ORIGINAL ARTICLE
ASIAN JOURNAL OF MEDICAL SCIENCES

A study to correlate trends in perfusion index and bispectral index for assessment of depth of anesthesia: A cross-sectional study

Karthik Raj M[1], Shalini Jain[2], Manish Banjare[3], Nidhi Sharma[4]

[1]Postgraduate Resident, [2]Professor, [3]Professor and Head, [4]Assistant Professor, Department of Anesthesia, M.G.M. Medical College and M.Y. Hospital, Indore, Madhya Pradesh, India

Submission: 19-02-2025 Revision: 03-04-2025 Publication: 01-05-2025

ABSTRACT

Background: Accurate anesthesia depth monitoring is crucial for patient safety. Bispectral index (BIS) measures brain activity, whereas perfusion index (PI) reflects peripheral blood flow and sympathetic tone. BIS is a gold standard but is limited by cost and interference, whereas PI is a simpler, more accessible alternative. **Aims and Objectives:** This study aimed to correlate trends in PI and BIS for assessing anesthesia depth. The primary objective was to examine the correlation between PI and BIS trends. The secondary objective was to monitor intraoperative hemodynamic fluctuations and their relationship with PI and BIS. **Materials and Methods:** A cross-sectional study was conducted over 12 months at M.G.M. Medical College and M.Y. Hospital, Indore. Seventy patients (18–65 years, the American Society of Anesthesiologists physical status 1 or 2) undergoing elective surgery under general anesthesia were enrolled in the study. Exclusion criteria included cardiovascular, neurological, psychiatric disorders, and peripheral vascular diseases. BIS and PI were monitored throughout the perioperative period. Statistical analysis was done using IBM SPSS Version 22, with significance set at $P<0.05$. **Results:** A strong negative correlation between BIS and PI ($P<0.05$) was found. BIS also showed negative correlations with heart rate, systolic, and diastolic blood pressure ($P<0.05$). PI had a significant positive correlation with heart rate ($P<0.05$) and a negative correlation with blood pressure ($P<0.05$). **Conclusion:** The significant negative correlation between BIS and PI supports PI as a potential alternative for anesthesia depth monitoring, especially in resource-limited settings.

Key words: Anesthesia depth; Bispectral index; Perfusion index; Intraoperative hemodynamics; Heart rate; Blood pressure; Systolic blood pressure; Diastolic blood pressure; General anesthesia; Anesthesia monitoring; Hemodynamic parameters; Portable monitoring tools

Access this article online

Website:

https://ajmsjournal.info/index.php/AJMS/index

DOI: 10.71152/ajms.v16i5.4465

E-ISSN: 2091-0576

P-ISSN: 2467-9100

INTRODUCTION

In modern medical practice, ensuring patient safety during surgical procedures involving general anesthesia relies heavily on accurate monitoring of anesthesia depth. This intricate balance necessitates a comprehensive understanding of how anesthetic agents influence patient hemodynamics. Innovative monitoring techniques have emerged as essential tools in this endeavor, particularly the bispectral index (BIS) and perfusion index (PI). BIS, derived from electroencephalographic signals, quantifies levels of consciousness and serves as a gold standard for anesthesia monitoring.[1] Conversely, PI measures peripheral blood flow dynamics and provides real-time insights into microcirculatory changes.[2]

The integration of BIS and PI in anesthesia monitoring presents a promising avenue for improving depth assessment.

