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Inferior vena cava collapsibility index pre-induction is superior to caval aortic index pre-induction in predicting hypotension after induction of general anaesthesia

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Abstract

***Objective*: The study aims to compare the pre-induction inferior vena cava collapsibility index (IVC-CI) and caval aortic index (CAo-I) as hypotension after induction of general anaesthesia (GAIH) predictors.**

***Design*: This is an analytic observational study.**

***Setting*: This study was conducted in Dr. Saiful Anwar General Hospital.**

***Patients and participant*: This study was conducted on thirty-six patients undergoing general anaesthesia.**

***Intervention*: IVC-CI and CAo-I were measured before induction using ultrasound guide. Baseline blood pressure, mean arterial pressure (MAP), heart rate, maximum IVC diameter (dIVCmax), aortic diameter (dAo) were recorded before induction, then were repeated five minutes after induction. Patients received general anaesthesia induction using propofol 2 mg/kg. Analgesic using fentanyl 2 µg/kg and muscle relaxant using atracurium 0.5 mg/kg. Patients received preoxygenation of 100% oxygen for 3-5 minutes.**

***Result*: MAP, heart rate, dIVCmax, dAo before and after induction were significantly different (p=0.000). Thirty patients (36.1%) experienced GAIH. There was no significant difference in age, gender, body mass index, physical status, and MAP pre-induction (p>0.05) between the hypotension and no-hypotension group, except for MAP induction (p=0.001). Pre-induction IVC-CI significantly correlated with hypotension (p=0.024; r=0.375), but not in CAo-I (p>0.05; r=-0.100). The receiver operating characteristic test showed that IVC-CI had higher sensitivity (69.57%), specificity (69.23%), and accuracy (69.44%) than CAo-I, with cut-off value greater than 62.70% (confident interval 95%).**

***Conclusion*: Pre-induction IVC-CI is superior to CAo-I in predict hypotension after induction of general anaesthesia.**

Key words: Inferior vena cava, inferior vena cava collapsibility index, caval aortic index, hypotension, mean arterial pressure.

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Introduction

General anaesthesia significantly correlated with cardiovascular stabilization by affecting cardiac function, circulation system, and several cardiovascular reflexes. (1) The anesthetic agent and patient's cardiovascular condition play an important role in cardiovascular fluctuation. (2) Anaesthesia induction also becomes a critical time in maintaining a patient's cardiovascular stability. (3)

Hypotension after induction of general anaesthesia (GAIH) is one of hemodynamic instability suffered by patients who undergo general anaesthesia. Hypo tension will follow tissue hypoperfusion and increase postoperative mortality and morbidity. (4)

Intraoperative hypotension may promote the incidence of acute kidney injury and myocardial ischemia. (5) Several factors increase the occurrence of GAIH, including critically ill patient, mean arterial pressure (MAP) below 70 mmHg, age more than 50 years old, and the use of anesthetic agents such as propofol and high dose fentanyl. (2)

Some studies found the GAIH predictor, including resting pupil size assessment, intravascular volume status assessment, prediction using propofol dose, or using invasive techniques. (6-8) However, volume status measurement before and after anaesthesia induction is challenging for an anesthesiologist. The invasive technique, the most common technique, by installing a central venous catheter to measure the central venous pressure, has a high risk and time-consuming. The latest approach by measure the dynamic parameter using ultrasound to measure the inferior vena cava (IVC) index could predict the incidence of hypotension after induction of spinal anaesthesia. (9)

There are three kinds of IVC index, including IVC-collapsibility index, IVC-distensibility index, and caval aortic index (CAo-I). (10) The previous study concluded that IVC index measurement could indicate intravascular volume status, predict the patient's fluid responsiveness, and vasodilatation effect of intravenous or inhalation anesthetic agents. (6) Several studies show that the distensibility index and collapsibility index are most accurate in determining the volume status. The study by Salama and Elkashlan (11) stated that the collapsibility index became a predictor of hypotension in spinal anaesthesia.

The empirical data of collapsibility index pre-induction as hypotension predictor in general anaesthesia is limited, especially in Indonesia. Also, there was no study compared inferior vena cava collapsibility index (IVC-CI) and CAo-I pre-induction as GAIH predictors. Thus, this study aimed to analyze the IVC-CI and CAo-I pre-induction potential to become the hypotension predictor in general anaesthesia.

