

Caval/Aorta Diameter Index to Predict Post-Induction Hypotension Associated with General Anaesthesia: An Observational Study

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CAVAL/AORTA DIAMETER INDEX TO PREDICT POST-INDUCTION HYPOTENSION ASSOCIATED WITH GENERAL ANAESTHESIA: AN OBSERVATIONAL STUDY

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ABSTRACT

BACKGROUND: Post induction hypotension is a common side effect of general anaesthesia with consequences of organ hypoperfusion and ischemia. Patients are at risk of developing hypotension immediately after induction of general anaesthesia due to the cardiovascular depressant and vasodilatory effects of commonly used anesthetic agents and pre-existing hypovolemia owing to nil per oral status of patients undergoing elective surgeries. IVC to aorta ratio using point-of-care ultrasound is being studied as a newer method for its ability to predict post induction hypotension with various cut-off values.

MATERIAL AND METHODS: One hundred and thirty-two ASA PS I and II patients scheduled for elective surgeries under general anaesthesia with endotracheal intubation were enrolled in this observational study from November 2024 to May 2025. After approval from IRC, written informed consent was obtained from all included patients. In the preoperative room, ultrasound was used to obtain IVC and aorta diameter and then IVC to aorta ratio (IVC/Aorta) was calculated. Blood pressure parameters were recorded at 5, 10 and 15 minutes post induction of general anaesthesia. Data was entered in Microsoft Excel and subsequently exported to SPSS, version 26 for analysis.

RESULTS: Among 132 patients, 72 patients (54.54%) had post induction hypotension. ROC curve analysis for caval/aorta diameter index in predicting post induction hypotension demonstrated an AUC of 0.713 for a cut off value of ≤ 0.81500 .

The flow of participants through the study is shown in Fig. 5.

CONCLUSION: Post induction hypotension is common with an incidence of 54.54% in ASA PS I and II patients undergoing surgery under general anaesthesia and caval/aorta diameter index can predict hypotension.

TRIAL REGISTRATION

The trial was registered with the Institutional Review Committee of the Institute of Medicine, Tribhuvan University, Kathmandu, Nepal on the 06th of September, 2024. The registration number was 172 081/082

Clinical trial number: Not applicable

KEYWORDS: *Hypotension, General Anaesthesia, Inferior vena cava: Aorta index, Ultrasound*

BACKGROUND

Post-induction hypotension is a common side effect of general anaesthesia with incidence as high as 70% and may cause organ hypoperfusion and ischemia.^{1,2} General anaesthesia is known to cause significant alterations in hemodynamics resulting in bradycardia, decreased systemic vascular resistance, decreased myocardial contractility, cardiac output and stroke volume. Patients are at particular risk of developing hypotension after induction of GA because of the existing cardiovascular depressant and vasodilatory effects of anaesthetic agents along with the pre-existing hypovolemia which surgical patients arrive with into the operating room owing to the nil-per-oral status required for safe induction.¹

Induction of anaesthesia is the most crucial period at which hypotension occurs. About one-third of perioperative hypotensive episodes occur in the period after the induction of general anaesthesia but before surgical incision and can be described as post induction or pre-incision hypotension.^{3,4} Post induction hypotension often leads to myocardial injury, stroke, acute kidney injury, septic complications, prolonged hospital stay, increased risk of 30-days mortality as well as increased risk of one-year mortality.⁵⁻¹²

There are several risk factors for post-induction hypotension associated with general anaesthesia, which can broadly for convenience be divided into non-modifiable risk factors which include: ASA III and IV status, old age, male sex, duration of surgery and modifiable risk factors, which include choice of anaesthetic drugs, discontinuation of anti-hypertensive agents before surgery, intravascular volume status, nil per oral duration before the surgery.^{13,14}

Latent hypovolemia is a clinical condition corresponding to a decrease in circulating blood volume without obvious hemodynamic changes and/or organ dysfunction, which increases the risk of the development of hypoperfusion in response to external impacts such as anaesthesia and surgery.¹⁵ The identification of latent hypovolemic patients affords anaesthesiologists a chance to implement proper fluid replacement before inducing general anaesthesia. However, for anaesthesiologists, determining the exact status of intravascular volume remains difficult.

Various parameters can be used to measure intravascular volume and each have inherent limitations to identify the exact intravascular volume status that they measure. The parameters popularly used include but are not limited to: measurement of the central venous pressure using a central venous catheter, pulmonary artery occlusion pressure, measured using the pulmonary artery catheter, PiCCO which is a combination of trans-pulmonary thermodilution and pulse contour analysis, heart rate variability index (HRV), perfusion index (PI), passive leg raising (PLR) test, inferior vena cava variability index, stroke volume variation (SVV) and pulse pressure variation (PPV).

Inferior vena cava ultrasonography measures during respiration have been suggested as a quick and non-invasive dynamic parameter for assessing the status of intravascular volume. Caval/Aorta diameter index further is a more effective and convenient method for evaluation of intravascular volume rather than relying on changes of IVC collapsibility as the diameter of the IVC changes with the respiratory cycle.¹⁶ The IVC diameter not only varies with respiration but also with the initial diameter of the IVC (maximum IVC diameter).

To overcome it, the caval aorta index (IVC/Ao) which compares the maximum diameter of the IVC with the abdominal aorta (Ao), which is independent of intravascular fluid status was studied and was found to be a better predictor of intravascular volume.¹⁶

METHODOLOGY

OBJECTIVES

a. General objectives

- To find out the ability of Caval/Aorta diameter index to predict post-induction hypotension associated with general anaesthesia.

b. Specific objectives

- To find out association of caval/aorta diameter index with post-induction hypotension
- To find out the incidence of post-induction hypotension

STUDY DESIGN

Study design: This was a quantitative, prospective, observational, diagnostic accuracy study.

Setting: The study was conducted in the preoperative preparation rooms and operation theaters of Tribhuvan University Teaching Hospital (TUTH) which is the primary teaching hospital of Maharajgunj Medical Campus from November 2024 to May 2025. TUTH is a university hospital with a bed capacity of 850 beds and 8 major operating theaters where approximately 8000 patients undergo surgery under anesthesia each year.

Participants:

All patients listed for surgery under general anaesthesia were screened for eligibility.

Inclusion criteria:

- Age 18 years to 65 yrs
- Patients undergoing elective surgery under general anaesthesia
- Patients with ASA-PS I and II

Exclusion criteria:

- Patients who refuse consent to participate in the study
- Body mass index more than 30 kg m⁻²
- Pregnant women
- Patients with baseline SBP < 90 mmHg or > 180 mmHg or mean arterial blood pressure < 65 mmHg
- Patients taking angiotensin converting enzyme inhibitors or angiotensin receptors blockers
- IVC non-visualization
- Aorta non-visualization
- Epidural catheter in use

Among this patient population, non-probability convenience sampling was done by including the patients who met the inclusion criteria and then by excluding the patients falling under the exclusion criteria.

The patients were followed from the time of inclusion in the study up until 15 minutes after the induction of general anaesthesia.

Study size:

A total of 143 patients were included in the study.

Sample Size Calculation:

The total sample size calculation for this study required that individual sample size be calculated keeping sensitivity and specificity at 95% C.I. Thus, 'n1' is the sample size needed to keep the study at 95% C.I. and 'n2' is the sample size needed to keep the study specificity at 95% C.I. and 'n' is the sum of 'n1' and 'n2'.

The precision of the study was within 95% C.I. with the following sample size.

- $n_1 = z_{\alpha/2} * S_N (100 - S_N) / (d^2 * \text{Prevalence}) = 16$ ¹⁹

where,

- ❖ n_1 = Sample size needed to keep the study sensitivity at 95% confidence interval
- ❖ $z_{\alpha/2} = 1.96$ at 95% confidence level
- ❖ S_N = Sensitivity of IVCD_{max}/Ao index = 77.5 (according to reference article)
- ❖ d = maximum tolerable error = 3% of $S_N = 2.325$
- ❖ prevalence of Post- induction Hypotension = 78.43% (according to reference article)
- $n_2 = z_{\alpha/2} * S_P (100 - S_P) / (d^2 * (100 - \text{Prevalence})) = 114$ ¹⁹

where,

- ❖ n_2 = Sample size needed to keep the study specificity at 95% confidence interval
- ❖ $z_{\alpha/2} = 1.96$ at 95% confidence level
- ❖ S_P = Specificity of IVCD_{max}/Ao index = 63.6 (according to reference article)
- ❖ d = maximum tolerable error = 3% of $S_P = 1.908$
- ❖ prevalence of Post- induction hypotension = 78.43% (according to reference article)

then,

- $n = 16 + 114 = 130$

- In the final sample size of 130, 10% was added to account for drop-out of the study participants that could have happened during the study interval.
- Total sample size= $130 + (10 \% \text{ of } 130) = 143$

Therefore, a total sample size of 143 was required.

