Ultrasonographic Evaluation of Inferior Vena Cava: Aorta Index with a Cut-off Value of 1.0 as a Predictor for Hypotension after Induction of General Anesthesia; An observational study

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ABSTRACT

Background

Hypotension after induction of general anesthesia (GA) is common due to pre-existing hypovolemia and has adverse effects on organ function. Out of several methods to predict post-induction hypotension, nowadays Inferior Vena Cava: Aorta (IVC: Ao) index has been studied with different cut-off values. However, limited studies have been performed in our part of the world.

Objective

To evaluate the efficacy of pre-induction Inferior Vena Cava: Aorta index with a cut-off value of 1.0 for predicting the occurrence of post-induction hypotension after general anesthesia in the Nepalese population.

Method

A total of 100 patients of ASA I and II, aged more than 18 years posted for elective surgeries under general anesthesia were enrolled in this cross-sectional, observational study. Ultrasonographic guided Inferior Vena Cava: Aorta index was calculated and based on a cut-off value of 1.0, two groups were formed. Seventy patients in group A with Inferior Vena Cava: Aorta index less than 1.0 and 30 patients in group B with Inferior Vena Cava: Aorta index more than 1.0 were enrolled. Vitals parameters were recorded every minute for five minutes after induction of general anesthesia. Incidence of hypotension was the primary outcome. Statistical analysis was done using student t-test, ANOVA test and Chi-square test.

Result

Inferior Vena Cava: Aorta index with cut-off value of 1.0 predicted post-induction hypotension with excellent efficacy. Total 65 patients developed post-induction hypotension, out of which 63 patients had Inferior Vena Cava: Aorta index less than 1.0.

Conclusion

We concluded that pre-induction Inferior Vena Cava: Aorta index with cut-off value of 1.0 have high diagnostic accuracy with high degree of sensitivity and specificity to predict hypotension after induction of general anesthesia.

KEY WORDS

General Anesthesia, Hypotension, Hypovolemia, Inferior vena cava: Aorta index

INTRODUCTION

Hypotension is common under general anesthesia (GA) and may cause organ under perfusion and ischemia.[1,2] Patients are at particular risk of developing hypotension after induction of GA because of cardiovascular depressant and vasodilatory effects of anesthetic agents, lack of surgical stimulation and pre-existing hypovolemia.[3,4] Clinicians can get a chance to implement proper fluid replacement before inducing GA when patients with latent hypovolemia are identified. Stable hemodynamics is very important as intra-operative hypotension may result myocardial injury, stroke, heart failure, acute kidney injury, septic complications, prolonged hospital stay, risk of 30-days mortality as well as risk of one-year mortality rates.[5-12]

To date, there are several methods either identification of risk factors or invasive and non-invasive techniques to identify fluid status and predict post induction hypotension with their own limitations that decrease their use in daily practice. Among them, Inferior Vena Cava: Aorta (IVC: Ao) index is one of the easily available non-invasive techniques. IVC: Ao index is the ratio of maximum inferior vena cava (IVC) diameter during expiration and maximum abdominal aorta diameter during systole. Limited studies have investigated IVC: Ao index with different cut-off values for prediction of post-induction hypotension after general anesthesia. There are some studies done in the Nepalese populations to evaluate the fluid status of the patients by ultrasonographic measurement of IVC and aorta but none of the studies have ever evaluate the efficacy of IVC: Ao index to predict post-induction hypotension after general anesthesia.[13,14] So, our aim in this study was to test the specific cut-off value of pre-induction IVC: Ao index for predicting the occurrence of post-induction hypotension after general anesthesia in Nepalese population with high efficacy.

