Original Article

Impact of FloTrac versus hypotension prediction index (HPI)-guided haemodynamic management on intraoperative hypotension in kidney transplantation: A retrospective observational study

Address for correspondence:
Dr. Vipin Kumar Goyal, Departments of Organ Transplant Anaesthesia and Critical Care, Mahatma Gandhi Medical College and Hospital, Jaipur, Rajasthan, India.
E-mail: dr.vipin28@gmail.com

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Vipin Kumar Goyal, Praveenkumar Shekhrajka[1], Saurabh Mittal, Medha Bhardwaj[2]
Departments of Organ Transplant Anaesthesia and Critical Care, [1]Anaesthesia and Critical Care and [2]Neuro-Anaesthesia, Mahatma Gandhi Medical College and Hospital, Jaipur, Rajasthan, India

ABSTRACT

Background and Aims: Intraoperative hypotension (IOH) is inevitable during moderate-to-high-risk surgeries. In kidney transplantation, intraoperative hypotensive events can badly affect postoperative graft and patient outcomes. Traditionally, central venous pressure monitoring has been regarded as a fundamental aspect of intraoperative haemodynamic management during kidney transplantation. Recently, the focus has changed by including newer haemodynamic tools (FloTrac, Hemosphere, etc.) to reduce intraoperative hypotensive events and postoperative complications. The primary objective was to record IOH (incidence, duration, and severity). **Methods:** This study was done retrospectively to observe the effect of haemodynamic monitoring on IOH. Recipients with dilated cardiomyopathy (DCMP) aged 18–60 years who underwent kidney transplantation from June 2022 to May 2024 were included and had cardiac output measured by FloTrac or Hemosphere. The primary outcome was to record the time-weighted average (TWA) of IOH. Secondary outcomes were to record the average number of hypotensive events per patient and the average duration of each hypotensive event. **Results:** Twenty-eight patients with DCMP were included. The primary outcome of TWA of the area under threshold (MAP < 65 mmHg) per patient was more in patients in the FloTrac group in comparison to the Acumen group (P = 0.613). Secondary outcomes, namely the incidence of hypotensive events per patient and total time of hypotension, were significantly higher in the FloTrac group as compared to the Acumen group (P < 0.0001). **Conclusion:** Hypotension prediction index (HPI) provides superior intraoperative haemodynamic management in kidney transplant recipients with DCMP in terms of reduced duration, incidence, and severity of IOH.

Keywords: Cardiac output, cardiomyopathy, haemodynamic monitoring, hypotension, kidney transplantation

INTRODUCTION

A mean arterial pressure (MAP) of <65 mmHg is known as intraoperative hypotension (IOH), which is always critical during any surgical procedure and is closely associated with postoperative outcomes.[1] In kidney transplantation, renal blood flow, after the removal of the donor graft, is dependent on the recipient's MAP due to loss of auto-regulation. Hence, even a short duration of IOH adversely affects the postoperative graft and recipient outcome. Although IOH is not defined for hypertensive end stage renal disease (ESRD) recipients, we included a standard definition of IOH (MAP <65 mmHg) for these patients.

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The adverse consequences related to IOH are acute tubular necrosis, acute kidney injury, delayed graft function, increased requirement for vasopressors or inotropes, and/or increased risk for other organ dysfunctions (acute ischaemic stroke, acute ischemic hepatitis, acute myocardial injury, etc.).[2]

Traditionally, central venous pressure is the most commonly employed haemodynamic parameter to manage intraoperative haemodynamics during kidney transplantation but has been proven to be suboptimal and has many limitations (invasive, risk of vascular injury/infection, etc.).[3,4] Intraoperative haemodynamic management using advanced haemodynamic indices such as stroke volume variation, pulse pressure variation, and stroke volume has shown improved postoperative outcomes.[5-12] Hypotension prediction index (HPI) is a numeric value that alerts the perioperative physician in advance by 15 minutes about the trending of the patient toward hypotension and, being a proactive approach, decreases the prevalence, duration, and severity of IOH.

Our study aimed to observe the impact of FloTrac and HPI-guided haemodynamic monitoring on IOH in patients undergoing kidney transplantation. The primary objective was to record IOH (incidence, duration, and severity).

