasound examination was performed by an anaesthesiologist trained in perioperative ultrasound to enhance reproducibility.

**Fluid preloading protocol**

Patients assigned to Group P (IVCCI ≥43.5%) received a crystalloid preload of Ringer lactate 10 mL/kg body weight over 15 minutes after completion of IVC assessment, aimed to optimise intravascular volume before spinal anaesthesia. Patients in Group C (IVCCI <43.5%) didnot receive this specific preloading bolus and proceeded to spinal anaesthesia without targeted preload apart from standard maintenance fluids.In both groups, all patients received a co-loading infusion of Ringer lactate at 10 mL/kg started at the time of intrathecal injection, consistent with current evidence favouring co-loading over preloading for routine prevention of spinal hypotension.

**Anaesthetic technique**

In the operating theatre, standard ASA monitors (non-invasive blood pressure, ECG and pulse oximetry) were attached and baseline hemodynamic values recorded prior to spinal anaesthesia. With the patient in the lateral decubitus position, spinal anaesthesia performed at the L3–L4 interspace using a 25G Quincke needle under aseptic precautions. After free flow of cerebrospinal fluid is confirmed, 3 mL of 0.5% hyperbaric bupivacaine with 120 µg buprenorphine was injected intrathecally at a controlled rate by anesthesiologist who was not involved in preoperative ultrasound assesment, and the patient positioned supine immediately after drug administration. The level of sensory block is assessed by loss of pinprick sensation and motor block by Bromage scale at defined intervals.

**Hemodynamic monitoring and definitions**

Non-invasive blood pressure (systolic, diastolic and mean arterial pressure), heart rate and oxygen saturation was recorded at baseline, immediately after spinal injection, every 3 minutes for the first 15 minutes, every 5 minutes up to 30 minutes, and then every 15 minutes until the end of surgery. Hypotension is defined as a fall in systolic blood pressure greater than 20% from baseline or a mean arterial pressure (MAP) <65 mmHg, consistent with commonly used thresholds in spinal hypotension literature. Bradycardia is defined as heart rate <50 beats per minute. Any episodes of nausea, vomiting or shivering occurring intraoperatively is recorded, given their known association with neuraxial hypotension and vasopressor use.

**Management of hypotension and bradycardia**

If hypotension is detected, an additional 100 mL bolus of Ringer lactate is administered rapidly in both groups as the first-line intervention. If hypotension persisted beyond 5 minutes despite fluid bolus,



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intravenous phenylephrine 100 µg is given, with repeat doses of 50 µg as required to restore systolic blood pressure and MAP to within 20% of baseline values. Occurrence of bradycardia after phenylephrine is monitored and treated with intravenous atropine 0.6 mg if heart rate falls below 50 beats per minute. Total intraoperative crystalloid volume and total phenylephrine dose used in each patient is recorded for comparison between groups.

**Outcome Measures**

The primary outcome was the incidence of spinal-anaesthesia-induced hypotension within the first 30 minutes after intrathecal injection, comparing IVCCI-guided preloaded patients (Group P) with non-preloaded controls (Group C).

Key secondary outcomes included

- Total intraoperative crystalloid volume administered,total dose of phenylephrine required to treat hypotension,incidence of bradycardia and treatment with atropine,Incidence of nausea, vomiting and shivering were recorded.

**Ethical Considerations**

Informed written consent was taken from patient before enrolment into the study. The study received approval from the Institutional Ethics Committee (Ref. No: BLDE(DU)/IEC-SBMPMC/070/2023-24, dated 10/02/2024). All procedures were conducted in accordance with the Declaration of Helsinki and institutional ethical guidelines for human research.

**Statistical Analysis**

Data was entered into Microsoft Excel and analysed using Statistical Package for the Social Sciences (SPSS) software version 20 (IBM Corp., Armonk, NY, USA) Continuous variables were summarized as mean ± standard deviation or median (interquartile range) depending on distribution, and categorical variables as frequencies and percentages. Normality of continuous data was assessed using appropriate tests and graphical methods. Between-group comparisons for normally distributed continuous variables (e.g. mean blood pressure, heart rate, total fluids) were performed using independent sample t-tests, while non-normally distributed variables were analysed using Mann–Whitney U tests.] Categorical variables such as incidence of hypotension, bradycardia and nausea/vomiting were compared using chi-square test or Fisher's exact test. If required, logistic regression was used to explore the independent association between IVCCI category and hypotension after adjusting for relevant covariates. A p-value <0.05 was considered statistically significant in all analyses.