Methods

Study date

This study was an observational analytic study on thirty-six patients undergoing general anaesthesia. The study was conducted in the operating room of Dr. Saiful Anwar General Hospital from March to April 2020.

Ethics

Ethical approval for this study (No. 400/095/K.3/302/2020) was provided by the Health Research Ethical Committee of Dr. Saiful Anwar General Hospital, Malang, Indonesia (Chairperson Hidayat Sujuti, MD, PhD).

The inclusion criteria including age 15-64 years old, physical status American Society of Anesthesiologist (ASA) 1-2, receive general anaesthesia, have the same fasting duration, and agree to join the study. The exclusion criteria including patients not cooperative, patients with cardiac disease, who receive vasodilator or vasoconstrictor therapy, and experience increased intrabdominal and intrathoracic pressure. Patients who experienced emergency conditions during induction (anaphylactic, airway obstruction, and cardiac arrest) were dropped out from the study.

Study subjects have fasted for 6-8 hours before surgery. Study subjects received crystalloid solution to maintain fluid. Blood pressure, MAP, heart rate, oxygen saturation, and IVC index before induction was examined. The IVC diameter measurement (internal anteroposterior IVC) and internal anteroposterior abdominal aortic diameter performed under an ultrasound guide. Patient positioned in supine. Ultrasound was set in adult echocardiography. IVC was examined using subcostal inferior vena cava long axis (SC-IVC-LAX) using M-mode 1 to 2 cm under hepatic vein. The probe was then placed under xiphoid, in the middle of xiphoid, and umbilicus. The maximum and minimum IVC diameter of internal anteroposterior (AP) abdominal aortic diameter was measured using M-mode (**Figures 1 and 2**).

Internal anteroposterior abdominal aortic diameter was measured using M-mode with the longitudinal axis, right in the left side of IVC or about 10 mm towards the cephalad of the celiac trunk. IVC and caval aoric index calculated according to the following formulas:

- IVC-CI = 100% x (maximum IVC diameter on expiration [$dIVCmax_{exp}$] - minimum IVC diameter on inspiration [$dIVCmin_{insp}$]) / $dIVCmax_{exp}$
- CAo-I = 100% x $dIVCmax_{exp}$ / maximum abdominal aortic diameter (dAbdominal aorta max). (12)

After completed the measurement, patients undergoing general anaesthesia induction with standard procedure using propofol 2 mg/kg, analgesic using fentanyl 2 µg/kg, and muscle relaxant using atracurium 0.5 mg/kg. Patients received preoxygenation of 100% oxygen for 3-5 minutes. After induction, blood pressure and MAP were recorded. The patient was then grouped into hypotension and non-hypotension. Patients experienced hypotension when MAP decreased more than or equal to 30% of the

MAP before induction (basal).

Statistical analysis

The study subjects were divided into two groups, the hypotension group and the non-hypotension one. The difference between groups were tested using t-test with significance p-value<0.05. Correlation between IVC index and CAo-I was analyzed using chi-square and Spearman test with significance p-value<0.05. The potential of IVC-CI and CAo-I to become hypotension diagnostic parameter tested using receiver operating characteristic (ROC) curve analysis, sensitivity specificity test, likelihood ratio, and predictive value test. Statistical analysis using SPSS version 23 (SPSS Inc., USA). All tests were done with a confidence interval of 95% or α=5%.

Result

The study subjects were thirty-six patients who underwent general anaesthesia. The majority of study subjects underwent gastrointestinal surgery. The mean age of the subject was 37.31±12.91 years old. The mean body mass index (BMI) was 23.11±3.56 kg/m^2 and most of the subjects were ASA 2 (**Table 1**). During pre-induction, the mean MAP was 97.7±12.5 mmHg, mean heart rate was 89.42±18.63 beats/minute, mean maximum IVC diameter was 1.53±0.37 cm, and mean aortic diameter was 1.69±0.22 cm.