Address for Correspondence:
Dr. Karthik Raj M. C/o. Mr. Manikandan C, 4/54, P.M.G. Street Cumbum - 625516, Theni District, Indore, Madhya Pradesh, India.
Mobile: +91-94895-86868. **E-mail:** karthickbell@gmail.com

BIS's capability to gauge central nervous system activity, combined with PI's insights into peripheral perfusion, offers a more nuanced understanding of patient responses to anesthesia. While BIS has demonstrated its validity in monitoring anesthesia depth for adults and children over 1-year old, its adoption faces challenges, including equipment costs and availability, which limit its routine use.[1]

PI, utilized within pulse oximeters, reflects changes in sympathetic tone during anesthesia, revealing significant variations in peripheral vascular resistance. Research indicates a strong correlation between neurophysiological arousal and sympathetic activity, with reductions in PI observed as patients transition from anesthesia to awakening. The ability to quantify these changes through PI, calculated as the ratio of pulsatile to non-pulsatile signals, presents a straightforward technique for clinicians.[3]

Given the critical importance of anesthesia depth assessment, this study aims to investigate the correlation between BIS and PI in evaluating anesthesia depth, as well as the intraoperative hemodynamic changes related to both indices. Through a thorough literature review, we seek to bridge existing gaps in understanding and advance more informed, individualized approaches to anesthesia administration to maintain adequate depth of anesthesia.

Aim

To correlate trends in Perfusion Index (PI) and Bispectral Index (BIS) for assessment of depth of anesthesia.

Objectives

Primary objective

The primary objective of the present study was to find out and observe the correlation in trends of Perfusion Index (PI) and Bispectral Index (BIS) in assessing the depth of anesthesia.

Secondary objective

To monitor fluctuation in intra-operative hemodynamics and its relation with PI [Perfusion index] and BIS [Bispectral index].

MATERIALS AND METHODS

The present study was conducted at the Department of Anesthesiology, M.G.M. Medical College and M.Y. Hospital in Indore (M.P.). This cross-sectional clinical study was carried out over 12 months, from September 2022 to September 2023, with approval from the Institutional Ethics Committee (Vide EC/MGM/September 22/39). The study population consisted of patients scheduled for elective surgeries under general anesthesia who met the specified inclusion criteria during the study period.

Sample size and sampling technique

The sample size was calculated using G*power software (Version 3.1.9.2) with a 95% confidence level and 80% power, yielding a sample size of 69, which was rounded to 70. Consequently, the study included 70 patients who met all inclusion criteria and none of the exclusion criteria.

Inclusion criteria

The study included patients who met the following criteria:

- Aged 18–65 years, of any gender
- ASA physical status of 1 or 2
- Scheduled for elective surgery under general anesthesia
- Willing to provide voluntary written informed consent, either directly or through a legally acceptable representative.

Exclusion criteria

Patients were excluded from the study if they had:

- Patient refusal to participate
- Peripheral vascular diseases
- Psychiatric illnesses
- Neurosurgical conditions
- Cardiovascular or neurological disorders.

Materials used

The materials used in the study included an anesthesia workstation equipped with gas supply, suction apparatus, cannulas, and catheters. A BIS monitor was utilized to assess brain activity, along with a multiparameter monitor to track vital signs. A pulse oximeter with a PI display was also used to measure peripheral blood flow. In addition, a laryngoscope and appropriately sized endotracheal tube were employed for airway management. Propofol was administered for induction, and various medications and gases were used for anesthesia maintenance. Emergency drugs and resuscitation equipment were on hand to address any unforeseen complications during the procedure.

Methods

Eligible patients were informed about the study, including its risks and benefits, in their preferred language. After obtaining verbal consent, written informed consent was secured from the patient or a legally acceptable representative. A thorough pre-anesthetic evaluation was conducted, and patients were advised to remain nil per oral for 6 h before surgery. In the pre-operative holding area, intravenous (IV) access was established, and Ringer's lactate was administered as routine care. Upon arrival in the operating room, standard monitors (electrocardiogram, non-invasive blood pressure, pulse oximetry with PI) were applied, and baseline values recorded. BIS electrodes were placed on the forehead, with specific placement instructions.