Data sources and measurement:

Demographic data including name, age, sex, in-patient number, date of surgery, diagnosis, procedure to be performed, ASA-PS status for inclusion in the study were sourced from the pre-anaesthesia checkup form.

Baseline BP was recorded from multiparameter patient monitors in the pre-anaesthesia patient room of Tribhuvan University Teaching Hospital.

Data starting from the time of induction of general anaesthesia to 15 minutes after the induction of anaesthesia was recorded from the post-anaesthesia record form.

Ultrasound was used to measure the IVC and the aorta diameters and the data obtained was used to calculate caval/aorta diameter index.

Statistical Methods:

For the purpose of data entry, Microsoft Excel spreadsheet was used. Statistical analysis was done using Statistical Package for Social Sciences [SPSS software version 26 (IBM Inc., Armonk, NY, USA)]. Data was expressed by descriptive and inferential statistics. Categorical variables were presented as frequencies and percentages, while numerical variables were expressed as mean $\pm$ standard deviation or median with interquartile range, as appropriate.

For comparisons between two independent groups, the Independent Samples t-test or the Mann-Whitney U test was applied. The Chi-Square test was used for inferential analysis of categorical data. A p-value less than 0.05 was considered statistically significant.

Receiver operating characteristic (ROC) curve analysis was employed to determine the optimal inferior vena cava (IVC) to aorta diameter index cutoff for predicting post-induction hypotension.

Sensitivity and specificity of the determined cut-off value was calculated by using the following formula:

Sensitivity = True positive / True positive + False negative

PROCEDURAL STEPS:

Ethical approval was obtained from the Institutional Review Committee (IRC) of the Institute of Medicine (IOM). Approval letter for the conduct of the study was also obtained from the Department of Anaesthesiology at TUTH. Informed and written consent was obtained from the patients before enrolment of patients into the study.

A day prior to surgery

- All the patients included in the study were explained in detail about the purpose of the study.
- Informed and written consent was obtained during pre-anaesthetic checkup.
- Patients were asked to remain nil per oral as per the institutional practice and guidelines
- Premedication was advised as per the institutional protocol.

In the pre-anaesthetic room

1. The NPO duration of the patient was confirmed and recorded.

2. Basic monitors were attached (electrocardiogram, non-invasive blood pressure, and pulse oximetry) and baseline vitals (Heart Rate, Blood Pressure and Saturation) were recorded.
3. An IV access was opened.
4. After this, the patient proceeded for an ultrasonographic examination following the steps as described below:

Image Acquisition:

Patient Setup:

- Position: supine position (Fig. 1).



[Insert Fig. 1 here]

**Figure 1: IVC Ultrasound in supine position
(Taken by the author with patient consent)**

1. Preparations:
 - a. Adjust ambient light
 - b. Expose the upper abdomen

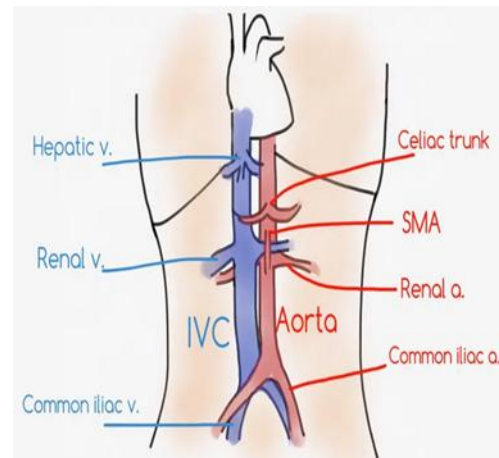
Probe selection:

- c. Curvilinear (3.5 to 5 MHz) transducer in B-mode scan
- d. Acoustic media: Apply gel

Scanning Technique:

The scanning technique followed was based on the guidelines for scanning of IVC and aorta as recommended by the American Society of Echocardiography.¹⁷

Scanning Plane: Sagittal/parasagittal plane in the subcostal area. (Fig. 2).



[Insert Fig. 2 here]

Figure 2: Green line being the scanning plane

Figure 2: IVC and aorta anatomy

Steps:

The steps for scanning for IVC and aorta involve the following as per the description from the American Society of Echocardiography.¹⁷

1. Transthoracic echocardiographic subcostal window was used for visualisation of IVC in the sagittal plane by angling and rotating the transducer to the left from the subcostal four chamber view.
2. M-mode imaging was used to obtain high frame rate measurements to minimise the error in size changes of IVC throughout the respiratory cycle.
3. Care was taken to ensure that the IVC did not translate out of the imaging plane during portions of the respiratory cycle, leading to pseudo-collapse.
4. The Ao was then identified on the left side of the IVC, approximately 1 cm above the celiac trunk.

Image Capture:

- Method: Still frames were captured.

Sonographic view of IVC and Aorta: (Fig. 4).



[Insert Fig. 3 here]

Figure 3: Sonographic view of the IVC and Aorta¹⁸

Measurements:

1. M-mode imaging was used to obtain high frame rate measurements to minimise the error in size changes of IVC throughout the respiratory cycle.
2. In M-mode, measurements of IVC internal anteroposterior diameter, which is maximum during expiration (IVC_{max}) and minimum during inspiration (IVC_{min}), was taken in one respiratory cycle.
3. The Ao was then identified on the left side of the IVC, approximately 1 cm above the celiac trunk, and its maximum internal diameter at systole was recorded.
4. The caval aorta index was derived using the IVC_{max} and Ao diameter ratio.

Caval\Aorta diameter index= Inferior vena cava maximum diameter (IVC_{max}) /
Aorta Diameter (Ao)

In the operating room

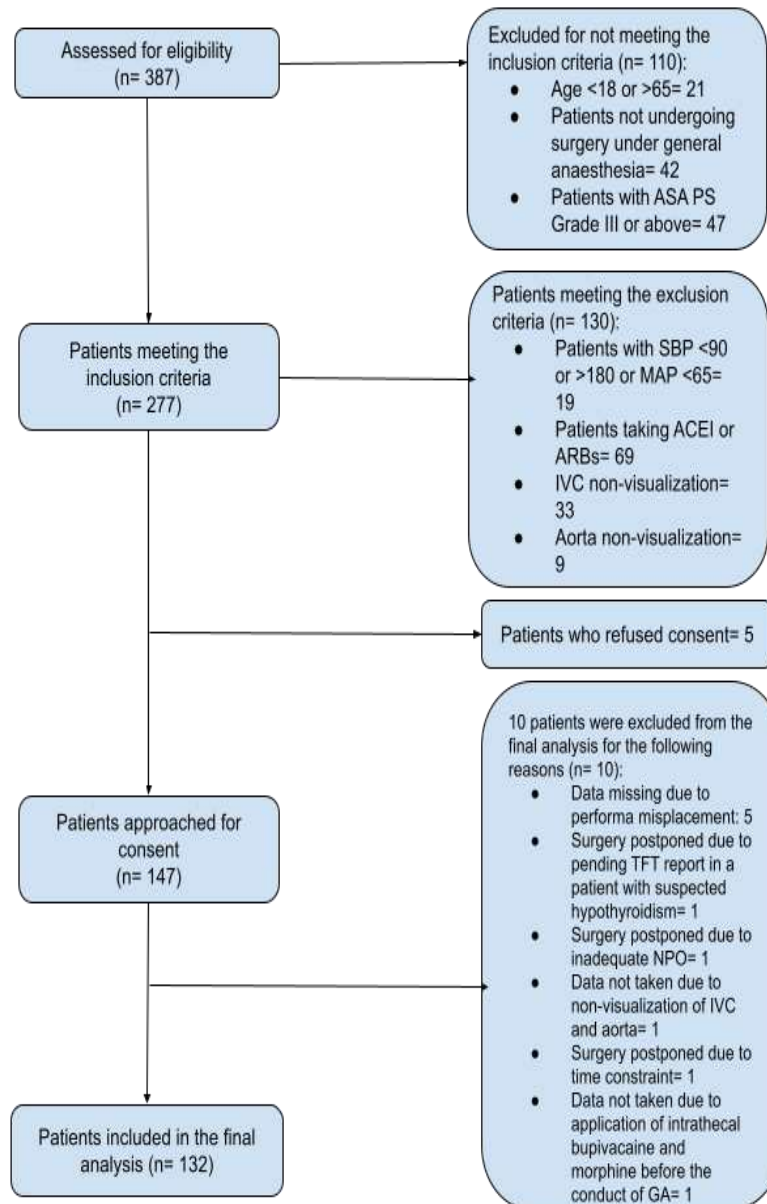
- General anaesthesia was administered as per the institutional protocol.
- Necessary deviations from the institutional protocol as deemed necessary by the anaesthesiologist or the anaesthesiology resident based on the individual requirement of a patient was recognized and recorded.