**RESULTS:**

**Table 1: Demographic Characteristics**

| Parameter | Group P (n=54) | Group C (n=54) | p-value |
|---|---|---|---|
| Age (years, mean ± SD) | 44.3 ± 9.8 | 43.7 ± 10.1 | 0.78 |
| Sex (M/F) | 32 (59.3%) / 22 (40.7%) | 31 (57.4%) / 23 (42.6%) | 0.84 |
| BMI (kg/m²) | 24.6 ± 3.1 | 24.2 ± 3.4 | 0.62 |
| ASA I / II (%) | 35 (64.8%) / 19 (35.2%) | 34 (63.0%) / 20 (37.0%) | 0.84 |

***Independent Student's t-test** for age and BMI(Body mass index)

***Chi-square test** for sex and ASA (American society of Anesthesiologist)status

No statistically significant difference was found with demographic variables.

**Table 2: Baseline Clinical Parameters**

| Parameter | Group P | Group C | p-value |
|---|---|---|---|
| Baseline HR (beats/min) | 82.4 ± 9.3 | 83.1 ± 8.7 | 0.68 |
| Baseline SBP (mmHg) | 128.6 ± 11.2 | 129.1 ± 10.8 | 0.82 |
| Baseline MAP (mmHg) | 93.4 ± 8.6 | 93.7 ± 8.1 | 0.87 |

*Independent Student's t-test,HR-Heart Rate,SBP-Systolic blood pressure,MAP-Mean Arterial Pressure No statistical significance seen between baseline parameters.

**Table 3: IVC Ultrasound Parameters**

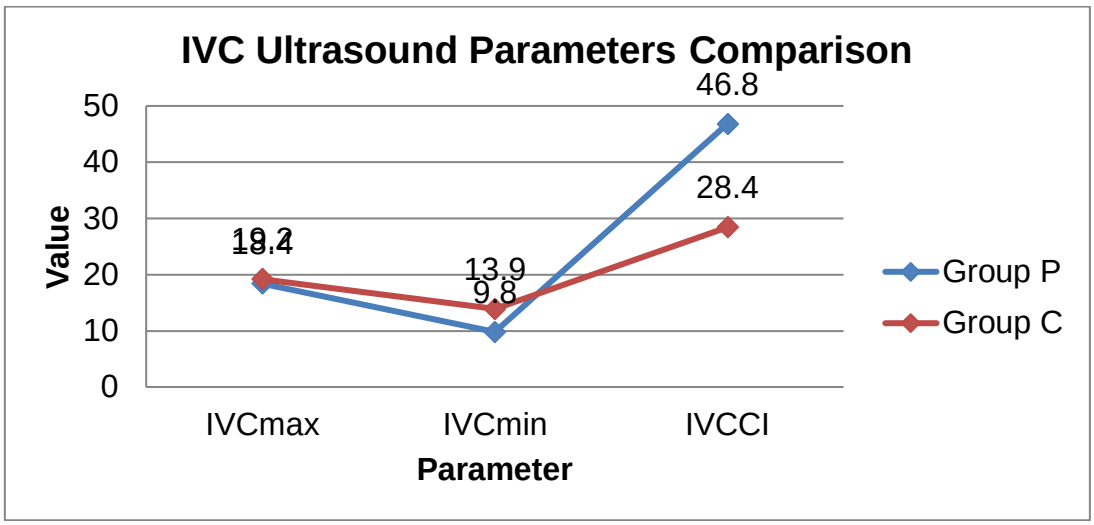
| Parameter | Group P | Group C | p-value |
|---|---|---|---|
| IVCmax (mm) | 18.4 ± 3.1 | 19.2 ± 2.9 | 0.18 |
| IVCmin (mm) | 9.8 ± 2.8 | 13.9 ± 2.6 | <0.001 |
| IVCCI (%) | 46.8 ± 3.1 | 28.4 ± 4.2 | <0.001 |

*Independent Student's t-test,IVC max-maximun diameter if inferior venacava,IVC min-minimum diameter of inferior venacava,IVCCI-inferior venacaval collapsibility index



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**Graph.3 A line graph representation of IVC Ultrasound parameters**

**Table 4: Incidence of Hypotension**

| Variable | Group P | Group C | p-value |
|---|---|---|---|
| Patients with hypotension (%) | 12 (22.2%) | 31 (57.4%) | <0.001 |
| Number of episodes (mean ± SD) | 0.41 ± 0.68 | 1.39 ± 1.02 | <0.001 |

***Chi-square test** for incidence of hypotension*

**Independent Student's t-test* for number of hypotensive episodes.* Incidence of hypotension was significantly low (22.2%) in the preload group compared to control group(57.4%),which was clinically and statistically highly significant.