Throughout the perioperative period, vital signs were monitored, using the same pulse oximeter for consistency. Patients received pre-medication with Glycopyrrolate (0.01 mg/kg IV) and Midazolam (0.05 mg/kg IV), followed by pre-oxygenation with 100% oxygen for 5 min. Induction was achieved with fentanyl (2 mcg/kg IV), and after 3 min, Propofol (2 mg/kg IV) was administered. A BIS value of 50 was targeted for intubation; upon reaching this value, succinylcholine (2 mg/kg IV) was given, and endotracheal intubation was performed, confirmed by end-tidal carbon dioxide ($ETCO_2$) and bilateral air entry.

Hemodynamic parameters, BIS, and PI were recorded upon entering the operating room and throughout the perioperative period, continuing up to 10 min post-extubation. Ventilation was maintained using the workstation in volume control mode (tidal volume of 6–8 mL/kg and frequency of 12–14 breaths/min). Anesthesia was maintained with nitrous oxide (66%), sevoflurane (1%), and oxygen (33%). Atracurium was administered as a loading dose (0.5 mg/kg IV) and maintenance doses (0.1 mg/kg IV).

Post-surgery, anesthesia was reversed using neostigmine (0.05 mg/kg IV) and glycopyrrolate (0.01 mg/kg IV), with extubation following established criteria. Patients were then transferred to post-operative care.

Assessment of BIS and PI

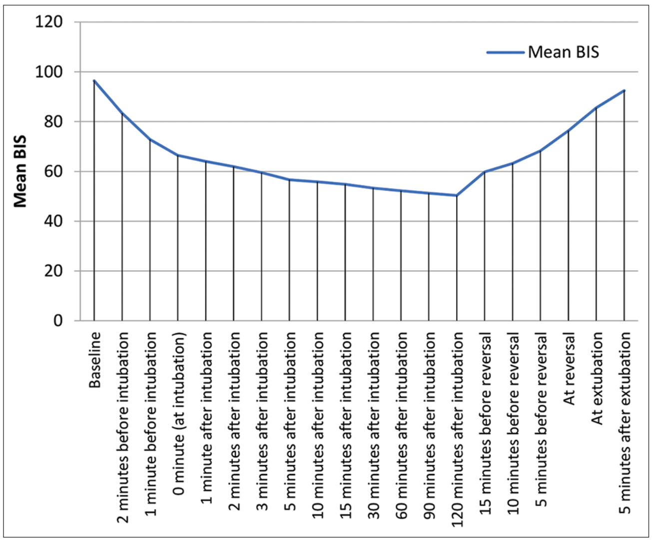
The BIS, developed by Aspect Medical Systems in 1994, monitors consciousness during anesthesia and sedation, with values ranging from 0 to 100. Adequate anesthesia is indicated by BIS values between 40 and 60. The PI derived from pulse oximetry, continuously measures peripheral perfusion as the ratio of pulsatile to non-pulsatile blood flow, ranging from 0.02% to 20%. An increase in PI suggests deeper plane of anesthesia, whereas a decrease indicates lighter plane of anesthesia.

The study's outcome measures included trends in PI, BIS, heart rate, and systolic and diastolic blood pressure (DBP) in relation to anesthesia depth.

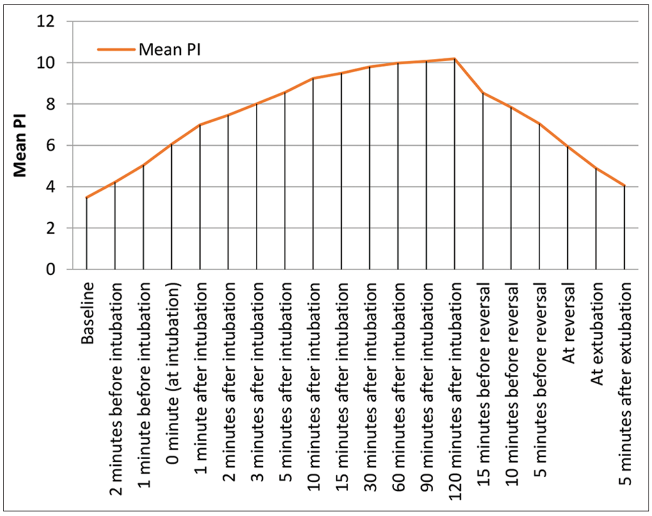
Statistical analysis was performed using IBM SPSS Version 22 to calculate P-values. Descriptive statistics were presented as frequencies and percentages. The Pearson correlation coefficient test was used to assess correlations between parametric variables, with statistical significance set at $P<0.05$.