METHODS

This retrospective analysis was conducted after obtaining approval from the Institutional Ethics Committee (vide approval no. MGMC and H/IEC/JPR/2024/4026, dated 31/07/2024). Informed consent was waived in view of the retrospective nature of the study. Medical records of end-stage kidney disease (ESKD) patients who were operated on for kidney transplantation at our centre from June 2022 to May 2024 were obtained from the institutional medical record department. This study was conducted as per the Declaration of Helsinki (2013) and Good Clinical Practice guidelines.

The primary outcome was the time-weighted average (TWA) of IOH (MAP < 65 mmHg). TWA is defined as 'depth of hypotension below a MAP of 65 mmHg × time (minutes) spent below a MAP of 65 mmHg)/total duration of surgery (minutes)'. Secondary outcomes were the average number of hypotensive events per patient (MAP < 65 mmHg for 1 minute or more) and the average duration of each hypotensive event.

Preoperative records of kidney transplant recipients having dilated cardiomyopathy were thoroughly searched from preoperative check-up sheets, including demographic data of patients (age, weight, height, gender, duration of disease, and haemodialysis (HD)), associated co-morbidities (hypertension, diabetes mellitus, cardiac or pulmonary disease, etc.), laboratory investigations (haemoglobin, serum albumin, creatinine, liver function tests, and coagulation parameters), electrocardiogram, chest X-ray, and 2D echocardiography (ECHO). Dilated cardiomyopathy was defined as ejection fraction <40% or fractional shortening <25% on preoperative. Patients were evaluated by the cardiologist, and an angiogram was done if indicated.

The intraoperative monitoring data of recipients who underwent haemodynamic management with FloTrac were labelled as Group F, and those monitored by Acumen HPI (Edwards Lifesciences, Irvine, California, United States) were labelled as Group A. Data were collected from the monitoring system and patient records.

Patients with incomplete records, age <18 or >60 years, and intraoperative arrhythmia were excluded from the study. Intraoperative fluid requirements and transfusions of blood products, blood loss, and duration of surgery were recorded.

Data were compiled using MS Excel 2013 and analysed using the Statistical Package for the Social Sciences 24.0 (Chicago, Illinois, United States of America). A normality test (Shapiro-Wilk test) was conducted on the data obtained. Normally distributed data (age, gender, height, weight, haemoglobin, albumin, ejection fraction, duration of anaesthesia, IV crystalloids, and blood loss) were represented as mean (standard deviation), and independent *t*-tests were used for the comparison of the mean value between the two groups. Non-normally distributed datasets (duration of chronic kidney disease (CKD) and HD) were represented as the median and interquartile range and compared using the Mann-Whitney U test. Categorical variables were mentioned as numbers and compared using the Chi-square test. $P < 0.05$ value was taken as statistically significant.

RESULTS

A total of 708 patients with ESRD who underwent kidney transplantation from June 2022 to May 2024 at our hospital were analysed. On preoperative ECHO, 37

patients were diagnosed with dilated cardiomyopathy, having an ejection fraction of <40%.

Nine patients had to be excluded from the study due to incomplete records, age >60 years, and atrial fibrillation during surgery. Twenty-eight patients (FloTrac = 15, Acumen = 13) were included and analysed for study outcomes [Figure 1]. All patients underwent haemodynamic management using either FloTrac or Acumen as per routine institutional protocol [Figures 2 and 3].

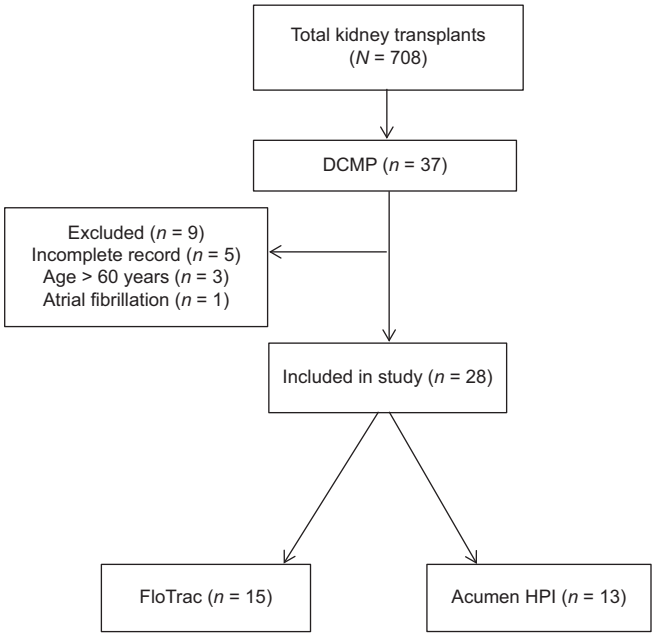

Figure 1: Consolidated Standards of Reporting. Trials (CONSORT) flow diagram of the study. DCMP = dilated cardiomyopathy, HPI = hypotension prediction index, n = number of cases