The institutional protocol for general anaesthesia with endotracheal tube is as follows:

- Standard monitoring of ECG, Spo2 and NIBP
 - Induction with injection fentanyl and titrated dose of injection propofol
 - Muscle relaxation with the relaxant as per the choice of the anaesthesiologist or the anaesthesiology resident
 - Standard size endotracheal tube intubation
 - Maintenance of anaesthesia with Isoflurane and oxygen
 - Reversal of muscle relaxation with injection neostigmine and injection glycopyrrolate
 - Balanced salt solution for maintenance fluid
 - Recording of data (heart rate, NIBP, Spo2) every 5 minutes
- SBP, DBP, MAP at baseline and at 5 minutes, 10 minutes and 15 minutes intervals after tracheal intubation was taken from the anaesthesia chart.
 - Patients with any deviation from the institutional protocol for general anaesthesia with endotracheal tube were excluded from the study.
 - Patients requiring more than three attempts at securing endotracheal intubation were excluded from the study.
 - Hypotension was defined as a decrease in SBP by more than 20% of the baseline value or an absolute value of SBP less than 90 mmHg or MAP less than 60 mmHg.
 - Total number of episodes of hypotension was recorded.
 - Patients received regular operation / anaesthesia care as per the institutional protocol.

- Data was filled in proforma and then in the master chart and data analysis was done.

RESULTS



[Insert Fig. 4 here]

Figure 4: Patient Flow Diagram

A. Baseline characteristics:

One hundred and thirty-two patients were enrolled into the study after obtaining informed consent. The baseline characteristics of this study population regarding age distribution, gender distribution and distribution according to their ASA-PS are listed below. (Table 1).

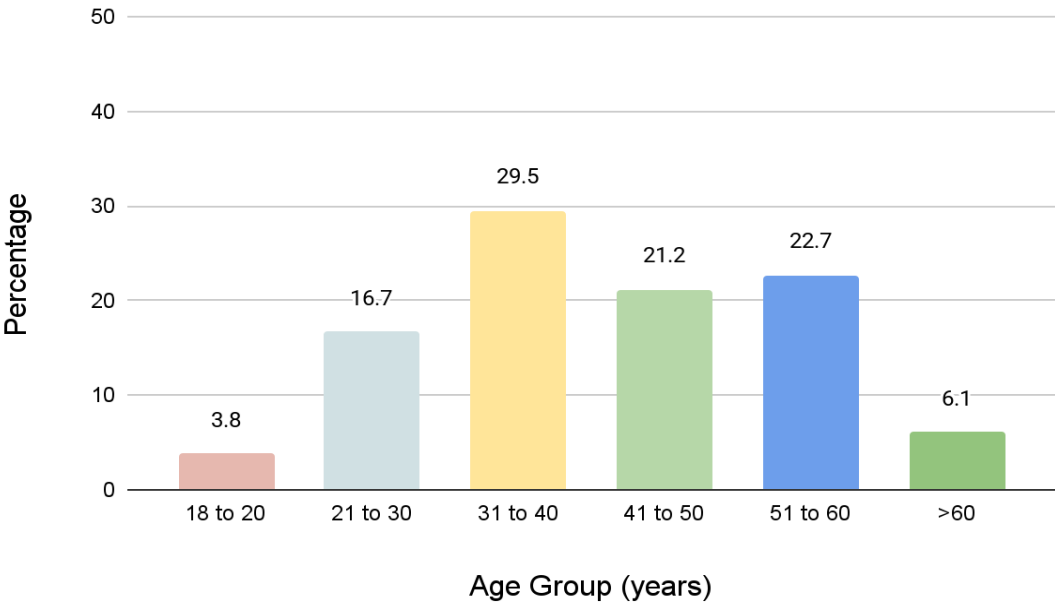
[Insert Table 1 here]

Table 1: Demographic data of the patients

Variable	Frequency	Percentage (%)
Age (years)		
18-20	5	3.8
21-30	22	16.7
31-40	39	29.5
41-50	28	21.2
51-60	30	22.7
60-65	8	6.1
Gender		
Female	82	62.1
Male	50	37.9
ASA PS Grade		
I	63	47.7
II	69	52.3
Total	132	100.0

1. Age Distribution:

Patients aged between 18 and 65 years were enrolled in the study. The minimum age was 18 years, and the maximum age was 65 years, with a mean age of 41.2 ± 12.3 years. The highest proportion of patients belonged to the 31–40 years age group $n = 39$ (29.5%), while the lowest proportion was observed in the 18–20 years age group $n = 5$ (3.8%). The age distribution is shown in Fig. 5.

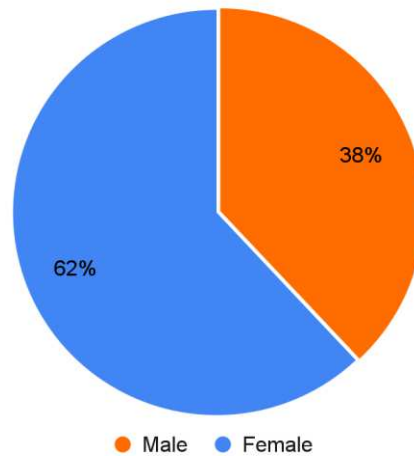


[Insert Fig. 5 here]

Figure 5: Age Distribution

2. Gender Distribution:

Among 132 patients, 82 patients (62.1%) were female and 50 (37.9%) were male. The gender distribution is shown in Fig. 6.

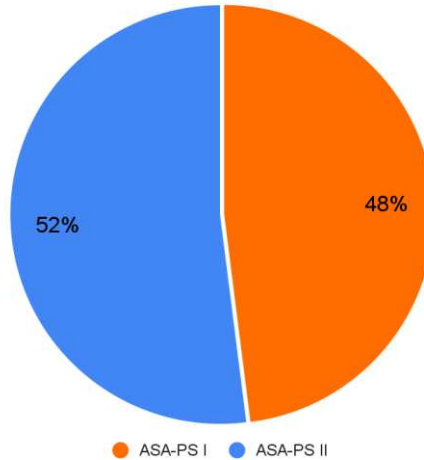


[Insert Fig. 6 here]

Figure 6: Gender distribution among the study population

3. ASA-PS grading:

Among 132 patients, 63 (47.7%) patients were ASA-PS I and 69 (52.3%) were ASA-PS II. The ASA-PS distribution is shown in Fig. 7.



[Insert Fig. 7 here]

Figure 7: ASA-PS

B. Status of IVC and Aorta parameters:

The mean maximum IVC diameter was 1.2 ± 0.3 cm. The maximum IVC diameter (IVC_{max}) among the study participants was 2.17 cm while the minimum IVC diameter was 0.16 cm. (Table 2).

The mean aortic diameter among the study participants was 1.5 ± 0.3 cm. The maximum aortic diameter among the study participants was 2.51 cm while the minimum aortic diameter was 0.78 cm.

The mean $IVC_{max}/Aorta$ ratio was 0.7 ± 0.3 . The maximum $IVC_{max}/Aorta$ ratio was 2.03 and the minimum $IVC_{max}/Aorta$ ratio was 0.13 while

[Insert Table 2 here]

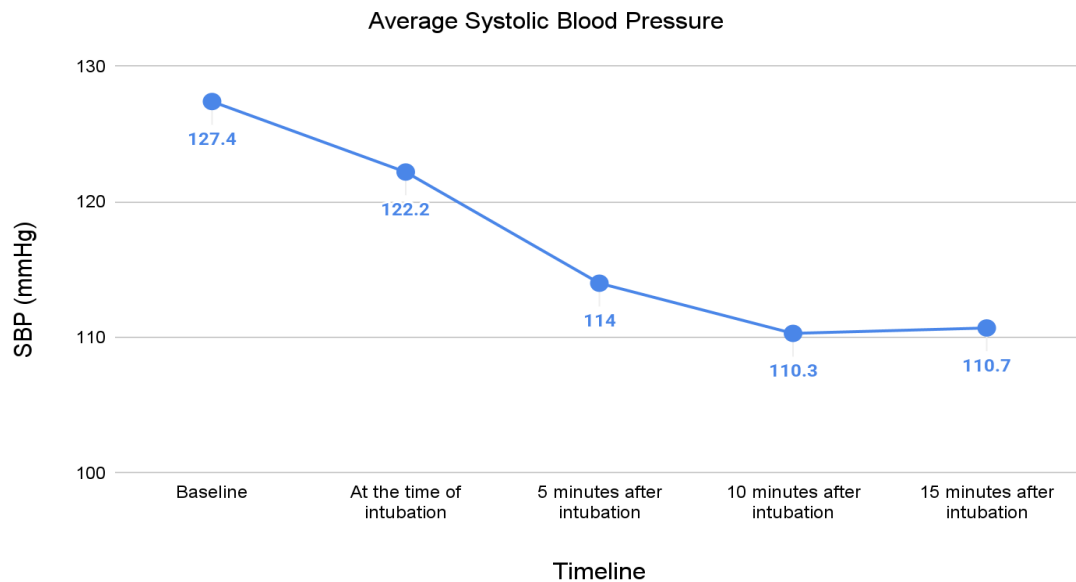
Table 2: IVC and Aorta parameters

Parameters	Mean±SD	Median (IQR)
IVC (Max) (cms)	1.2±0.3	1.1(0.9-1.4)
Aorta (cms)	1.5±0.3	1.5(1.3-1.8)
IVC/Aorta Ratio	0.7±0.3	0.7(0.5-0.8)