RESULTS

The study included 70 patients, with a mean age of 42.16±15.68 years. The distribution by age was: 14.3% aged 18–20, 31.4% aged 21–40, 37.1% aged 41–60, and 17.1% over 60 years. The majority of patients were female (64.3%). Most patients were classified as ASA Physical Status I (75.7%).



Graph 1: Line diagram showing trend of mean bispectral index over various time points



Graph 2: Line diagram showing trend of mean perfusion index over various time points

Correlation between BIS and PI

Mean BIS decreased from 96.43 at baseline to 50.33 at 120 min post-intubation, whereas PI increased from 3.47 to 10.18 during the same interval (Graphs 1 and 2).

The R values at various time points ranged from −0.948 at baseline to −0.961 5 min after extubation, with significant decreases observed before and after intubation and reversal, whereas a strong, negative correlation between BIS and PI was found at all-time points ($P<0.05$), indicating that as BIS decreased, PI significantly increased.

Correlation between BIS/PI and heart rate

Correlation between BIS and heart rate

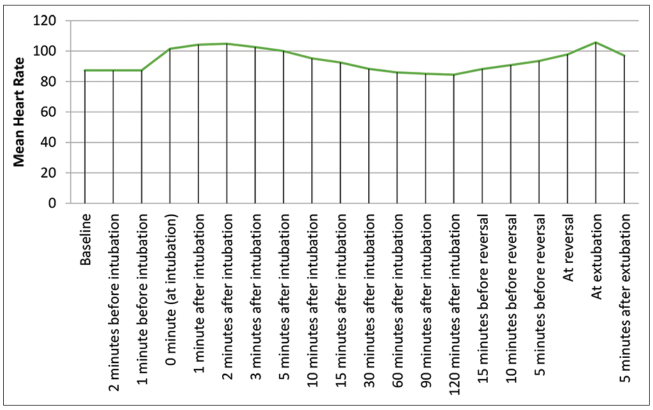
At baseline, the mean BIS was 96.43±1.53, dropping to 66.46±4.29 at intubation, then gradually decreasing to 50.33±5.93 by 120 min post-intubation, before rising again at reversal and extubation. Heart rate remained stable until intubation, when it spiked to 101.46±10.55, peaking at 104.76±10.89 2 min post-intubation, then gradually decreasing to 84.49±8.14 by 120 min. A slight rise was noted just before reversal and extubation (Graph 3).

At baseline, the R-value of −0.921 indicated a strong negative correlation, which peaked at −0.980 just before and during reversal, with other significant values of −0.971 2 min before intubation, −0.958 at intubation, and −0.959 1 min after intubation, remaining between −0.863 and −0.980 throughout, the lowest being −0.863 at extubation, all statistically significant (P=0.001), whereas a strong negative correlation between BIS and heart rate was observed at all-time points (P<0.05), with heart rate increasing as BIS decreased.