Between pre-induction and during induction there were significant differences in some parameters. During anaesthesia induction, the study subjects experienced significant decreases in MAP, heart rate, and aortic diameter from 97.69±12.53 mmHg, 97.69±12.53 beats/minute, and 1.69±0.22 cm, respectively, became 74.14±13.08 mmHg, 89.42±18.63 beats/minute, and 1.59±0.28 cm, respectively (p<0.05). The maximum IVC diameter (dIVC-max) significantly increased from 1.53±0.37 cm to 1.89±0.33 (p<0.05) (**Table 2**).

After anaesthesia induction, 13 (36.1%) of the subjects experienced GAIH. The study subjects' mean age was 37.15±15.33 years old in the hypotension group and 37.39±11.69 years old in the non-hypotension group. Majority of the subjects were female. The subjecs' mean BMI was 21.33±4.20 kg/m^2 in the hypotension group and 24.55±3.34 kg/m^2 in the non-hypotension group. Majority of the subjects had physical status ASA 2. The mean heart rate was 88.00±22.85 beats/minute in the hypotension group and 90.23±16.29 beats/minute in the non-hypotension group. The mean IVC-CI pre-induction was 61.27±16.99% in the hypotension group and 48.31±20.74% in the non-hypotension group. The mean CAo-I pre-induction was 0.84±0.23% in the hypotension group and 0.95±0.21% in the non-hypotension group. However, there was no significant difference between those parameters in the hypotension and non-hypotension group, except for the mean MAP induction. The MAP induction in the hypotension group (64.69±10.39 mmHg) significantly lower than in the non-hypotension group (79.47±11.42 mmHg) (p=0.001) (**Table 3**).

The ROC curve was done to analyze IVC-CI and CAo-I's potential as the diagnostic parameter of GAIH. Based on the ROC test, IVC-CI had area under the ROC curve (AUC) 0.674 with the cut-off value greater or equal to 62.7% (confidence interval 95%). The CAo-I had AUC 0.654 with an optimum cut-off value greater or equal to 85.5% (**Figures 3 and 4**).

Based on the diagnostic test, IVC-CI with a cut-off value of 62.7% had greater sensitivity (69.57%) than CAo-I (43.48%). IVC-CI also had higher (69.23%) specificity than CAo-I (46.15%). The positive predicted value (PPV) of IVC-CI was 80%, and the negative predictive value (NPV) was 56.25%. The PPV of CAo-I was 58% and the NPV was 31.58%. The likelihood ratio, accuracy, and odds ratio of IVC-CI were higher than CAo-I (**Table 4**).

The chi-square test and correlation test were also done to analyze the correlation between IVC-CI and CAo-I with hypotension episodes after general anaesthesia induction. It found that IVC-CI was significantly correlated with hypotension (p=0.024) with a correlation coefficient (r) of 0.375. There was no significant correlation between CAo-I and hypotension (p>0.05) with r=-0.100 (**Table 5**). The chi-square analysis also found that IVC-CI was associated with hypotension (p=0.024).

Discussion

This is the first national study comparing IVC-CI and CAo-I pre-induction as hypotension predictors in general anaesthesia. Based on the statistical analysis, the study subject during pre-induction was homogenous. During induction, the study subject experienced a significant decreased in MAP, heart rate, and aortic diameter, but experienced an increase in dIVCmax (p=0.000). After general anaesthesia induction using propofol 2 mg/kg, 36.1% of the subjects developed hypotension. However, there was no significant difference in the age, gender, BMI, physical status, IVC-CI, and CAo-I between the hypotension and non-hypotension group, except for MAP (p=0.001). MAP of the hypotension group significantly lower than the non-hypotension group. This study found that IVC-CI pre-induction was re-

liable to predict GAIH at a cut-off value of 62.7% with an AUC of 0.674 (sensitivity of 69.57% and specificity of 69.23%). IVC-CI pre-induction was also significantly correlated with hypotension (p=0.024). Zhang and Critchley's study also found that IVC-CI pre-induction could predict GAIH at a cut-off value of 43% with higher sensitivity (78.6%). (13) Szabo et al. also suggested that IVC-CI at 50% could predict post-induction hypotension with low sensitivity (45.5%) but with high specificity (90.0%). (14) The latest study by Purushothaman et al. found that IVC-CI at a cut-off value of 43.0% could predict propofol-induced hypotension in general anaesthesia (sensitivity 53.33%). (15) Our study cut-off was relatively higher than in the previous studies. We chose the cut-off value at 62.7% according to the highest sensitivity and specificity, which were 69.57% and 69.23%. The risk of GAIH would be more significant when IVC-CI pre-induction was ≥62.7%.