C. Evaluation of blood pressure among study participants

1. Systolic blood pressure at baseline, at the time of tracheal intubation and at 5, 10, 15 minutes after intubation:

The average baseline systolic blood pressure was 127.4 ± 131 mmHg. At the time of tracheal intubation, it was 122.2 ± 19.6 mmHg. At 5 minutes of tracheal intubation, it decreased to 114.0 ± 19.1 mmHg. At 10 minutes of tracheal intubation, it was 110.3 ± 16.8 mmHg and at 15 minutes of tracheal intubation, average systolic blood pressure among the study participants was 110.7 ± 17.2 mmHg. The systolic blood pressure trend is shown in Fig. 8.

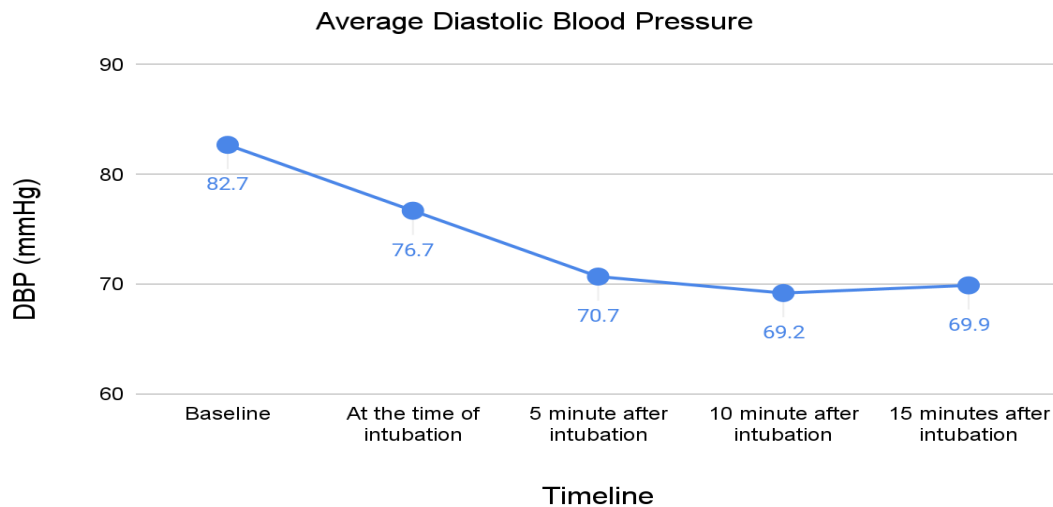


[Insert Fig. 8 here]

Figure 8: Average systolic blood pressure of the study participants

2. Diastolic blood pressure at baseline, at the time of tracheal intubation and at 5, 10, 15 minutes after intubation:

The average baseline diastolic blood pressure was 82.7 ± 8.9 mmHg. At the time of tracheal intubation, it was 76.7 ± 13.5 mmHg. At 5 minutes of tracheal intubation, average diastolic blood pressure decreased to 70.7 ± 14.0 mmHg. At 10 minutes of tracheal intubation, it was 69.2 ± 12.4 mmHg and at 15 minutes of tracheal intubation, average diastolic blood pressure among the study participants was 69.9 ± 13.2 mmHg. The diastolic blood pressure trend is shown in Fig. 9.

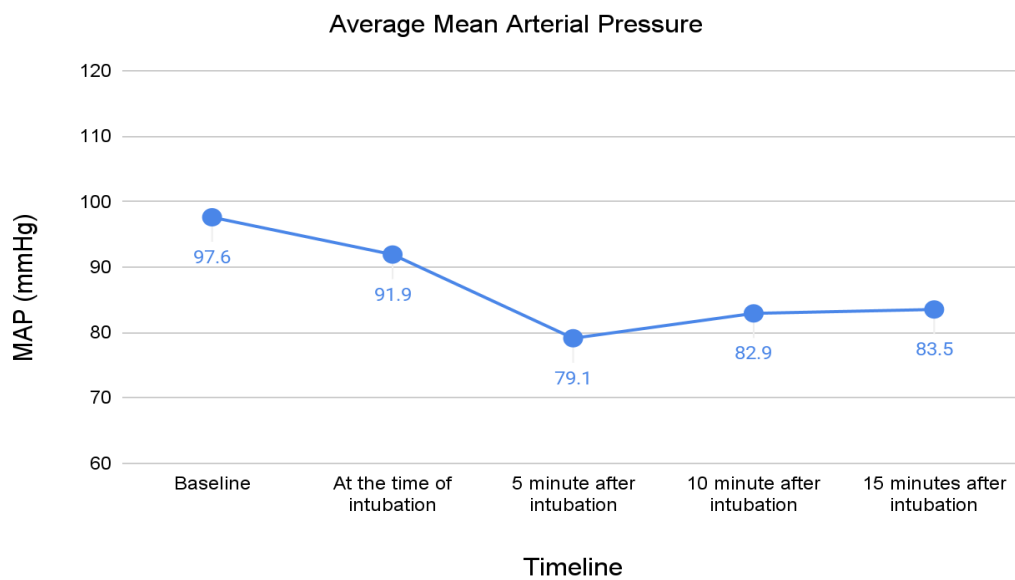


[Insert Fig. 9 here]

Figure 9: Average diastolic blood pressure of the study participants

3. Mean blood pressure at baseline, at the time of tracheal intubation and at 5, 10, 15 minutes after intubation:

The average baseline mean arterial pressure was 97.6 ± 9.2 mmHg. At the time of tracheal intubation, it was 91.9 ± 14.8 mmHg. At 5 minutes of tracheal intubation, it decreased to 79.1 ± 26.3 mmHg. At 10 minutes of tracheal intubation, it was 82.9 ± 13.3 mmHg and at 15 minutes of tracheal intubation, average mean arterial pressure was 83.5 ± 14.0 mmHg. The mean arterial pressure trend is shown in Fig. 10.



[Insert Fig. 10 here]

Figure 10: Average mean arterial pressure of the study participants

D. Incidence of hypotension among the patients

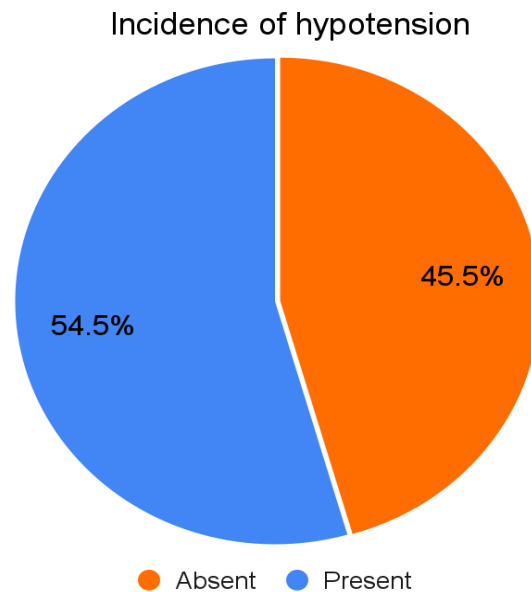
1. Overall incidence of hypotension among the patients:

According to the criteria for a patient to have post induction hypotension in our study which was, ‘decrease in SBP by more than 20% of the baseline value or an absolute value of SBP less than 90 mmHg or MAP less than 60 mmHg’, post-induction hypotension was observed in 72(54.54%) of the patients while post-induction hypotension was not observed in 60(45.54%) of the patients. The overall incidence of hypotension is shown in Fig. 11. (Table 3).