The demographic profiles of patients, such as age, weight, height, and gender, were comparable among both groups. The median duration of CKD and HD were similar without statistical significance. The incidence of preoperative co-morbidities (hypertension, diabetes mellitus, and coronary artery disease) was nearly equal in both groups.

Preoperative haemoglobin, serum albumin, and ejection fraction were similar in both groups with no statistical significance. The duration of anaesthesia, the intraoperative requirement of intravenous crystalloids, and blood loss were comparable among both groups [Table 1].

Although the number of patients with hypotension was similar in both groups (5 vs 5), the incidence of IOH (total number of hypotensive events in the study group and average number of hypotensive events per patient) was higher in the FloTrac group in comparison to the Acumen group, which was found to be statistically significant ($P = 0.002$). The total duration of hypotension in the FloTrac group was significantly longer compared to the Acumen group ($P < 0.0001$), although the average duration of hypotensive events was similar in both cohorts. The average MAP under 65 mmHg per patient was non-significant ($P = 0.057$), but the area under threshold (AUT) (mmHg × minutes) was higher in the FloTrac group in comparison to the Acumen group ($P = 0.0001$). TWA of AUT (MAP < 65 mmHg) per patient was higher in the FloTrac group in comparison to the Acumen group ($P = 0.613$) [Table 2].

Table 1: Preoperative characteristics of patients

Variable	Group F (*n*=15)	Group A (*n*=13)	*P*
Age (years), mean (SD)	42.4 (16.19)	39.2 (11.05)	0.553
Gender, *n*			
Male	12	9	0.512
Female	3	4	0.512
Weight (kg), mean (SD)	59.67 (7.04)	60.76 (7.87)	0.702
Height (cm), mean (SD)	159.6 (24.31)	162.2 (12.28)	0.730
Duration of CKD (months), median (IQR)	15 (12.0, 28.0)	20 (15.5, 29.0)	0.511
Duration of HD (months), median (IQR)	10 (7.0, 16.0)	10 (7.0, 16.5)	0.950
Hypertension, *n*	13	12	0.630
Diabetes mellitus, *n*	2	1	0.630
CAD, *n*	2	2	0.880
Haemoglobin (g/dL), mean (SD)	8.58 (0.92)	8.44 (0.85)	0.681
Albumin (g/dL), mean (SD)	3.29 (0.56)	3.41 (0.45)	0.542
Ejection fraction (%), mean (SD)	27.6 (5.63)	27 (4.77)	0.765
Duration of anaesthesia (minutes), mean (SD)	211.33 (19.95)	209.23 (14.41)	0.755
IV crystalloid (mL), mean (SD)	1553.33 (199.52)	1500 (204.12)	0.491
Blood loss (mL), mean (SD)	218 (25.69)	219.23 (27.83)	0.900

Data expressed as mean (SD), median (IQR) or numbers. *n*=Number of patients, Group F=FloTrac group, Group A=Acumens group, CKD=Chronic kidney disease, HD=Haemodialysis, CAD=Coronary artery disease, IV=intravenous, IQR=Interquartile range, SD=Standard deviation

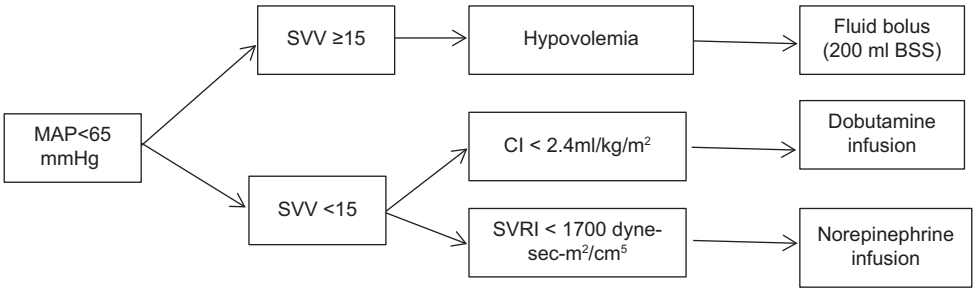

Figure 2: FloTrac protocol of intraoperative haemodynamic management. MAP = mean arterial pressure, SVV = stroke volume variation, CI = cardiac index, SVRI = systemic vascular resistance index, BSS = balanced salt solution