The exploration study on the other IVC index, such as CAo-I as GAIH predictor, was not yet well established. The only study on CAo-I was conducted by Salama et al., who compared the CAo-I and IVC-CI as hypotension predictors in spinal anaesthesia. CAo-I was reported to be a more reliable as hypotension predictor than IVC-CI. (11) Our result shows that CAo-I pre-induction was not correlated with hypotension in general anaesthesia. Our study assessed the IVC diameter during spontaneous breathing. Kalshetty et al. also reported that IVC-CI in spontaneous breathing patients was sensitive to identify fluid responsiveness. (16) Zhang et al. also reported that dIVCmax and IVC-CI were strong indicators of body fluid status. IVC receives deoxygenated blood from the inferior part of the body and is correlated with venous return. (17) In spontaneous breathing, the inferior vena cava is correlated with right atrium pressure. Nagdev et al. stated that IVC-CI more than 50% was strongly correlated with right atrium pressure <8 mmHg. (18) CAo-I was less superior than IVC-CI in assessing fluid status due to the difference in the anatomical structures. The arterial wall is eight times more rigid than the vein, so its diameter is not affected by volume status, making the CAo-I value relatively constant. Because of that, CAo-I is more suitable for cardiac preload prediction. (17,19)

General anaesthesia induction agent induces hypotension by influencing the blood vessel wall and promoting vasodilatation, resulting in decreased systemic vascular resistance (SVR). (4) The usage of anesthetic drugs such as sevoflurane, propofol, and others, also contribute to the episode of hypotension. (20) In our study, propofol 2 mg/kg was used, where propofol itself was known to cause hypotension. (15,21) Propofol is used due to the rapid onset, short action duration, and short recovery duration. (22) In the induction dose, propofol decreases systolic pressure by 25-40%, decreases cardiac output (CO) by 15%, decreases stroke volume (SV) by 20%, decreases SVR by 15-25%, and decreases left ventricle performance index by up to 30%. (23-26) The decrease of MAP due to the decrease of SVR affects preload and myocardial contractility. (23-25) By these consequences, the hypotension predictor is needed to provide quick assessment and management of GAIH.

Based on the statistical analysis, IVC-CI can be used as a hypotension predictor with higher sensitivity and specificity than CAo-I. The odds ratio analysis found that patients with IVC-CI greater or equal to 62.7% experiencing hypotension 5.143 times higher.

This study had limitations. First, the number of study subjects was small due to the pandemic and the study duration. During the pandemic, the majority of general anaesthesia is done using rapid sequence induction without ventilation. However, from 36 samples, it was found that IVC-CI was acceptable to become a hypotension predictor after general anaesthesia induction. This study can be considered as a pilot study to do the following research with a more significant number of samples. Second, we could not do an IVC-CI and CAo-I measurement during induction due to the patient's respiration change from spontaneous to positive pressured ventilation. Third, the IVC and aortic diameters were measured by one person due to the operator number's limitation in the operating room during the pandemic.

Conclusion

IVC-CI pre-induction is superior to CAo-I in predicting GAIH with a cut-off value of 62.7%. Patient with IVC-CI equal or greater than 62.7% has a higher risk of hypotension. IVC-CI can be used to predict hypotension with higher sensitivity and specificity than CAo-I.

Table 1. Characteristic of the study subjects

Characteristic	Mean±SD	p-value
Age (years)	37.31±12.91	p>0.05
BMI (kg/m^2)	23.11±3.56	p>0.05
Gender (n) - Male - Female	 18 18	
ASA (n) - I - II	 4 32	
Operation types, n (%) - Orthopedic - Eye - Plastic - Gastrointestinal - Oncology - Otorhinolaryngology - Other	 6 (16.67) 4 (11.11) 4 (11.11) 10 (27.78) 5 (13.89) 4 (11.11) 3 (8.33)	

Legend: SD=standard deviation; BMI=body mass index; ASA=American Society of Anesthesiologist. Homogeneity test: significant if p-value >0.05.