METHODS

The current cross-sectional observational study was conducted in the main operation theater of Kathmandu University Hospital during the period of 15th Sept, 2021 to 15th Feb, 2022 after obtaining written informed consent from all included patients. Ethical approval for this study was provided by Kathmandu University School of Medical Science Institutional Review Committee on 5th September, 2021. Eligible Nepalese participants aged more than 18 years, ASA-PS I and II posted for first elective surgeries of the day under general anesthesia were included in this study. Exclusion criteria were body mass index more than 30 kg m^{-2}, pregnant women, emergency cases, ASA PS 3 or more, patients taking angiotensin converting enzyme inhibitors or angiotensin receptors blockers, documented heart failure, elevated pulmonary arterial pressure > 40 mmHg, significant valvular heart disease, significant carotid stenosis, peripheral vascular diseases, unstable angina or cardiac ejection fraction less than 40%, implanted pacemaker or cardioversion, patients with baseline systolic blood pressure (SBP) < 90 mmHg or > 180 mmHg or mean blood pressure (MBP) < 65 mmHg, respiratory distress, increased intraabdominal pressure, autonomic nervous system disorders, anticipated difficult airways or mental incompetence, documented negative fluid balance > 1000 ml on preceding day, pheochromocytoma, Sequential organ failure assessment score > 1, Richmond agitation sedation scale > 1, IVC non-visualized and epidural catheter in use.

Procedures

Detail preoperative evaluation was done a day before surgery. Patients were premedicated with tablet ranitidine 150 mg for acid prophylaxis and tablet pregabalin 75 mg for anxiolytic at the night before surgery. All patients were kept nil per oral (NPO) for 6 hours for solid foods and 2 hours for clear liquids before surgery. All first cases of all elective days were shifted to pre-anesthetic care unit where we performed ultrasonography. While patients were conscious, lying supine and spontaneously breathing for at least 5 minutes, IVC and aorta were examined using M7 premium Mindray ultrasound machine by expert anesthesiologist. IVC was visualized using a paramedian long-axis view via a subcostal approach according to methodology described by American Society of echocardiography.[15] Measurement was performed by a curvilinear (3.5 to 5 MHz) ultrasound transducer with a B-mode scan. Transducer was placed in subxiphoid region in longitudinal position. A two-dimensional image of IVC as it entered right atrium was first obtained. Pulse wave doppler, pulsatile nature, compressibility and phasic collapse with respiration was used to differentiate IVC from aorta. Variation in IVC diameter with respiration was assessed using M-mode imaging just down to IVC-hepatic vein junction, approximately (3-4) cm down to right atrium.[16] To ensure consistent IVC measurement, 3 scan was performed in each patient and if there were difference of more than 0.2 cm in measurements between any two of images then that patient’s data was excluded from study. The average of these three measurements was taken for analysis. The maximum (dIVCmax) and minimum (dIVCmin) internal anteroposterior (AP) diameter of IVC at the end of expiration and inspiration respectively over same respiratory cycle was measured. To the left of IVC, abdominal aorta was visualized 10 mm above coeliac trunk. The maximum internal diameter of abdominal aorta was measured during systole. The IVC: Ao index was derived by taking ratio of maximum IVC diameter during expiration and maximal abdominal aortic diameter during systole.[17] First 100 patients were enrolled in this study then the IVC: Ao index was calculated and two groups was formed according to this index. Group A was characterized by IVC: Ao index lower than 1.0 whereas Group B was characterized by IVC: Ao index more than 1.0. This level was arbitrarily set with regard to results in previously published literatures and pilot study done in the same institute.[18-20]