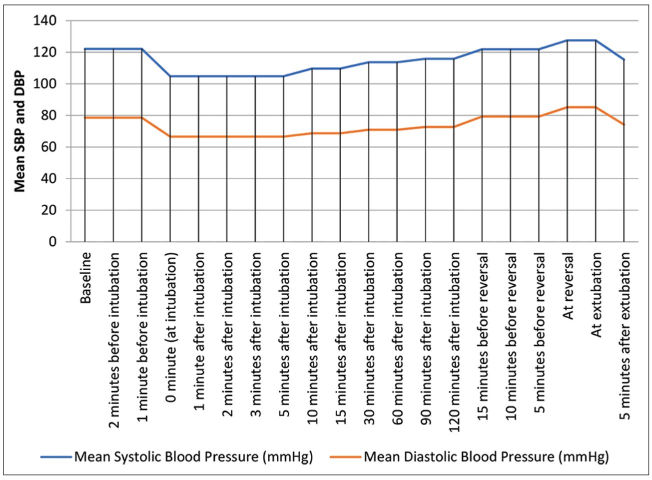
Correlation between PI and heart rate

PI increased from 3.47±0.86 at baseline to 6.05±1.09 at intubation, peaking at 10.18±1.03 by 120 min. Heart rate rose sharply at intubation (101.46±10.55), then gradually decreased to 84.49±8.14 by 120 min (Graph 3).

The correlation coefficients (r values) throughout the intubation and extubation process consistently demonstrated strong, positive, and statistically significant correlations (P=0.001), ranging from 0.961 at baseline to 0.918 at intubation, peaking at 0.987 3 min post-intubation, and remaining high at subsequent time points (e.g., 0.967 at 5 min, 0.984 at 60 min, and 0.968 at extubation), with a final value of 0.874 5 min after extubation, indicating a sustained positive correlation, while a strong, positive correlation between PI and heart rate (P<0.05) was also observed, with increases in PI linked to higher heart rates.



Graph 3: Line diagram showing trend of mean heart rate over various time points



Graph 4: Line diagram showing trend of mean systolic and diastolic blood pressure over various time points

Correlation between BIS/PI and blood pressure

Correlation between BIS and systolic blood pressure (SBP)

The mean BIS at baseline was 96.43±1.53, decreasing to 66.46±4.29 during intubation and maintaining low levels (50.33±5.93) at 120 min post-intubation, followed by an increase before reversal and extubation. Baseline SBP was stable at 122.06±12.20 mm Hg until intubation when it dropped to 104.83±10.33, remaining low until 5 min after intubation. SBP rose to 127.49±11.06 by extubation, then decreased slightly (Graph 4).

Starting at baseline with an r=0.945, the correlation strengthened to 0.953 before intubation, peaked at 0.960 post-intubation, and remained robust between 0.873 and 0.909 over time, with the lowest values of 0.770 at 15 min and 0.789 at 10 min; pre-reversal values were 0.949 at 15 min, 0.971 at 10 min, and 0.943 at 5 min, with 0.937 at reversal and 0.903 at extubation, all P<0.001, whereas a strong positive correlation between BIS and SBP (P<0.05) was observed, with SBP decreasing as BIS decreased.

Correlation between BIS and DBP

Baseline BIS was 96.43±1.53, decreasing to 66.46±4.29 at intubation, then dropping to 50.33±5.93 by 120 min post-intubation, followed by an increase before reversal and extubation. The baseline DBP was stable at 78.51±8.22 mm Hg until intubation, where it fell to 66.57±9.06, remaining low until 5 min post-intubation. DBP then rose to 85.19±7.71 at extubation, followed by a decrease at 5 min post-extubation (Graph 4).

The correlation coefficients (r-values) throughout the intubation and extubation process remained strong and statistically significant, ranging from 0.947 at baseline to

0.905 at intubation, peaking at 0.973 2 min post-intubation, and staying strong through later stages (0.927 at 60 min, 0.930 at 90 min, 0.963 before the reversal, and 0.960 at extubation, with 0.953 5 min post-extubation), indicating a sustained positive relationship; In addition, a significant correlation between BIS and DBP (P<0.05) was observed, with BIS decline linked to a decrease in DBP.

Correlation between PI and SBP

PI increased from 3.47±0.86 at baseline to 6.05±1.09 at intubation, peaking at 10.18±1.03 by 120 min. SBP dropped significantly at intubation (104.83±10.33), then increased to 127.49±11.06 by extubation, followed by a decline at 5 min post-extubation (Graph 4).