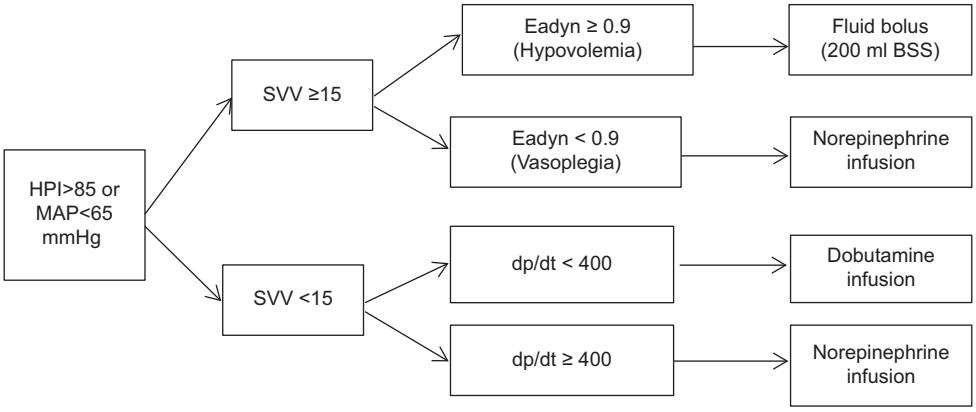

Figure 3: Hypotension prediction index (HPI) protocol of intraoperative haemodynamic management. HPI = hypotension prediction index, MAP = mean arterial pressure, SVV = stroke volume variation, Eadyn = dynamic arterial elastance, dp/dt = rate of change of pressure over time, BSS = balanced salt solution

Table 2: Intraoperative hypotension - incidence, duration, and severity

Variable	Group F (*n*=15)	Group A (*n*=13)	*P*
Number of patients with hypotension	5	5	0.781
Average number of hypotensive events per patient, mean (SD) (95% CI)	2.2 (1.22) (1.583, 2.817)	0.69 (1.38) (−0.060, 1.440)	0.002
Average duration of each hypotensive event (minutes), mean (SD) (95% CI)	4.01 (3.34) (2.320, 5.700)	4.67 (2.35) (3.393, 5.947)	0.556
Total duration of hypotension in cohort (minutes) mean (SD) (95% CI)	132.33 (32.42) (115.924, 148.736)	42 (28.64) (26.431, 57.569)	<0.001
Mean MAP under 65 mmHg per patient (mmHg), mean (SD) (95% CI)	61.26 (3.1) (59.523, 60.817)	58.61 (3.95) (56.523, 60.817)	0.057
Area under 65 mmHg for MAP per patient (AUT) (mmHg x minutes), mean (SD) (95% CI)	51.47 (22.95) (39.856, 63.084)	19.92 (9.95) (14.511, 25.329)	0.001
TWA of AUT (MAP <65 mmHg) per patient (mmHg), mean (SD) (95% CI)	0.15 (0.31) (−0.007, 0.307)	0.1 (0.18) (0.0021, 0.198)	0.613

Data expressed as mean (SD) or numbers. N=Number of patients, Group F=FloTrac group, Group A=Acumen group, SD=Standard deviation, CI=confidence interval, MAP=mean arterial pressure, TWA=time-weighted average, AUT=area under threshold

DISCUSSION

In this retrospective, observational study, we found a lower incidence of IOH in terms of the number of hypotensive events and the average number of hypotensive events per patient in the Acumen group. In addition, the total duration of hypotension and the severity of hypotension (the AUT, MAP <65 mmHg) were lower in the Acumen group.