Anesthetic management

After transferring patients to operating theater, an 18-gauge intravenous cannula was inserted in peripheral vein and ringer's lactate (RL) was infused at the rate of 100 ml/hr. Standard non-invasive monitoring including electrocardiograph (ECG), non-invasive blood pressure (BP) measurement and pulse oximetry were applied. Heart rate (HR), SBP, MBP, diastolic blood pressure (DBP) and oxygen saturation (SpO_2) were recorded just before induction of GA and defined as baseline readings. In case of invasive monitoring such as arterial cannula, it was inserted at least 10 minutes prior to induction. Induction of GA was done by different anesthesiologist who was unaware of USG parameter of patients and with inj. Fentanyl 2 mcg/kg, propofol 1.5 mg/kg and non-depolarizing muscle relaxants (vecuronium 0.1 mg/kg). Adequate depth of anesthesia was monitored as no movements of body parts during positive pressure ventilation. Anesthesia was maintained with isoflurane 1MAC (Minimal alveolar concentration) in oxygen enriched air. Bag and mask ventilation was done with two-person two handed technique. Adequate ventilation was assured with the help of expired tidal volume and minute ventilation generated by ventilator. Any difficult mask ventilation in terms of Jaw thrust maneuver or use of naso-pharyngeal/oro-pharyngeal airway was excluded from data analysis because of excessive sympathetic stimulation. Vital parameters were recorded every minute for five minutes immediately after induction of GA as defined by complete injection of muscle relaxants and loss of consciousness until the start of laryngoscopy procedure. Post-induction hypotension was defined as SBP less than 90 mmHg or more than 30% decrease from its baseline or MBP less than 65 mmHg. Episode of hypotension either severe (MBP less than 55 mmHg) or prolonged (MBP less than 65 mmHg with duration greater than or equal to two minutes) were treated with intermittent bolus dose of intravenous mephentermine 3 mg and 100 ml of RL. Significant bradycardia (HR less than 40 beats/min) was treated with injection atropine 0.6 mg. Airway of all the patients were later secured with the help of endotracheal tubes.

The primary outcome was to evaluate the predictive value of pre-induction IVC: Ao index with cut-off value of 1.0 for detecting post-induction hypotension after general anesthesia.

Statistical analysis

Sample size calculation was done based on previously published article and pilot study of 15 patients.[18] With two independent study group and dichotomous primary end point, sample size calculation was done on the basis of anticipated incidence of hypotension as 70% in group A and 35% in group B with enrolment ratio of 2.5, type I error of 5% and power of 90%. The resulted sample size was 98 (70 in group A and 28 in Group B). We included total of 100 patients, 70 in Group A and 30 in Group B. Data was pooled for analysis in Microsoft excel 2021 and for statistical analysis, we used SPSS version 24 for windows (IBM corp. Armonk, NY, USA). Continuous data variable was presented as mean ± SD. Categorial variables was shown as percentages, ratios and numbers. Student's two sample test and ANOVA test was used for comparison. Chi-square test was used to analyze categorial data. Two-sided p-value less than 0.05 was considered significant. Receiver operating characteristic (ROC) curves was used to assess the diagnostic value of IVC: Ao index to predict hypotension.

RESULTS

A total of 112 patients were recruited; however, 12 patients were excluded due to inadequately visualized IVC (7 cases), change in anesthesiologist management due to difficult mask ventilation (5 cases). So, 100 eligible patients were enrolled in this study. After calculation of the IVC: Ao index, seventy (70) patients were evaluated in Group A [IVC: Ao index less than 1.0] and thirty (30) patients were evaluated in Group B [IVC: Ao index more than 1.0].

Total 65 patients developed post-induction hypotension. Out of which 63 patients were in Group A and only two patients were in Group B which was statistically significant (p value < 0.01). Meanwhile, only 24 patients in Group A and none in Group B required treatment for hypotension with Ringer Lactate 100 ml and injection mephentermine 3 mg IV (table 1). Two patients who developed hypotension in group B had systolic blood pressure less than 90 mmHg. Similarly, out of 63 patients in group A; 20 patients had systolic blood pressure less than 90 mmHg, 19 patients had more than 30% decrease in systolic blood pressure, 3 patients had mean blood pressure less than 65 mmHg and 21 patients had both systolic blood pressure less than 90 mmHg along with mean blood pressure less than 65 mmHg.

Table 1. Incidence of Hypotension

Hemodynamics	Group A	Group B	P value
1. Hypotension			0.000**
Yes	63	2	
No	7	28	
2. Treatment of hypotension	24	0	0.000**

Values are numbers: p-value < 0.05 -significant; p-value < 0.01 -highly significant; Pearson Chi-square test

Performance characteristics of IVC: Ao index

The ROC curve analysis showed that the pre-induction IVC: Ao index to predict hypotension after induction of general anesthesia had excellent diagnostic accuracy. The area under the curve was 0.907 (95% CI 0.843 to 0.972). The cutoff value of IVC: Ao index to differentiate the two groups was 1.0. At this cutoff point, the resulted sensitivity was high as 96.9% and specificity of 80%. The positive predictive value was 90% and the negative predictive value was 93.3%.