[Insert Table 3 here]

Table 3: Incidence of hypotension

Hypotension	Frequency	Percent (%)
Absent	60	45.54
Present	72	54.54

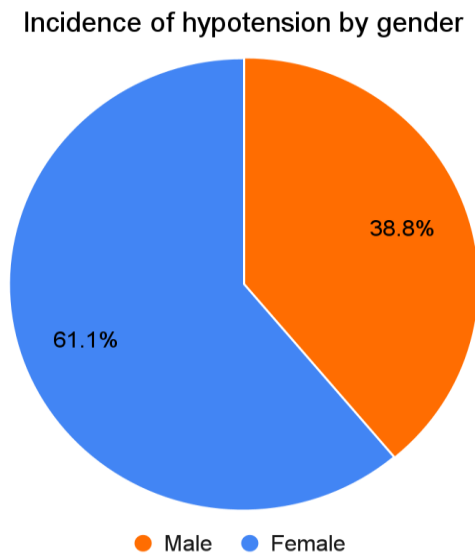


[Insert Fig. 11 here]

Figure 11: Incidence of hypotension

2. Incidence of hypotension by gender:

Forty-four (61.11%) female study participants had an episode of hypotension while 28 (38.88%) male study participants had hypotension during the study interval. The incidence of hypotension by gender is shown in Fig. 12.

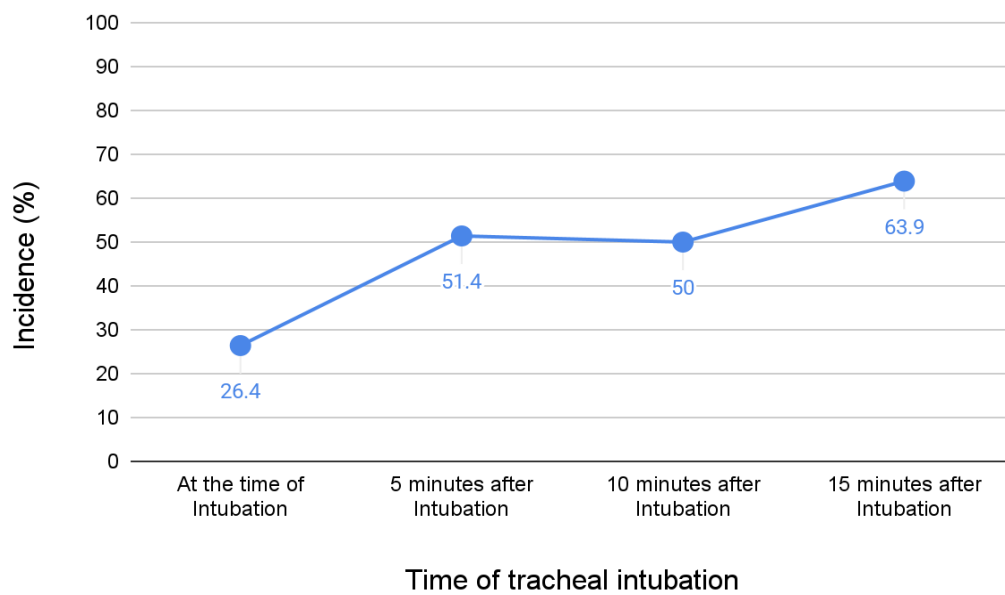


[Insert Fig. 12 here]

Figure 12: Incidence of hypotension by gender

E. Occurrence of post induction hypotension at different time interval after intubation:

Nineteen patients (26.4%) had hypotension at the time of tracheal intubation while 37 (51.4%) patients had hypotension at 5 minutes after tracheal intubation, 36 (50.0%) patients had hypotension at 10 minutes after tracheal intubation and 46 (63.9%) patients had hypotension at 15 minutes after tracheal intubation. The occurrence of hypotension at the specified time intervals is shown in Fig. 13.



[Insert Fig. 13 here]

Figure 13: Occurrence of post induction hypotension

F. Comparison of patients with post-induction hypotension and those without post-induction hypotension

The demographic data including the ASA-PS status, drugs used during induction of general anaesthesia between the patients who developed and those who did not develop hypotension after induction of general anaesthesia is comparable in both the groups. (Table 4).

[Insert Table 4 here]

Table 4: Comparison of demographics and drugs used during induction between hypotensive and non-hypotensive patients

Indicators	No Hypotension (N=60) (Mean)	Hypotension (N=72) (Mean)	P-value
Age (years)	40.6±11.7	41.7±12.9	0.619
Sex(M/F)	22(36.7%)/38(63.3%)	28(38.9%)/44(61.1%)	0.793*
ASA-I	30(50.0%)	33(45.8%)	0.633*
ASA-II	30(50.0%)	39(54.2%)	0.633*
Propofol (mg)	118.1 ± 37.1	115.3 ± 29.6	0.629
Fentanyl (µg)	130.5 ± 30.7	137.2 ± 31.6	0.221

* *Independent Samples Test, Man-Whitney U Test*

G. Comparison of vital parameters between hypotensive and non-hypotensive patients (Table 5).

[Insert Table 5 here]

Table 5: Comparison of vitals between patients who developed and who did not develop hypotension after induction of general anesthesia

Indicators	No Hypotension (N=60) (Mean)	Hypotension (N=72) (Mean)
SBP Baseline	122.6 ± 12.6 mmHg	131.2 ± 12.3 mmHg
SBP at intubation	125.3 ± 16.5 mmHg	119.3 ± 21.6 mmHg
SBP 5 min	123.5 ± 18.1 mmHg	106.2 ± 16.2 mmHg
SBP 10 min	118.1 ± 16.7 mmHg	103.7 ± 13.9 mmHg
SBP 15 min	117.8 ± 15.3 mmHg	104.8 ± 16.5 mmHg
DBP Baseline	81.1 ± 9.6 mmHg	84.3 ± 8.0 mmHg
DBP at intubation	79.3 ± 12.0 mmHg	74.6 ± 14.0 mmHg
DBP 5 min	77.3 ± 12.8 mmHg	65.2 ± 12.6 mmHg
DBP 10 min	74.3 ± 11.4 mmHg	64.9 ± 11.6 mmHg
DBP 15 min	74.7 ± 10.7 mmHg	66.0 ± 13.8 mmHg
MAP Baseline	94.9 ± 7.6 mmHg	99.9 ± 6.7 mmHg
MAP at intubation	94.8 ± 12.9 mmHg	89.5 ± 15.9 mmHg
MAP 5 min	92.7 ± 13.9 mmHg	78.9 ± 13.2 mmHg
MAP 10 min	88.9 ± 12.4 mmHg	77.9 ± 11.9 mmHg
MAP 15 min	89.0 ± 11.6 mmHg	79.0 ± 14.3 mmHg
HR at intubation	81.4 ± 14.2 bpm	81.8 ± 15.1 bpm
HR 5 min	84.2 ± 15.3 bpm	80.7 ± 14.6 bpm
HR 10 min	80.1 ± 13.7 bpm	78.8 ± 15.8 bpm
HR 15 min	78.2 ± 13.4 bpm	79.1 ± 15.2 bpm

A progressive decrease in systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) is observed from the time of tracheal intubation up to 15 minutes post-intubation.

The minimum blood pressure observed during the study was 70/40 mmHg in a 19 years old female for which phenylephrine 100 mcg was given intravenously.

H. Comparison of maximum IVC diameter, aorta diameter and caval aorta diameter index between the study participants who developed and those who did not develop hypotension (Table 6).

[Insert Table 6 here]

Table 6: Comparison of maximum diameter of IVC, diameter of aorta and IVC/Aorta diameter index between hypotensive and non-hypotensive patients

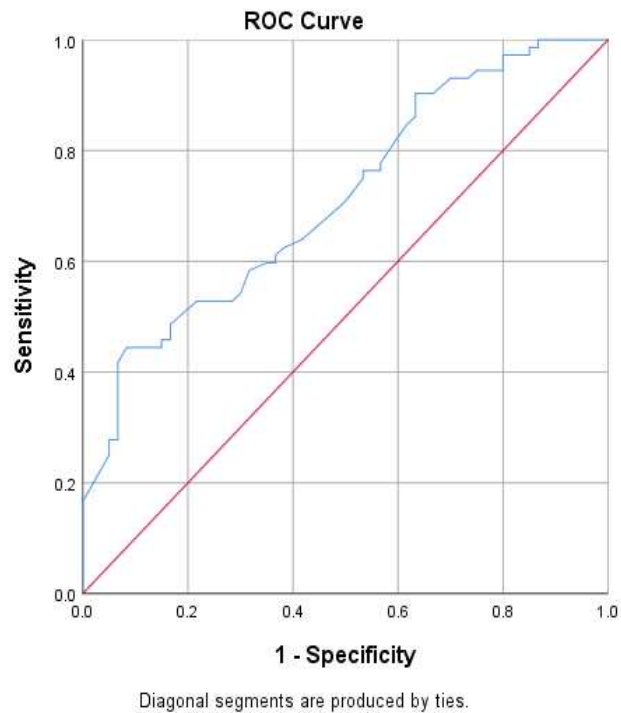
Variable	No Hypotension (N=60)	Hypotension(N=72)	P-value
IVC (Max) (Mean±SD) in cms	1.3 ± 0.3	1.0 ± 0.3	<0.0001
Aorta((Mean±SD) in cms	1.5 ± 0.3	1.6 ± 0.3	0.570
IVC/Aorta Diameter Index Median(IQR)	0.8(0.6-0.9)	0.6(0.5-0.8)	<0.0001*

* *Independent Samples Test, Man-Whitney U Test*

There is a statistically significant difference between the maximum IVC diameter and the IVC/Aorta ratio between the two groups whereas there is no statistically significant difference between the aortic diameter between the two groups.