**Table 5: SBP Trends Over Time (mmHg)**

| Time Point | Group P (mean ± SD) | Group C (mean ± SD) | p-value |
|---|---|---|---|
| Baseline | 128.6 ± 11.2 | 129.1 ± 10.8 | 0.82 |
| 3 min | 122.1 ± 10.4 | 113.2 ± 12.8 | <0.001 |
| 6 min | 118.6 ± 11.1 | 108.4 ± 13.2 | <0.001 |
| 9min | 117.1 ± 15.0 | 106.5 ± 12.68 | <0.001 |
| 10 min | 116.5 ± 12.3 | 104.1 ± 14.1 | <0.001 |
| 12min | 115.7 ± 13.5 | 104.6 ± 15.52 | <0.001 |
| 15 min | 114.3 ± 11.9 | 102.7 ± 13.9 | <0.001 |
| 20 min | 113.8 ± 13.7 | 102.9 ± 14.84 | <0.001 |
| 25 min | 113.3 ± 12.8 | 103.2 ± 13.65 | <0.001 |
| 30 min | 112.8 ± 10.7 | 103.5 ± 12.4 | <0.001 |

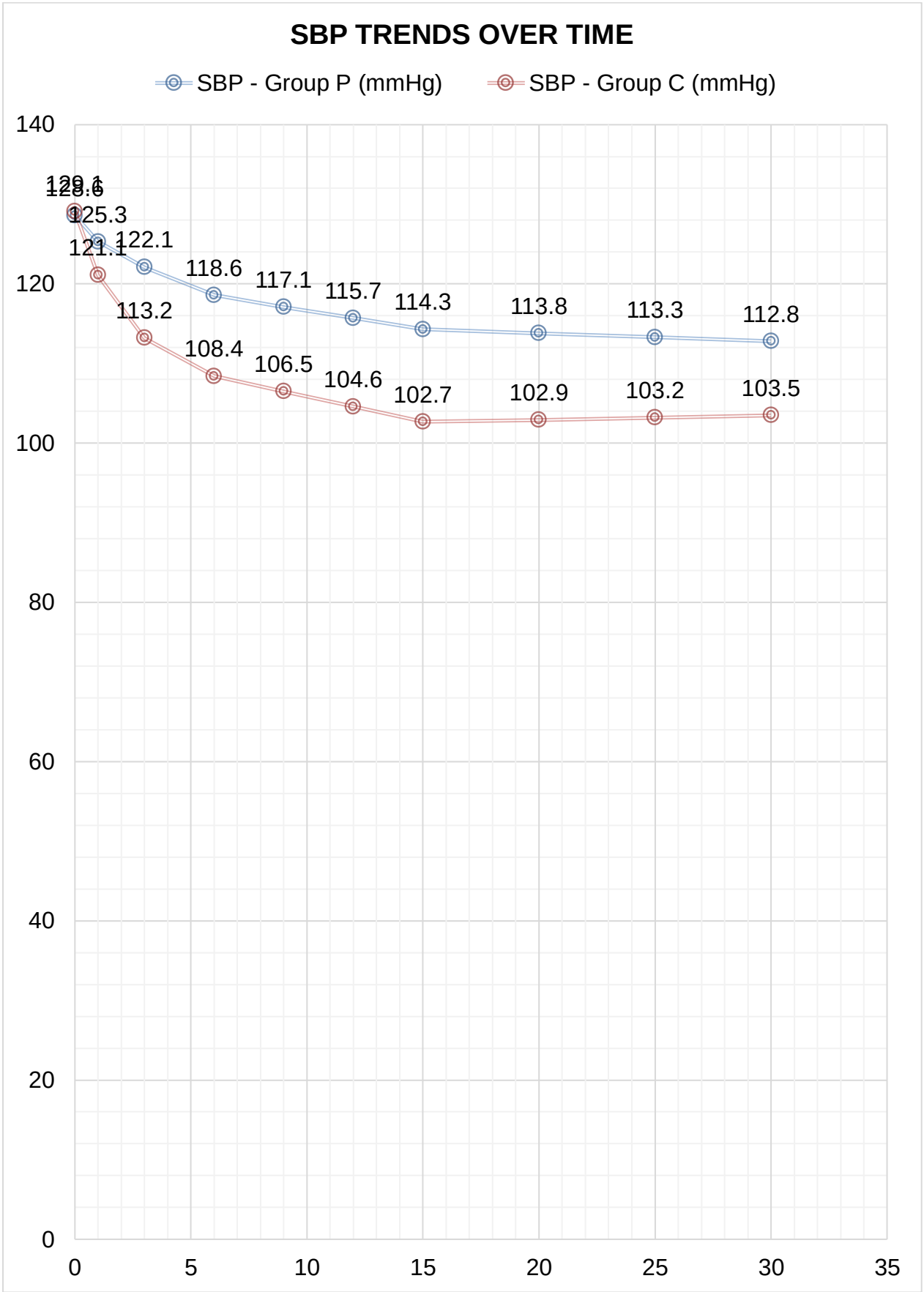
*Independent Student's t-test

Baseline SBP were comparable and statistically not significant, from 3 minutes to 30 minutes patients in group C has less SBP recordings compared to group P which was clinically and statistically significant.