Table 2. Parameter during pre-induction and during induction

Parameter	Pre-induction (baseline)	Induction	p-value
MAP (mmHg)	97.69±12.53	74.14±13.08	0.000*
Heart rate (beats/minute)	89.42±18.63	76.33±16.69	0.000*
dIVCmax	1.53±0.37	1.89±0.33	0.000*
Abdominal aortic diameter (cm)	1.69±0.22	1.59±0.28	0.000*

Legend: MAP=mean arterial pressure; dIVCmax=maximum inferior vena cava diameter; *significantly different. T-test: significant if p-value <0.05.

Table 3. Characteristic of hypotension and non-hypotension group during induction

	Hypotension episode		p-value
	No hypotension (n=23), mean±SD	Hypotension (n=13), mean±SD	
Age (year)	37.39±11.69	37.15±15.33	0.959
Gender (n) - Male - Female	 11 12	 6 7	0.729
BMI (kg/m^2)	24.55±3.34	21.33±4.20	0.153
ASA (n) - I - II	 3 20	 1 12	0.705
MAP pre-induction (mmHg)	96.56±11.37	99.69±14.62	0.480
MAP induction (mmHg)	79.47±11.43	64.69±10.39	0.001*
IVC-CI pre-induction (%)	48.31±20.74	61.27±16.99	0.064
CAo-I pre-induction (%)	0.95±0.21	0.84±0.23	0.152

Legend: SD=standard deviation; BMI=body mass index; ASA=American Society of Anesthesiologist; MAP=mean arterial pressure; IVC-CI=inferior vena cava collapsibility index; CAo-I=caval aortic index; *significantly different. T-test: significant if p-value <0.05.

Table 4. The diagnostic test of IVC-CI and CAo-I

Parameter	AUC	Cut-off	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	LR	Accuracy (%)	Odds ratio
IVC-CI	0.674	62.70	69.57	69.23	80.00	56.25	2.261	69.44	5.143
CAo-I	0.654	85.55	43.48	46.15	58.82	31.58	0.807	44.44	0.659

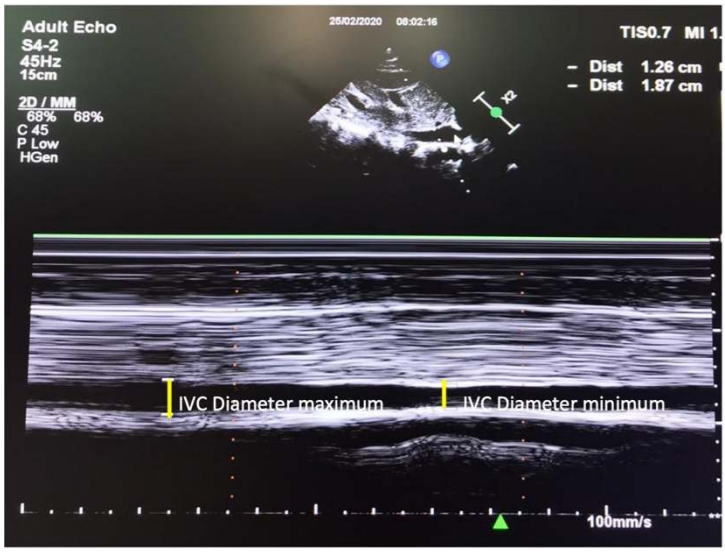
Legend: IVC-CI=inferior vena cava collapsibility index; CAo-I=caval aortic index; AUC=area under the ROC curve; PPV=positive predictive value; NPV=negative predictive value; LR=likelihood ratio.