I. ROC Curve and cut off value of IVC to aorta ratio

The Receiver Operating Characteristic (ROC) curve for the caval aorta diameter index in predicting post-induction hypotension demonstrates an area under the curve (AUC) of 0.713 (SE = 0.044, 95% CI: 0.627–0.799, $p < 0.001$). The ROC curve is shown in Fig. 14. The ROC analysis is summarized in Table 7, and the evaluated cut-off values are presented in Table 8.



[Insert Fig. 14 here]

Figure 14: Receiver Operating Characteristics for IVC Aorta Ratio in the prediction of hypotension

[Insert Table 7 here]

Table 7: Receiver operating characteristic (ROC) analysis of IVC/Aorta ratio for prediction of post-induction hypotension

Area	Std. Error ^a	Asymptotic Sig. ^b	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
0.713	0.044	0.000	0.627	0.799

[Insert Table 8 here]

Table 8: Cut off values of IVC/Aorta ratio for prediction of post-induction hypotension

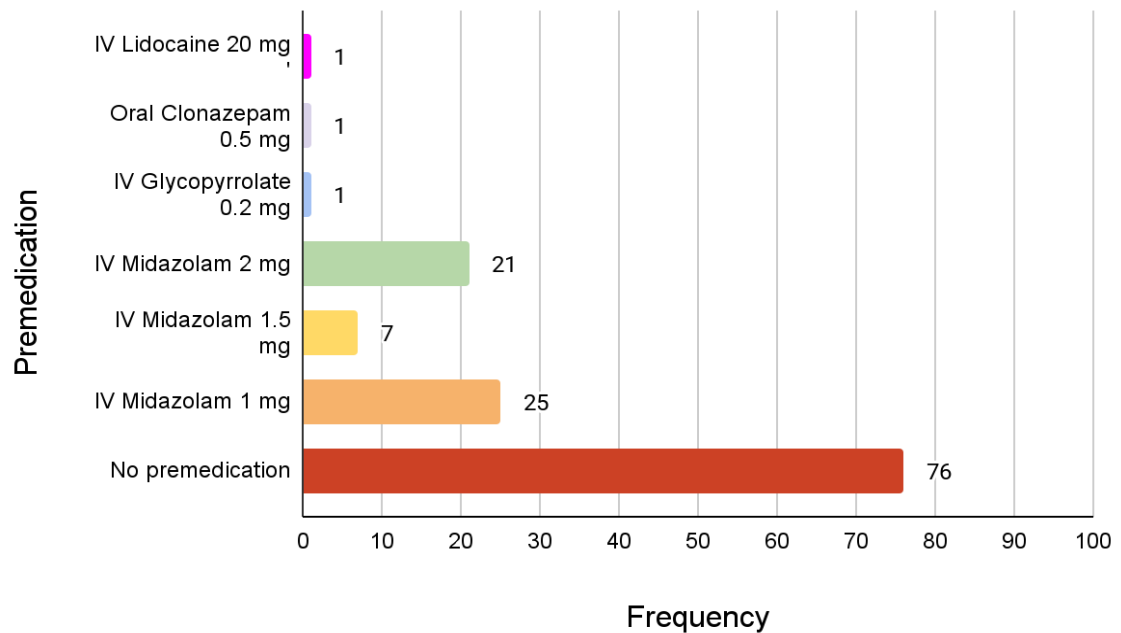
Best Cut off Positive if $\leq$	Sensitivity (%)	1-Specificity	Specificity (%)
0.78500	63.9	41.7	58.3
0.79500	65.3	43.3	56.7
0.80500	68.1	46.7	53.3
0.81500	69.4	48.3	51.7
0.82500	70.8	50.0	50.0
0.84000	75.0	53.3	46.7

For analysis, the continuous variable of IVC/Aorta diameter index was categorized into three groups: ≤ 0.79500 , $0.79500 - \leq 0.81500$ and $0.81500 - \leq 0.84000$. These cut-offs were chosen based on receiver operating characteristic (ROC) curve analysis and previous studies.

The Receiver Operating Characteristic (ROC) curve for the IVC-to-aorta ratio in predicting post-induction hypotension demonstrates an area under the curve (AUC) of 0.713 (SE= 0.044, 95% CI: 0.627–0.799, $p < 0.001$). For the cut off value of ≤ 0.81500 with a sensitivity of 69.4%, and specificity of 51.7% in predicting post induction hypotension.

J. Premedication administered

The majority: 76 (57.4%) of the patients did not receive any premedication. Twenty-five (18.9%) patients received IV Midazolam 1mg. Seven (5.3%) patients received IV Midazolam 1.5 mg while 21 (15.9%) patients received IV Midazolam 2 mg. One (0.8%) patient received IV Glycopyrrolate 0.2 mg. One (0.8%) patient received Tablet Clonazepam 0.5 mg and finally, one (0.8%) patient received IV Lidocaine 20 mg. The distribution of premedication administered is shown in Fig. 15.



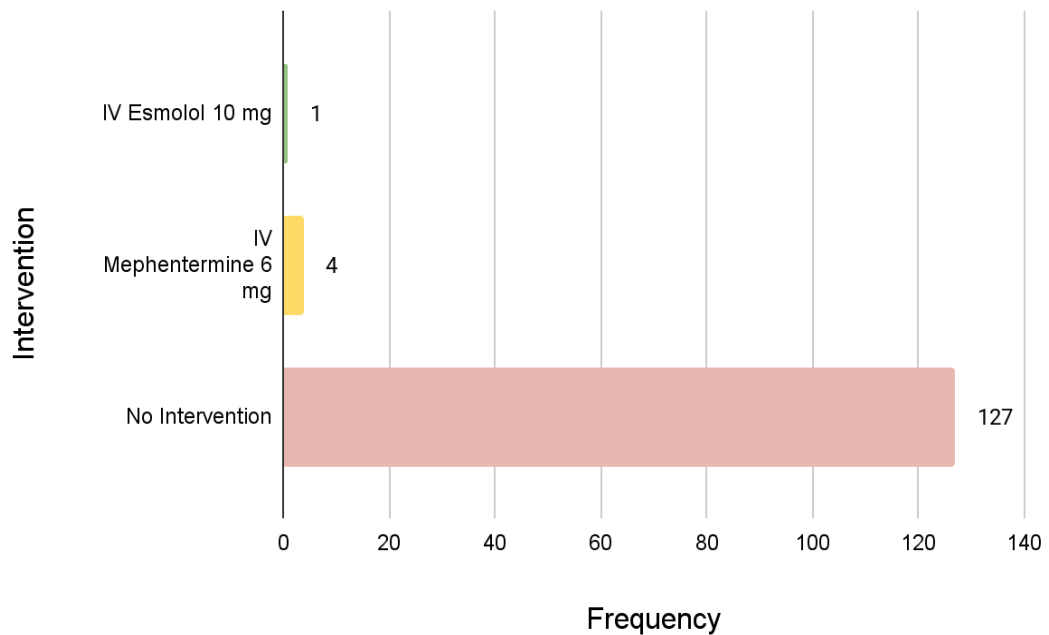
[Insert Fig. 15 here]

Figure 15: Premedication administered among patients

K. Intervention received by the patients

1. Intervention at the time of tracheal intubation

A total of 127(96.2%) patients did not receive any intervention at the time of tracheal intubation while four (3.0%) patients received IV Mephenterime 6 mg and one (0.8%) patient received IV Esmolol 10 mg. The interventions at the time of tracheal intubation are shown in Fig. 16.