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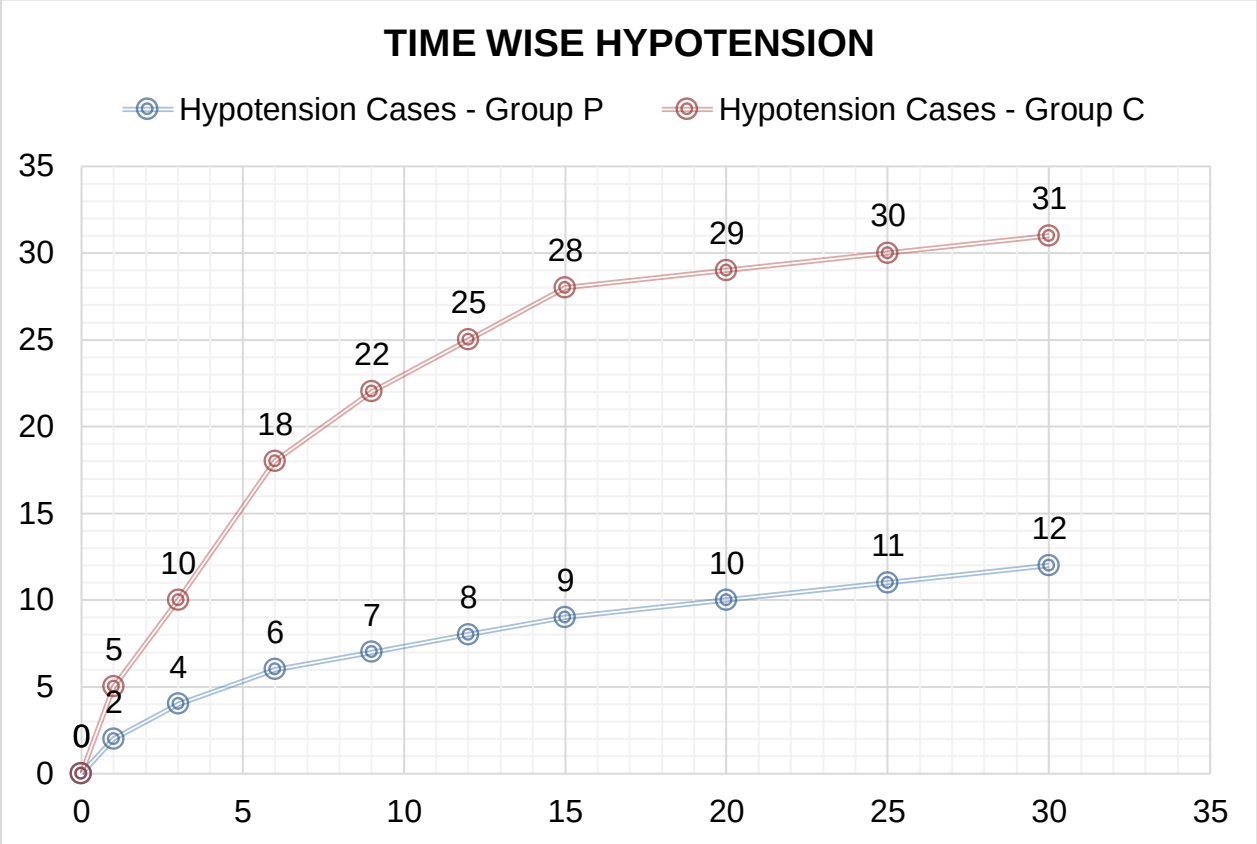

**Graph.5 A line graph representation of SBP trends over time (smooth curve)**

*Both groups followed the trend of fall of SBP from baseline till 30 minutes.*



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**Graph.6 A line graph representation of time wise hypotension**

**Table 6: Fluid Administration**

| Parameter | Group P | Group C | p-value |
|---|---|---|---|
| Pre-operative fluid (mL) | 612 ± 74 | 0 | — |
| Intra-operative fluid (mL) | 812 ± 128 | 1046 ± 152 | <0.001 |
| **Total fluid administered (mL)** | **1424 ± 167** | **1536 ± 181** | **0.003** |

*Independent Student's t-test

The preload group significantly had lower total fluid administration compared to control group (p=0.003) ,which was statistically significant.