The correlation coefficients (r-values) during the intubation, reversal, and extubation processes consistently showed very strong, negative, and statistically significant correlations (P=0.001), ranging from −0.956 at baseline to −0.976 at intubation, peaking at −0.988 5 min post-intubation, and remaining strong through later stages, with values like −0.961 at 60 min and −0.958 at extubation, indicating a sustained negative correlation; In addition, a strong, negative correlation between PI and SBP (P<0.05) was observed, with increases in PI linked to significant decreases in SBP.

Correlation between PI and DBP

PI rose from 3.47±0.86 at baseline to 6.05±1.09 at intubation, peaking at 10.18±1.03 by 120 min. DBP fell from 78.51±8.22 at baseline to 66.57±9.06 during intubation, then gradually increased to 85.19±7.71 by extubation, before dropping to 74.17±9.14 at 5 min post-extubation (Graph 4).

The correlation coefficients (r values) throughout the intubation, reversal, and extubation process consistently showed very strong, negative, and statistically significant relationships (P=0.001), ranging from −0.941 at baseline to −0.977 at intubation, peaking at −0.979 5 min post-intubation, and remaining strong at later time points such as −0.956 at 60 min and −0.929 at extubation, with a final value of −0.974 5 min after extubation, indicating a sustained negative correlation, while a very strong, negative correlation between PI and DBP (P<0.05) was observed, with increases in PI linked to significant decreases in DBP.

DISCUSSION

Demographics

This study included 70 patients, aged 18–65, undergoing elective surgeries under general anesthesia. Our patient demographics, with a mean age of 42.16±15.68 years and a predominance of females (64.3%), align with previous studies, reinforcing the validity of our inclusion criteria.

Correlation between BIS and PI

We observed a significant negative correlation between BIS and PI at all-time points. The initial BIS value of 96.43±1.53 dropped to 66.46±4.29 at intubation, further decreasing to 50.33±5.93 after 120 min, while PI rose from 3.47±0.86 to 10.18±1.03 in the same period. These results support the potential of PI as an effective monitor of anesthesia depth, complementing BIS.

Previous studies, such as those by Kheir et al.,[4] have suggested that PI can provide critical insights into anesthesia depth, potentially surpassing BIS in certain contexts. Our findings align with this perspective, highlighting the utility of both metrics in anesthesia monitoring.

Correlation between BIS and hemodynamics

Our study found a statistically significant negative correlation between BIS and heart rate, with BIS reductions linked to heart rate increases. Conversely, systolic and DBPs exhibited a positive correlation with BIS, declining as BIS values dropped. In a study by Rao et al.[5] evaluated the relationship between BIS and hemodynamic parameters during standard general anesthesia practices, found predictable changes in BIS scores and hemodynamics during anesthesia, a clear correlation between BIS and hemodynamic parameters could not be established.

Correlation between PI and hemodynamics

A strong positive correlation between PI and heart rate was observed, whereas significant negative correlations were noted between PI and both systolic and DBPs. A study by Kumar et al.,[6] evaluated whether PI can predict hypotension during subarachnoid block. They found a significant relationship between a decrease in SBP from baseline and baseline PI, suggesting that PI can help in predicting hypotension. Similarly, another study by Abdullah Mohamed et al.,[7] assessed if PI can predict hypotension in geriatric patients. They also confirmed a good predictability of early hypotension using PI and found a significant correlation between PI and onset of hypotension.

Limitations of the study

Despite our best efforts to meet the study's objectives, there are several limitations that may influence the results. These include a small sample size and a single-center design, both of which could introduce potential bias. In addition, there is a scarcity of relevant studies directly aligned with the topic of this thesis. To strengthen the validity of these findings, future research with larger sample sizes across multiple centers is recommended.