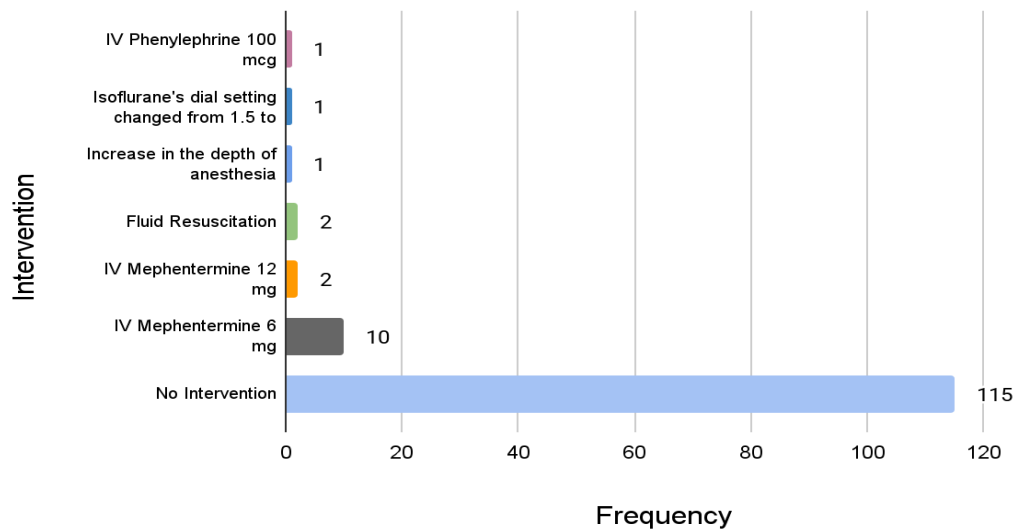


[Insert Fig. 16 here]

Figure 16: Intervention received at the time of intubation

2. Intervention at 5 minutes after tracheal intubation

A total of 115 (87.1%) patients did not receive any intervention at 5 minutes after tracheal intubation while 10 (7.57%) patients received IV Mephentermine 6 mg, two (1.51%) patients received IV Mephentermine 12 mg, two (1.6%) patients received intervention in the form of fluid resuscitation, one (0.8%) patient required an increase in the depth of anesthesia. For one (0.8%) patient, Isoflurane's dial setting was changed from 1.5 to 0.8 and one (0.8%) patient received IV Phenylephrine 100 mcg. The interventions at 5 minutes after tracheal intubation are shown in Fig. 17.

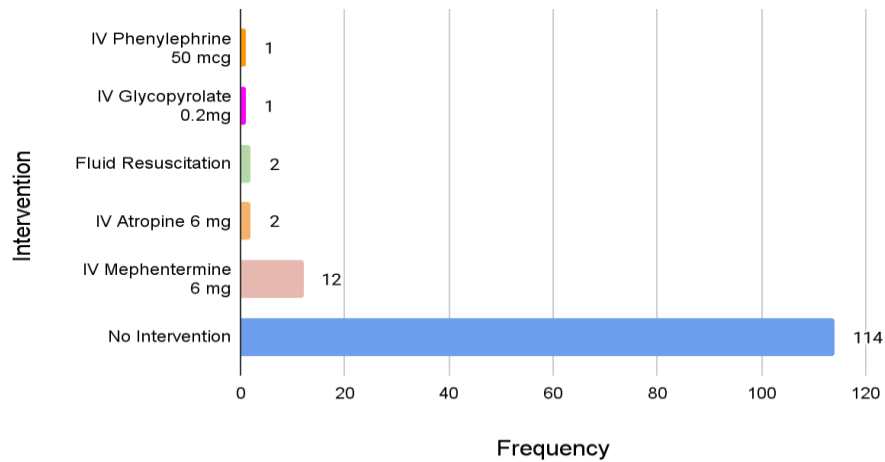


[Insert Fig. 17 here]

Figure 17: Interventions received at 5 minutes after Intubation

3. Intervention at 10 minutes after tracheal intubation

A total of 114 (86.36%) patients did not receive any intervention at 10 minutes after tracheal intubation. Twelve patients (9.09%) received IV Mephentermine 6 mg, two (1.51%) patients received IV Atropine 6 mg, two (1.51%) patients received intervention in the form of fluid resuscitation, one (0.8%) patient received IV Glycopyrrolate 0.2 mg and one (0.8%) patient received IV Phenylephrine 50 mcg. The interventions at 10 minutes after tracheal intubation are shown in Fig. 18.



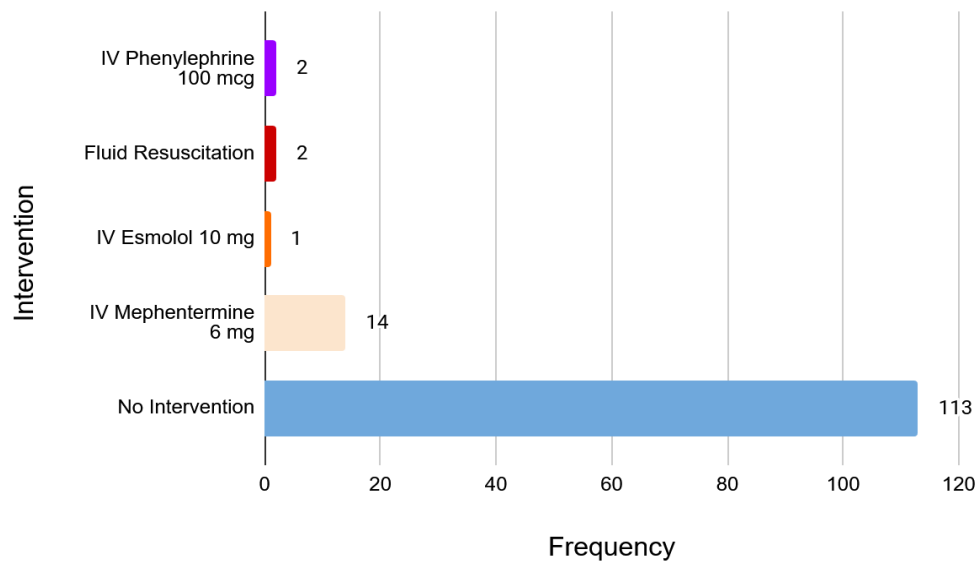
[Insert Fig. 18 here]

Figure 18: Interventions received at 10 minutes after Intubation

4. Intervention at 15 minutes after tracheal intubation

A total of 113 (85.6%) patients did not receive any intervention at 15 minutes after tracheal intubation while 14 (10.60%) patients received IV Mephentermine 6 mg. One (0.8%) patient received IV Esmolol 10 mg, two (1.52%) patients received intervention in the form of fluid resuscitation and two (1.52%) patients received IV Phenylephrine 100 mcg. The interventions at 15 minutes after tracheal intubation are shown in Fig. 19.

All interventions were provided according to the clinical judgment of either the attending anaesthesiologist or the anaesthesiology resident assigned to the operating room and responsible for the patient's intraoperative care.



[Insert Fig. 19 here]

Figure 19: Interventions received at 15 minutes after Intubation

DISCUSSION

Avoidance of an undesired hypotensive event has a key role in patient safety. A patient undergoing surgery under general anaesthesia is susceptible to intra-operative hypotension.²⁰ Among the multiple factors that make a patient susceptible to intraoperative hypotension, pre-operative volume status is a major determinant.²¹ The degree of hypotension is more severe in patients who are about to undergo surgery due to their nil per oral status pre-operatively and due to the effects of anaesthesia at and post induction. This study aimed to assess the ability of IVC to aorta ratio in fasted patients before elective surgery under general anaesthesia to predict post induction hypotension.

A total of 387 patients were assessed for eligibility from which 132 patients were included in the final analysis. The study population consisted of patients between 18 and 65 years of age, with the majority of the population falling into the 31-40 age group, representing 29.5% (n= 39) of the total population. Gender distribution revealed a predominance of female population, with n= 82 (62.1%) females compared to n= 80 (37.9%) males. Sixty-three (47.7%) patients were of ASA-PS I while n= 69 (52.3%) patients were ASA-PS II. The demographics of this study was similar to the study conducted by Moktan SL et al.²² and Omar et al.²³ with similar age group, gender distribution and ASA PS grade.

The present study found 54.54% incidence of post-induction hypotension in healthy ASA I and II patients undergoing general anaesthesia. The ultrasound guided Caval/Aorta diameter index demonstrated good diagnostic accuracy for predicting this hypotensive response. With a cut off value of ≤ 0.81500 , Caval/Aorta diameter index had a sensitivity of 69.4% and specificity of 51.7% for the prediction of post induction hypotension. The values indicate that the Caval/Aorta diameter Index is reasonably sensitive in detecting patients who are likely to develop post-induction hypotension, though its modest specificity highlights the possibility of false positives.

High incidence of post-induction hypotension may be related to the effect of anesthetic agents as found in a system review by Chen B et al²⁴ in which it is seen that the odd's ratio

of developing post induction hypotension due to propofol induction in comparison to thiopental or etomidate induction is 3.94 (2.42-6.43) with a p value of <0.0001. All patients had undergone propofol induction in our study.

Prolonged nil-per-oral status can also be a contributing factor to post-induction hypotension, as demonstrated by Wrobel JR et al.²⁵ In our study, all patients were kept nil per oral for a minimum of 6 hours for solid food and 2 hours for clear liquids which is consistent with the standard fasting guidelines. This approach is similar to the study by Wrobel JR et al.²⁵, in which elective surgery patients fasted according to recommended guidelines and exhibited a 44.4% incidence of post-induction hypotension within the first ten minutes following induction of general anaesthesia..