**Table 7: Phenylephrine Requirement**

| Variable | Group P | Group C | p-value |
|---|---|---|---|
| Patients requiring phenylephrine (%) | 10 (18.5%) | 29 (53.7%) | <0.001 |
| Total dose (µg, mean ± SD) | 58 ± 41 | 132 ± 78 | <0.001 |

***Chi-square test**

***independent Student's t-test**

**Phenylephrine protocol applied:**

- For first episode of hypotension 100 µg of phenylephrine followed by 50 µg for subsequent episodes when SBP fall below 20% of baseline or MAP falls below 65mmHg

The preload group showed significantly lower requirement of phenylephrine

**Table 8: Bradycardia & Atropine Use**

| Parameter | Group P | Group C | p-value |
|---|---|---|---|
| Bradycardia (%) | 4 (7.4%) | 9 (16.6%) | 0.14 |
| Atropine required (%) | 4 (7.4%) | 9 (16.6%) | 0.14 |

*Chi-square test

All bradycardia patients were given injection.Atropine 0.6mg when HR<50/min.

Bradycardia and Atropine requirement in preload group is significantly less compared to control group.



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**Table 9: Adverse Events**

| Event | Group P | Group C | p-value |
|---|---|---|---|
| Nausea | 5 (9.2%) | 14 (25.9%) | 0.02 |
| Vomiting | 3 (5.5%) | 11 (20.3%) | 0.01 |
| Shivering | 6 (11.1%) | 12 (22.2%) | 0.12 |

***Chi-square test**

**Incidence of nausea and vomiting (5 vs 14),(3 vs11) respectively was less in group P compared to group C,which was statistically significant.**

**Table 10: Duration of Surgery**

| Parameter | Group P | Group C | p-value |
|---|---|---|---|
| Duration (min) | 104 ± 12 | 106 ± 11 | 0.41 |
| Range | 90–122 | 92–120 | — |

*Independent Student's t-test

The surgery duration is comparable between 2 groups.

## DISCUSSION

### Hypotension Incidence & Episodes:

IVCCI-guided preloading demonstrated a marked reduction in the occurrence of hypotension among patients who received targeted fluid therapy. The frequency of hypotensive events was substantially lower in the preload group(22.2%)compared to control group(57.4%), and repeated episodes of blood pressure drops were also minimized. These observations were consistent with findings reported by Ni et al.[11]Ceruti et al.[13] and Ayyanagouda et al.[18] reinforcing the utility of IVCCI as a reliable non-invasive predictor for identifying patients who would benefit from prophylactic volume administration.

### Blood Pressure Stability:

Serial blood pressure monitoring revealed that patients receiving IVCCI-guided preload maintained notably higher systolic blood pressure values throughout the critical post-spinal period. While both groups started with comparable baseline readings, a clear divergence emerged within the first few minutes following spinal anaesthesia and persisted throughout the observation period. This sustained hemodynamic stability during the most vulnerable window after spinal blockade mirrors the protective trends documented in studies by Ceruti et al.[13] and Ayyanagouda et al[18].

### Fluid Administration & Vasopressor Use:

Targeted preloading based on IVCCI assessment led to more efficient fluid management overall. Despite receiving an initial preload, patients in the guided group required considerably less fluid administration during surgery, resulting in lower cumulative fluid consumption(1424+/-167ml)compared to control group(1536+/-181ml). Furthermore, the need for vasopressor intervention was substantially diminished, with fewer patients requiring phenylephrine and those who did needing smaller doses. These observations align with the fluid-sparing and vasopressor-reducing benefits reported by Ni et al[11]. and Ayyanagouda et al[18].

### Adverse Events:

Hypotension-related complications were notably less frequent in the IVCCI-guided preload group. Symptoms such as nausea and vomiting, which commonly accompany intraoperative hypotension, occurred at considerably lower rates. Shivering and bradycardia were also observed less often, though the difference in bradycardia did not reach statistical significance. Importantly, the duration of surgery remained unaffected by the preloading strategy, confirming that hemodynamic optimization did not interfere with operative workflow.

## CONCLUSION

The present study demonstrates that IVCCI-guided fluid preload is an effective strategy for preventing spinal-anaesthesia-induced hypotension in elective lower abdominal surgeries and provides superior hemodynamic stability, reduces vasopressor requirement, optimises fluid administration, and decreases hypotension-related adverse effects, supporting its routine use for individualised fluid management during spinal anaesthesia.

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