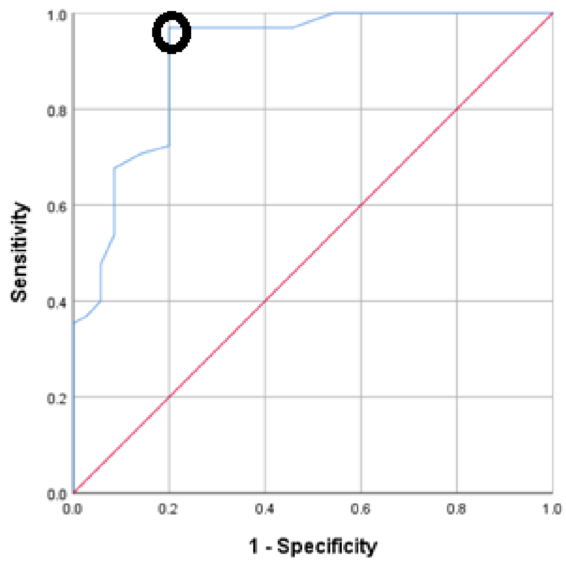

Figure 1. Receiver operating charactristic curve showing the ability of preinduction IVC:Ao index to predict postinduction hypotension of general anesthesia. Area under the curve is 0.907.

Hemodynamic data

The mean maximum decrease in SBP (mmHg) from the baseline after induction of general anesthesia was 40.13±19.53 in Group A which was significantly higher than the 32.20±11.27 in Group B (p value < 0.05). Similarly, the mean maximum decrease in MBP (mmHg) from the baseline was 34.34±11.54 in Group A and 29.53±8.98 in Group B which was statistically significant (p value < 0.05). Whereas, the mean maximum decrease in DBP from the baseline was higher in Group A in compare to Group B but was not statistically significant (table 2).

Table 2. Hemodynamic parameters after induction after general anesthesia

Hemodynamic parameters	Group A	Group B	P-value
1. SBP difference			
(Maximum decrease of SBP from Baseline)	40.13±19.53	32.20±11.27	0.040*
2. MBP difference			
(Maximum decrease of MBP from Baseline)	34.34±11.54	29.53±8.98	0.045*
3. DBPdifference			
(Maximum decrease of DBP from Baseline)	29.47±11.43	25.40±8.73	0.085

Values are Mean±SD, p value < 0.05-significant; p value < 0.01- highly significant, ANOVA test

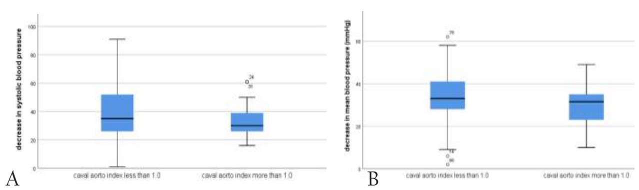

Figure 2. Decrease blood pressure from baseline after induction of general anesthesia measured in this study groups. A. decrease in systolic blood pressure in mmHg (mean, standard deviation and range). B. decrease in mean blood pressure in mmHg (mean, standard deviation and range).

Table 3. Baseline patients characteristics

Variable	Group A	Group B	P value
1. Age, years	41.74±14.74	37.80±13.73	0.214
2. Gender, M: F	31:39	14:16	0.826
3. ASA grade, I: II	56:14	23:7	0.270
4. Weight, kgs	63.73±10.94	65.50±9.69	0.445
5. Co-morbidities			
Diabetes Mellitus	10	6	0.476
Hypertension	12	6	0.585
COPD	1	2	0.159
Asthma	1	0	0.511
6. Pre-operative NPO for clear liquids (minutes)	160.71±33.11	153.00±30.86	0.279
7. Antihypertensive medications			
Amlodipine	10	5	0.911
Amlodipine±Atenolol	2	1	
8. Baseline Hemodynamics			
SBP (mmHg)	134.91±17.01	138.10±11.89	0.354
MBP (mmHg)	105.61±11.53	104.27±10.87	0.587
DBP (mmHg)	86.46±10.85	84.57±8.97	0.404
HR (bpm)	82.40±15.18	83.73±15.40	0.690
SpO_2 (%)	97.99±1.79	98.47±1.54	0.203
9. IVC maximum diameter, cm	1.04±0.19	1.30±0.29	0.000**
10. IVC minimum diameter, cm	0.72±0.19	0.97±0.30	0.000**
11. Aorta maximum diameter, cm	1.21±0.15	1.20±0.22	0.823
12. IVC:Ao index	0.85±0.08	1.08±0.12	0.000**
13. Surgical types			0.712
General surgery	39	15	
Urology surgery	9	2	
Orthopedic and traumatology	10	6	
ENT	10	5	
OMFS	2	2	