Among the patients who gave consent for inclusion in the study, 10 patients were excluded from the final analysis. Five patients were excluded due to missing data, one patient was excluded due to rescheduling of surgery due to a pending thyroid function test report. The patient was suspected of hypothyroidism. One patient was excluded due to inadequate NPO status, one patient was excluded for time constraint which resulted in rescheduling of the operation for the next day, one patient was excluded as the patient received intrathecal 0.5% heavy bupivacaine and morphine before the conduct of general anaesthesia. Similarly, one patient was excluded from the study as the patient's IVC and aorta both were not visualized. The patient was diagnosed with multiple hepatic, intraperitoneal and splenic hydatid cyst with cholelithiasis and was planned for open pericystectomy with splenectomy. Hydatid cysts can obscure the retroperitoneal vessels due to posterior shadowing and beam deflection from calcified cyst walls. Consequently, both vessels appear partially or completely obscured thus limiting accurate diameter measurement.

IVC and aorta were visualized by USG in 132 patients in supine position. Among 132 patients, 72 patients (54.54%) exhibited post-induction hypotension whereas 60 patients (45.54%) did not exhibit post-induction hypotension. The Caval/Aorta diameter indices were 0.6 in the hypotensive and 0.8 in the non-hypotensive group. Omar et al.²³ reported that among 102 patients, 80 (78.43%) patients developed post-induction hypotension. Shakya S et al.²⁶ reported that out of 100 patients, 65(65%) patients developed post-

induction hypotension. Fathy (MD) S et al.²⁷ reported that among 96 patients, post-induction hypotension occurred in 54 (56%) patients. Our study aligned with that of Fathy (MD) S et al.²⁷ with similar incidence of post induction hypotension. The study population for both the studies includes ASA-PS I and ASA-PS II patients. This along with the elective nature of the surgery in which the patients are often well optimized medically before the surgery for any medical problems that they may have could have contributed to this finding.

On evaluation of hypotension by gender distribution, 44(61.1%) female patients had an episode of hypotension while 28(38.88%) male patients had an episode of hypotension. The prevalence of post induction hypotension among female patients was noted in study by Omar H et al.²³ in which, 49 (61.2%) female study participants developed hypotension after induction of general anaesthesia. Estrogen- particularly, 17β -estradiol has a negative feedback on the release of catecholamines that increase the blood pressure like epinephrine, norepinephrine thus decreasing the sympathetic tone.²⁸ The 17β -estradiol is the most dominant estrogen during the reproductive years and has the highest receptor affinity and potency. Most of the participants of our study were of the reproductive age group, further amplifying the effect. Their study using several logistic variables detected that female sex was one of the predictors of post-induction hypotension. Our study aligns with this finding.

In our study, the receiver operating characteristic (ROC) analysis of the Caval/Aorta diameter index for predicting post-induction hypotension yielded an area under the curve (AUC) of 0.713 with a standard error of 0.044, an asymptotic significance of $p < 0.001$, and a 95% confidence interval of 0.627 to 0.799 for a cut-off value of ≤ 0.815 . An AUC of 0.713 indicates a fair discriminatory ability of the Caval/Aorta diameter index in predicting post-induction hypotension. The lower limit of the confidence interval being above 0.5 suggests that the predictive capacity is statistically significant and not a result of chance, while the upper limit, approaching 0.8 shows that the ratio can reach a level of good predictive performance in certain cases. Shakya S et al.²⁶ in their study showed that at a cut off value of 1.0, the AUC was 0.907 and resulted in sensitivity of 96.9% and specificity of 80%. However, Omar et al.²³ in their study had an AUC of 0.666 for the cut off value of 0.852 for the same, resulting in a sensitivity of 77.5% and specificity of 63.6%.

Similarly, Fathy S et al.²⁷ had an AUC of 0.95 for the cut off of 0.84 with a sensitivity of 91% and specificity of 98% . On the contrary, Jaya et. al.²² had an AUC of 0.654 with an optimum cut off value of 0.8555 with a sensitivity of 85% and specificity of 43.48%. Our study is in line with the previous studies conducted in this regard.

At the best cut-off value of ≤ 0.815 , the sensitivity was 69.4% and specificity was 51.7%. The values indicate that the Caval/Aorta diameter index is reasonably sensitive in detecting patients who are likely to develop post-induction hypotension, though its modest specificity highlights the possibility of false positives.

In the context of peri-operative fluid and hemodynamics management, this implies that the Caval/Aorta diameter index may serve as a clinically useful, non-invasive ultrasound marker to predict risk of post-induction hypotension. However, while the index demonstrates moderate accuracy, it is not sufficient as a standalone predictor as post induction hypotension might be caused by a multitude of factors with volume status being a single entity in the conundrum of post induction hypotension. It should therefore be considered as part of a multimodal assessment strategy, integrating pre-operative clinical risk factors and intra-operative haemodynamic monitoring to optimize patient safety.

LIMITATIONS

There were certain limitations in our study. First, body mass index (BMI) was not taken into account. The study included only ASA PS I and II adult patients undergoing elective surgeries; therefore, the findings may not be applicable to ASA PS III and above patients or patients undergoing emergency surgeries. These groups may have a higher risk of developing post-induction hypotension. Finally, as this was a single-center study, the generalizability of the results is further limited.

CONCLUSION

Post induction hypotension is common with an incidence of 54.55% in ASA PS I and II patients undergoing surgery under general anaesthesia. Caval/Aorta diameter index of 0.81500 predicts post-induction hypotension with a sensitivity of 69.4% and specificity of 51.7%.

LIST OF ABBREVIATIONS

ACE	Angiotensin Converting Enzyme
ACEP	American College of Emergency Physicians
ANS	Autonomic Nervous System
Ao	Aorta
AP	Antero Posterior
ARB	Angiotensin Receptor Blocker
ASA	American Society of Anaesthesiologists
ASA PS	American Society of Anaesthesiologists physical status
CI	Confidence Interval
CVP	Central Venous Pressure
DBP	Diastolic Blood Pressure
ECG	Electrocardiogram
GA	General Anaesthesia
HRV	Heart Rate Variability
IP No	Inpatient Number
IQR	Interquartile range

IRC	Institutional Review Committee
IVC	Inferior Vena Cava
IVCmax	Maximum Inferior Vena Cava diameter
IVCmin	Minimum Inferior Vena Cava diameter
M-mode	Motion-mode
MAP	Mean Arterial Pressure
Mhz	Mega Hertz
MMC	Maharajgunj Medical Campus
mmHg	millimeters of mercury
MS	Microsoft
NIBP	Non Invasive blood pressure
OT	Operating Theater
PAC	Pre-anaesthetic checkup
PAOP	Pulmonary Artery Occlusion Pressure
PEEP	Positive End Expiratory Pressure
PI	Perfusion Index
iCCO	Pulse Contour Cardiac Output
PLR	Passive Leg Raising
PPV	Pulse Pressure Variation
ROC	Receiver Operating Curve
SBP	Systolic Blood Pressure
SD	Standard Deviation
Spo2	Peripheral oxygen saturation
SPSS	Statistical Package for Social Sciences
SVV	Stroke Volume Variation

TUTH	Tribhuvan University Teaching Hospital
USG	Ultrasonography
%	Percentage
<	Less than
>	Greater than
$\leq$	Less than or equal to
$\geq$	Greater than or equal to

DECLARATIONS

Ethical approval and consent to participate:

Ethical approval for this study was obtained from the Institutional Review Committee (IRC) of the Institute of Medicine, Tribhuvan University, Kathmandu, Nepal, on 06 September 2024 (registration number 172 081/082).

Approval to conduct the study was also obtained from the Department of Anaesthesiology, Tribhuvan University Teaching Hospital.

Written informed consent was obtained from all participants before enrolment.

All procedures involving human participants were conducted in accordance with the principles of the Declaration of Helsinki and applicable ethical guidelines and regulations.

Consent for publication:

Consent for publication is not applicable.

Availability of data and materials:

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests:

The authors declare that they have no competing interests.

Funding:

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Authors' contributions:

AD conceived and designed the study, developed the study protocol, conducted the study, collected and managed the data, performed the statistical analysis, interpreted the results, and drafted and revised the manuscript.

RG supervised the study, provided methodological guidance, reviewed the progress of the research, contributed to interpretation of the findings, and critically revised the manuscript.

ASB served as co-guide for the study and provided academic oversight during the research process.

HP supervised the conduct of the study, provided guidance regarding study methodology and its implementation, identified areas requiring improvement during the study, and contributed substantially to the preparation and critical revision of the thesis and manuscript.

AT contributed to data collection and assisted with the conduct of the study.

All authors reviewed and approved the final manuscript and agreed to be accountable for all aspects of the work.

Acknowledgements:

Not applicable

Gels and Blots are not applicable.

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