CONCLUSION

This study demonstrated a significant negative correlation between PI and BIS at all-time points, indicating that during deeper plane of anesthesia as BIS decreases, PI increased and vice versa during light plane of anesthesia. This supports PI as a viable alternative or complement to BIS for monitoring anesthesia depth. In addition, significant correlations between BIS and hemodynamic parameters, such as heart rate, systolic, and DBP, were observed. Similar correlations were noted between PI and heart rate, as well as between PI and blood pressures. These findings highlight the potential of PI as an accessible and cost-effective tool for monitoring anesthesia depth and hemodynamic stability, particularly in resource limited settings primary health centers, community health centers, and magnetic resonance imaging suites where BIS may not be available. Further research is needed to confirm these results across broader patient populations and diverse clinical settings.

ACKNOWLEDGMENT

We acknowledge the support of the department staff and library staff who helped us in data collection and literature review search for the present study.

REFERENCES

1. Mathur S, Patel J, Goldstein S, Hendrix JM and Jain A. Bispectral index. In: StatPearls. Treasure Island, FL: StatPearls Publishing; 2025. Available from: https://www.ncbi.nlm.nih.gov/books/nbk539809 [Last accessed on 2025 Mar 12].
2. Sun X, He H, Xu M and Long Y. Peripheral perfusion index of pulse oximetry in adult patients: A narrative review. Eur J Med Res. 2024;29(1):457.
   http://doi.org/10.1186/s40001-024-02048-3
3. Inamanamelluri R, Das S, Senapati LK and Pradhan A. Perfusion index and its correlation with intraoperative hypotension in lower-segment Cesarean section under spinal anesthesia: A prospective observational study in a tertiary care hospital in Eastern India. Cureus. 2022;14(10):e30431.
   http://doi.org/10.7759/cureus.30431
4. Kheir TM, Salama AM, Obayah GM, Elmoughazy MF and Sheded AF. Validation of perfusion index to measure the depth of general anesthesia in patients undergoing ophthalmic surgery: Before-and-after-study. Eur Chem Bull. 2023;12(1):3297-3306.
   http://doi.org/10.31838/ecb/2023.12.1.434
5. Rao GV, Chand KN, Murthy AS and Balabhaskar S. Bispectral index analysis in general anesthesia: An observational study. Ind J Clin Anaesth. 2018;5(3):361-367.
   http://doi.org/10.18231/2394-4994.2018.0068
6. Kumar U, Tripathi A, Somvanshi M and Karasala V. Clinical evaluation of perfusion index (PI) as a predictor of post spinal hypotension in lower segment caesarean section (LSCS). Indian J Clin Anaesth. 2022;9(4):445-449.
   https://doi.org/10.18231/j.ijca.2022.090
7. Abdullah Mohamed S, Yousry Helmy M, Khattab SA, Hossam AM and Arafa MS. Perfusion index as a predictor of hypotension after induction of general anesthesia in elderly patients-a prospective observational study. Egypt J Anaesth. 2023;39(1):619-625.
   https://doi.org/10.1080/11101849.2023.2238524

Authors' Contributions:
KRM- Data collection, literature search, prepared first draft of the manuscript, then final manuscript preparation and submission of article; **SJ**- Concept of the study, design of the clinical protocol, data analysis and interpretation; **MB**- Review of the draft and final manuscripts; **NS**- Coordination and manuscript revision.

Work attributed to:
Department of Anesthesia, M.G.M. Medical College and M.Y. Hospital, Indore, Madhya Pradesh, India.

Orcid ID:
Karthik Raj M - https://orcid.org/0009-0001-6546-5090
Dr. Shalini Jain - https://orcid.org/0000-0001-6702-9666
Dr. Manish Banjare - https://orcid.org/0000-0001-7695-5645
Dr. Nidhi Sharma - https://orcid.org/0009-0009-5675-8842

Source of Support: Nil, **Conflicts of Interest:** None declared.