Values are number, ratio, mean±SD, ASA- American society of Anesthesiology, COPD- Chronic obstructive pulmonary diseases, NPO- Nil Per Oral, SBP- systolic blood pressure, MBP- Mean blood pressure, DBP- Diastolic blood pressure, IVC- Inferior venacava, ENT – Ear Nose and Throat, OMFS- oral maxillofacial surgery Significant difference between two groups (p-value <0.05). Student's two sample test, ANOVA test, Pearson Chi-square test

Baseline characteristics

Baseline characteristic in terms of surgical procedures, anthropometry, associated co-morbidities, physiologic status, antihypertensive medication, baseline hemodynamic parameters (SBP, MBP, DBP, HR, SpO_2) are summarized in table 3. All the variables were similar in the two groups without any significant intergroup difference. (p value > 0.05) Ultrasonographic measurement of IVC and aorta are summarized in table 4. Maximum measurement of aorta at systole between the two groups are similar. (p value > 0.05) whereas there is highly significant difference between two groups in terms of IVC: Ao index, maximum and minimum IVC measurements.

DISCUSSION

Our study showed that the patients who developed post-induction hypotension after GA had IVC: Ao index less than 1.0. Mean maximum decrease in SBP and MBP from baseline were comparatively higher in the patients with IVC: Ao index less than 1.0. Hypotension may occur due to anesthetic effects as well as pre-existing hypovolemia in patients. Hypovolemia is probably most common risk factor provoking post induction hypotension, even with improvement in pre-operative optimization and avoidance of unnecessary fasting and mechanical bowel preparation. In our study, we find similar NPO status for clear liquid between two groups (table 3). However, optimized fluid therapy remains cornerstone of treatment with excellent effectiveness.[21] Prevention of an undesired hypotensive events is important whereas empirical volume loading carries potential of volume overload particularly in patients with cardiac disease.[22] Therefore, search for predictors of hypotension is becoming mandatory to avoid blind volume loading and reserve it only for patients who are expected to develop hypotension.

Available prediction models used for estimation of risk of hypotension are mostly based on non-modifiable factors (Age, comorbidities). There is a need to identified easily available tool that can help clinicians to recognize patients with impaired preload. Central venous pressure monitoring are traditional static parameters and have been criticized for invasiveness and lack of accuracy.[23] Several methods have been tried including heart rate variability (HRV), passive leg raise test and perfusion index.[24-26] Although, some studies found positive predictive value of HRV but other concluded that it was not reliable predictor as it can be influenced by numerous factors such as diabetes mellitus, ischemic heart diseases, antihypertensive medications, anxiety and spontaneous respiration.[27] Several invasive devices (pulmonary arterial catheterization, PiCCO, Vigilo) are available for evaluating preload but their universal use is not reasonable option due to financial constraints, relatively high complication rates, known limitation and unnecessary invasiveness compared to most surgical procedures.[28] A number of dynamic parameters that assess volume status have been recommended recently.[29,30] Ultrasonographic determination of maximum dIVCmax. at end of expiration during spontaneous respiration; IVCCI and IVC:Ao index was introduced into clinical practice for assessment of intravascular volume in many studies and reported to be reliable, non-invasiveness and easy technique for evaluating volume status and can be obtained by practitioners with little experience in echocardiography.[15,16] Zhang et al. suggested that pre-operative ultrasonographic measurement of IVCCI had a good predictive value for hypotension after induction of general anesthesia.[29] However, Ceruti et al. did not find any correlation between the reductions of MBP after spinal anesthesia and IVCCI measured before spinal anesthesia.[31] Szabó et al. also found that, in spontaneously breathing noncardiac surgical patients, preoperative IVCCI measurement is feasible and can predict postinduction hypotension with high specificity but low sensitivity. Despite its moderate performance, IVCCI is an easy, noninvasive and attractive option to identify patients at risk of postinduction hypotension and should be explored further.[32] Salama et al. found that pre-operative IVCCI and IVC: Ao index are good predictor of occurrence of post spinal anesthesia hypotension, however; IVC: Ao index is a more effective, quick and convenient method for evaluation of intravascular volume than relying on changes of IVC collapsibility with respiratory cycle.[33] Kosiak et al. suggested that IVC: Ao index is more specific in this assessment of body fluid status.[18] Jauregui et al. found that IVC: Ao index is more helpful than IVCCI in predicting dehydration in children.[34]