Table 5. IVC-CI significantly correlated with hypotension

Parameter	No hypotension, n (%)	Hypotension, n (%)	p-value (chi-square)	The correlation coefficient (r) and p-value
IVC-CI<62.7%	16 (44.4%)	4 (11.1%)	0.024	r=0.375 p=0.024*
IVC-CI≥62.7%	7 (19.4%)	9 (25.0%)		
CAo-I<85.5%	10 (27.8%)	7 (19.4%)	0.549	r=-0.100 p=0.563
CAo-I≥85.5%	13 (36.1%)	6 (16.7%)		

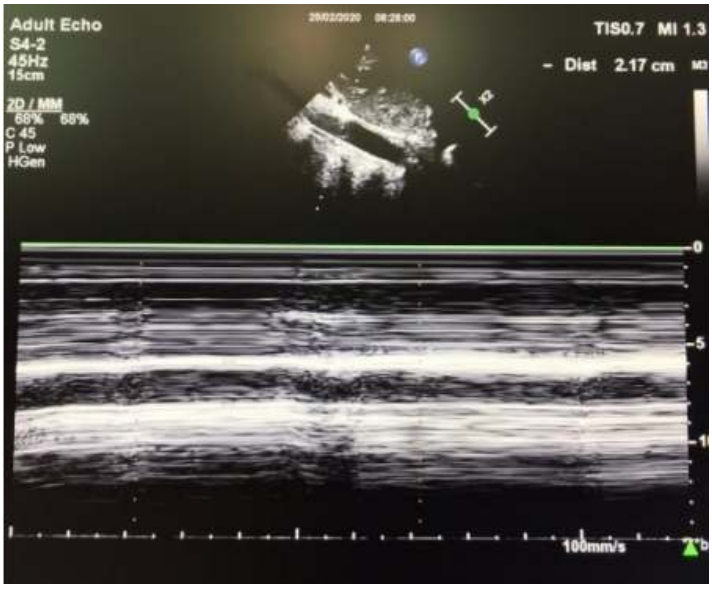
Legend: IVC-CI=inferior vena cava collapsibility index; CAo-I=caval aortic index; *significant correlation between non-hypotension and hypotension group. Chi-square test: significant if p-value <0.05.

Figure 1. Maximum and minimum IVC diameter measurement using USG guide



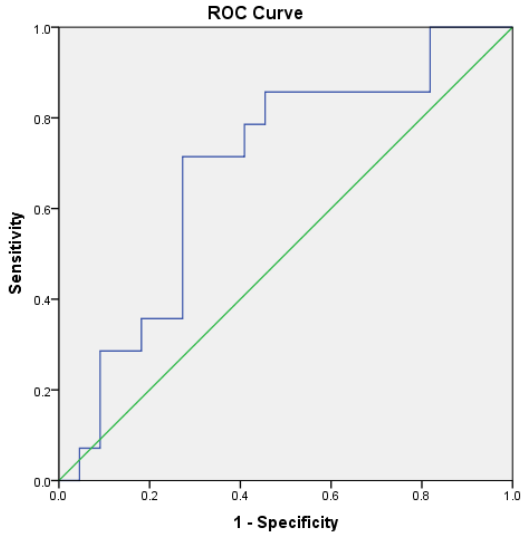
Legend: IVC=inferior vena cava; USG=ultrasonography.

Figure 2. Abdominal aortic diameter measurement under USG guide



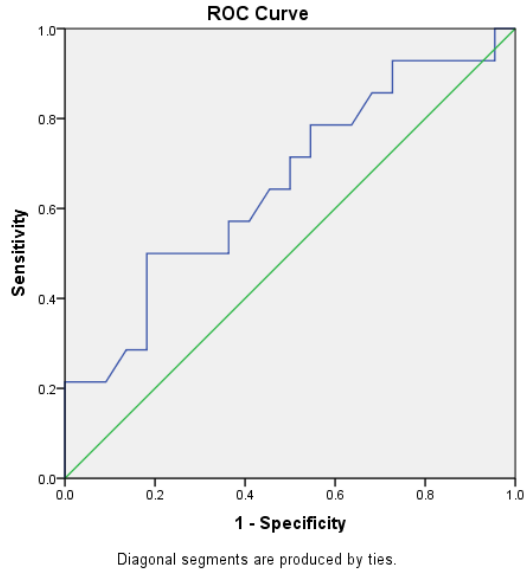
Legend: USG=ultrasonography.

Figure 3. Receiver operating characteristic curve of IVC-CI



Legend: The AUC of IVC-CI was 0.674.
IVC-CI=inferior vena cava collapsibility index; AUC=area under the ROC curve.

Figure 4. Receiver operating characteristic curve of CAo-I



Legend: The AUC of CAo-I was 0.654.
CAo-I=caval aortic index; AUC=area under the ROC curve.

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