As a primary outcome, we studied TWA of AUT (MAP <65 mmHg) per patient and observed that it was less in recipients monitored with Acumen HPI as compared to the FloTrac group ($P = 0.613$). A study by Wijnberge *et al.*[13] In elective non-cardiac surgery, it was also found that the TWA of hypotension was significantly reduced with the use of HPI ($P = 0.001$). Another randomised controlled clinical trial by Frassanito *et al.*[14] in major gynaecologic oncology

surgeries also found similar outcomes, but they enroled more patients as compared to our study ($P < 0.001$). Similar findings were found by Schneck E. *et al.*[15] in patients who underwent haemodynamic management with the HPI-based protocol in total hip arthroplasty. Maheshwari *et al.*[16] studied the use of HPI for hypotension prevention in high-risk non-cardiac surgery. They observed that there is no significant difference in TWA of MAP <65 mmHg among the Acumen and control groups ($P = 0.757$).

We studied the incidence of hypotensive events per patient and the total duration of hypotension as our secondary outcomes, which were found to be significantly higher in the FloTrac group as compared to the Acumen group ($P < 0.0001$). Wijnberge *et al.*,[13] in their study of elective noncardiac surgeries, also saw similar observations (HYPE trial) with a reduced incidence, duration, and severity of hypotension ($P < 0.05$). They also observed that there were no adverse events resulting in death with the use of Acumen as compared to the control group. A randomised trial by Šribar *et al.*[17] In thoracic surgeries, similar outcomes were observed in the Acumen group. However, they also found no difference in terms of laboratory and clinical outcomes among both groups. Gangakhedkar GR and colleagues[18] reported the use of HPI in patients undergoing cytoreductive surgery with hyperthermic intraperitoneal chemotherapy. They concluded its usefulness in major surgeries with large fluid shifts and wide haemodynamic fluctuations. Sriganesh K. and colleagues provided a systematic review and meta-analysis of controlled trials to study the role of HPI in minimising IOH, offering a higher level of evidence to guide clinicians in incorporating HPI into practice.[19] They highlighted that while some RCTs have demonstrated the benefits of HPI in preventing hypotension, others have not.

The strength of our study is that we observed the use of the HPI in high-risk patients with dilated cardiomyopathy who underwent kidney transplantation surgeries. Utilising HPI to facilitate individualised blood pressure management can help anticipate and mitigate IOH, thereby reducing postoperative organ dysfunction.

The limitations of our study are its retrospective nature, small sample size, male predominance in study groups, and the lack of inclusion of the impact of IOH on postoperative recipient and graft outcomes. In addition, MAP <65 mmHg is not justified for hypertensive patients and different phases of kidney transplantation. Further prospective studies with large sample sizes studying the adverse events and laboratory parameters such as serum lactate, arterial blood gas, and postoperative graft function are required to observe the effect of the HPI-guided protocol on postoperative patients and graft outcomes in kidney transplant patients.

CONCLUSION

HPI-guided haemodynamic management during kidney transplantation helps to reduce the incidence, duration, and severity of the hypotension.

Study data availability

De-identified data may be requested with reasonable justification from the authors (email to the corresponding author) and shall be shared after approval as per the authors' Institution policy.

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Conflicts of interest

There are no conflicts of interest.

ORCID

Vipin Kumar Goyal: https://orcid.org/0000-0002-3318-3726

Praveenkumar Shekhrajka: https://orcid.org/0000-0003-2918-3210

Saurabh Mittal: https://orcid.org/0000-0002-7056-996X

Medha Bhardwaj: https://orcid.org/0009-0001-8634-989X

REFERENCES

1. Shah NJ, Mentz G, Kheterpal S. The incidence of intraoperative hypotension in moderate to high-risk patients undergoing non-cardiac surgery: A retrospective multicentre observational analysis. J Clin Anesth 2020;66:109961. doi: 10.1016/j.jclinane.2020.109961.
2. D'Amico F, Fominskiy EV, Turi S, Pruna A, Fresilli S, Triulzi M, *et al.* Intraoperative hypotension and postoperative outcomes: A meta-analysis of randomised trials. Br J Anaesth 2023;131:823-31.
3. Marik PE, Baram M, Vahid B. Does central venous pressure predict fluid responsiveness? A systematic review of the literature and the tale of seven mares. Chest 2008;134:172-8.
4. Bacchi G, Buscaroli A, Fusari M, Neri L, Cappuccilli ML, Carretta E, *et al.* The influence of intraoperative central venous pressure on delayed graft function in renal transplantation: A single-center experience. Transplant Proc 2010;42:3387-91.
5. Campos L, Parada B, Furriel F, Castelo D, Moreira P, Mota A. Do intraoperative hemodynamic factors of the recipient influence renal graft function? Transplant Proc 2012;44:1800-3.