However, limited studies have investigated IVC: Ao index for predictors of post-induction hypotension after GA in Nepalese population. So, our aim in this study was to evaluate the efficacy of IVC: Ao index for predicting the occurrence of post-induction hypotension after GA and we found to have excellent diagnostic accuracy, high sensitivity and specificity with good positive as well as negative predictive value. So, patients who had pre-induction caval-aorto index less than 1.0 developed post-induction hypotension. And we also found that caval-aorto index significantly correlated with SBP and MBP. Lesser the caval-aorto index more the decrease in SBP and MBP from baseline. Jaya et al. also described that there were significant changes in the IVC-CI and CA-I pre and post-spinal anesthesia.[35] The delta inferior vena cava index, both IVC-CI and CA-I, correlated with mean arterial pressure.[35] The cut-off value for caval-aorto index is still matter of discussion. Kosiak et al. showed that in healthy young people caval-aorto index reference value of 1.2 ± 2.[18] Similarly, Menon et al. also stated that normal IVC/Ao diameter index for nonpregnant healthy women of reproductive age was 1.11 ± 0.29 in subxiphoid view.[19] Sridhar et al. showed that mean IVC/Aorta index in patients who had normal CVP range was 1.2 ± 0.12 SD, while in patients with low CVP, the mean index was 0.7 ± 0.09 SD, and, patients with high CVP, the mean index was 1.6 ± 0.05 SD.[20] We did a pilot study of 15 patients with enrollment ratio of 2:1 and found to have the average IVC: Aorto index to be 1.0. On the basis of this pilot study and previously published literatures, we set the cut-off value of IVC: Aorto index as 1.0. ROC curve analysis in our study explained the cutoff value of 1.0 to be optimal for prediction of hypotension as nearby cutoff value resulted into imbalance between sensitivity and specificity. At cutoff value of 0.9, sensitivity was 67.7% and specificity of 91.4%. Similarly, at cut off value of 1.1 sensitivity was 100% but specificity was only 22.9%. Salama et al. showed that IVC:Ao index had sensitivity of 96%, specificity of 88%, and accuracy of 95% to predict PSAH at a cut-off point less than 1.2.[33] However, Jauregui et al. showed that IVC/Ao ratio at cut-off value of 0.8 is a modest predictor of significant dehydration in children.[34] Hisamuddin et al. had also described IVC:Aorta index of 1.14±2 SD as a cut off value for class 1 hypovolemic shock.[36] In our study, though the baseline BP parameters are in normal range for the Nepalese population but it lies in the high limit of the range. This might be due to anxiety of surgery and fear of operation theater environment. Our study had some limitations. It was single-center study and to evaluate the perfect cut-off point of such predictors, multi-center study is recommended. Measurements of IVC may be compromised by movements of diaphragm. We had to exclude patients due to not having better visualization of IVC.

CONCLUSION

Pre-induction ultrasonographic measurement of Inferior Vena Cava: Aorta index with cut-off value of 1.0 have excellent diagnostic accuracy with high sensitivity and specificity for predicting the occurrence of post-induction hypotension after general anesthesia. We recommend to use IVC: Ao index to determine the patients with hypovolemia and prevent post induction hypotension after general anesthesia.

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