6. Adelmann D, Bicknell L, Niemann CU, Feiner J, Roll GR, Burdine L, *et al*. Central venous pressure monitoring in living donor kidney recipients does not affect immediate graft function: A propensity score analysis. Clin Transplant 2018;32:e13238. doi: 10.1111/ctr.13238
7. Goyal VK, Gupta P, Baj B. Anesthesia for renal transplantation in patients with dilated cardiomyopathy: A retrospective study of 31 cases. Braz J Anesthesiol 2019;69:477-83.
8. Collange O, Tacquard C, Oulehri W, Biehler J, Moulin B, Mertes PM, *et al*. Hemodynamic management during kidney transplantation: A French survey. Transplant Proc 2021;53:1450-3.
9. Goyal VK, Gupta P, Baj B, Garg VK. A randomized comparison between pulse pressure variation and central venous pressure in patients undergoing renal transplantation. J Anaesthesiol Clin Pharmacol 2021;37:628-32.
10. De Cassai A, Bond O, Marini S, Panciera G, Furian L, Neri F, *et al*. Pulse pressure variation guided fluid therapy during kidney transplantation: A randomized controlled trial. Braz J Anesthesiol 2020;70:194-201.
11. Kannan G, Loganathan S, Kajal K, Hazarika A, Sethi S, Sen IM, *et al*. The effect of pulse pressure variation compared with central venous pressure on intraoperative fluid management during kidney transplant surgery: A randomized controlled trial. Can J Anaesth 2022;69:62-71.
12. Srivastava D, Sahu S, Chandra A, Tiwari T, Kumar S, Singh PK. Effect of intraoperative transesophageal Doppler-guided fluid therapy versus central venous pressure-guided fluid therapy on renal allograft outcome in patients undergoing living donor renal transplant surgery: A comparative study. J Anesth 2015;29:842-9.
13. Wijnberge M, Geerts BF, Hol L, Lemmers N, Mulder MP, Berge P, *et al*. Effect of a machine learning-derived early warning system for intraoperative hypotension vs standard care on depth and duration of intraoperative hypotension during elective noncardiac surgery: The HYPE randomized clinical trial. JAMA 2020;323:1052–60.
14. Frassanito L, Giuri PP, Vassalli F, Piersanti A, Monge Garcia MI, Sonnino C, *et al*. Hypotension prediction index guided goal directed therapy and the amount of hypotension during major gynaecologic oncologic surgery: A randomized controlled clinical trial. J Clin Monit Comput 2023;37:1081–93.
15. Schneck E, Schulte D, Habig L, Ruhrmann S, Edinger F, Markmann M, *et al*. Hypotension Prediction Index based protocolized haemodynamic management reduces the incidence and duration of intraoperative hypotension in primary total hip arthroplasty: A single centre feasibility randomised blinded prospective interventional trial. J Clin Monit Comput 2020;34:1149-58.
16. Maheshwari K, Shimada T, Yang D, Khanna S, Cywinski JB, Irefin SA, *et al*. Hypotension prediction index for prevention of hypotension during moderate- to high-risk noncardiac surgery. Anesthesiology 2020;133:1214–22.
17. Šribar A, Jurinjak IS, Almahariq H, Bandić I, Matošević J, Pejić J, *et al*. Hypotension prediction index guided versus conventional goal directed therapy to reduce intraoperative hypotension during thoracic surgery: A randomized trial. BMC Anesthesiol 2023;23:101.doi: 10.1186/s12871-023-02069-1
18. Gangakhedkar GR, Solanki SL, Divatia JV. The use of Hypotension Prediction Index in cytoreductive surgery (CRS) with hyperthermic intraperitoneal chemotherapy (HIPEC). Indian J Anaesth 2022;66:294-8.
19. Sriganesh K, Francis T, Mishra RK, Prasad NN, Chakrabarti D. Hypotension prediction index for minimising intraoperative hypotension: A systematic review and meta-analysis of randomised controlled trials. Indian J Anaesth 2024;68:942-50.