ORIGINAL ARTICLE

Prospective observational study to compare subclavian vein collapsibility index with inferior venacava collapsibility index in predicting hypotension after induction of general anaesthesia

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Abstract

Background: Intraoperative hypotension leads to many postoperative complications which can be avoidable. In contrast with inferior vena cava, subclavian vein collapsibility index is found to be a better predictor of intravascular volume status. *Aim and Objectives:* To compare subclavian vein/infraclavicular axillary vein collapsibility index with inferior vena cava collapsibility index (during spontaneous breathing or deep inspiration) in predicting hypotension after induction of general anesthesia. *Material and Methods:* In this study, 70 ASA I and II healthy individuals were enrolled. Using ultrasonography, diameters of subclavian vein and inferior venacava during one respiratory cycle were recorded and their collapsibility indices were calculated. Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), and Mean Arterial Pressure (MAP) were noted at every 2 minutes interval after induction of general anesthesia. Intraoperative blood pressure measurements were correlated with the collapsibility indices of great veins to predict intraoperative hypotension. *Results:* MAP at 2, 4, 6 and 8 minutes showed insignificant correlation with the inferior vena cava collapsibility index on spontaneous breathing with values of '*p*' being 0.63, 0.98, 0.93 and 0.65, respectively. MAP at 2, 4, 6 and 8 minutes showed insignificant correlation with the inferior vena cava collapsibility index on deep inspiration with values of '*p*' being 0.78, 0.20, 0.17 and 0.20, respectively. MAP at 2, 4, 6 and 8 minutes showed very significant correlation with the subclavian vein's collapsibility index on spontaneous breathing with values of '*p*' being 0.48, 0.20, 0.17 and 0.20, respectively. MAP at 2, 4, 6 and 8 minutes showed very significant correlation with the subclavian vein's collapsibility index on deep inspiration with values of '*p*' being 0.0010, 0.0020, 0.0007 and 0.0012, respectively. *Conclusion:* Subclavian vein collapsibility index on spontaneous breathing and deep inspiration had highly substantial association with the MAP, as compared to inferior vena cava collapsibility indices.

Keywords: Intraoperative Hypotension, Subclavian Vein Collapsibility Index, Inferior Venacava Collapsibility Index, Spontaneous Breathing, Deep Breathing

Introduction

Patients undergoing non-cardiac surgery under general anesthesia frequently experience Intraoperative Hypotension (IOH) during the procedure. Its multifaceted etiology is associated with serious postoperative side effects which includes acute renal injury, neurological problems, cardiac damage, and mortality of patient [1]. Many pathophysiologic processes can result in IOH in individuals receiving general anesthesia. IOH could be a preventable risk factor for complications after surgery. It is essential to recognize and avoid modifiable risk factors in order to prevent the postoperative problems. There are various factors leading to IOH such as age, gender, ASA Class, general anesthesia, emergency surgeries, antihypertensive medications (ACE inhibitors, and antagonists of the angiotensin II receptor) [2].

IOH is defined as "more than 30% reduction of Mean Arterial Pressure (MAP) from baseline or any absolute value of MAP less than 55 mmHg" [3]. One of the intervals of general anesthesia during which hypotension is prevalent is the period after the induction of anesthesia but before the onset of surgical stimulus. After induction of general anesthesia due to vasodilatory effects of anesthetic agents and other cardiac depressive agents, patients are more prone for hypotension. Factors like preoperative patient's physical status, fasting, comorbidities also contribute for the susceptibility of IOH [4]. Different interventions can be adopted to overcome the IOH like preloading the patients with crystalloids /colloids before induction of anesthesia, avoiding drugs which cause myocardial depression, co- induction and priming principle of the induction agent etc. Opioid free Total Intravenous Anesthesia (TIVA) with dexmedetomidine and propofol is known to provide faster recovery and discharge with stable hemodynamic parameters for minor gynecological surgeries [5]. Also, dexmedetomidine in a dose of 1 µg/kg as preoperative bolus dose in patients undergoing laparoscopic surgeries gives better haemodynamic stability, postoperative analgesia, sedation and reduction in the dose of inhalational anaesthetic agent compared to 0.7 µg/kg dose without increase in the incidence of adverse effects [6].

Measurements of Inferior Vena Cava (IVC) such as its diameter and collapsibility index preoperatively has been recommended as a way to identify individuals who are at risk of developing IOH [7]. However, there are few barriers in IVC examination like patients with abdominal distention and pain. The subclavian vein is situated upstream of the Superior Vena Cava (SVC) and close to the pleura and can be easily visualized in a majority of patients using a standard ultrasound linear probe. In one study, high frequency ultrasound probe demonstrated an admissible result of association between the subclavian vein and IVC collapsibility indices in surgical patients and patients in intensive care unit [8]. Studies using subclavian vein diameter and collapsibility index that are measured preoperatively to forecast hypotension following the induction of general anesthesia are lacking. Hence, this study was conducted with the aim to compare subclavian vein/infraclavicular axillary vein collapsibility index with IVC collapsibility index (during spontaneous breathing or deep inspiration) in predicting hypotension after induction of general anesthesia.

Material and Methods

This was an observational study where 70 healthy volunteers of American Society of Anesthesiologists I and II aged 18 and 60 years, who underwent surgery under general anesthesia at KLE's Dr. Prabhakar Kore Charitable Hospital and Medical Research Centre, Nehru Nagar, Belagavi for a period of one year, were recruited after taking written informed consent and approval from the departmental research committee and clearance from the Institutional Ethics Board. Patient undergoing emergency surgery, requiring rapid sequence intubation, on vasopressor drugs to maintain MAP > 65 mmHg, with major peripheral vascular diseases and raised intraabdominal pressure were excluded.

All the patients were asked to be nil by mouth from midnight on the day before surgery. On the day of surgery, the blood pressure was recorded non-invasively in the pre-operative room. All the patients, who were included in the study underwent ultrasound examination of the subclavian vein and IVC in the pre-operative holding area. Right subclavian vein diameter was assessed using the

$$\textbf{Collapsibility Index (CI)} = \frac{\textbf{Maximum diameter of vein – Minimum diameter of vein}}{\textbf{Maximum diameter of vein}}$$

high frequency (6-13 Hz) linear probe in infra- clavicular region and two-dimensional image of the IVC was obtained in the subcostal, paramedian long-axis view where it enters the right atrium using low frequency curvilinear probe (2-5 Hz) of Micromaxx Sonosite ultrasound apparatus. Instructions were given to patients to breathe normally while at rest (spontaneous breathing), then to breathe in deeply and out normally (deep inspiration). The minimum and maximum diameters of veins during spontaneous breathing and deep inspiration were measured in M mode. The above equation was used to determine the collapsibility index both during spontaneous and deep breathing.

Further the patients were shifted to operation theatre and all the standard monitors to measure oxygen saturation, electrocardiogram and non-invasive blood pressure were attached. Then the patients were pre-oxygenated with 100% O_2 using closed circle system. Patients were pre-medicated using injection glycopyrrolate 0.004-0.006 mg/kg, injection midazolam 0.05 mg/kg and injection fentanyl 2 mcg/kg. Patient was induced with injection thiopentone 5 mg/kg. Endotracheal intubation was facilitated by injection vecuronium 0.08-0.1 mg/kg. Oxygen + air (50:50) were used to maintain the anesthesia. Non- invasive BP was recorded every two minutes [Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), and Mean Arterial Pressure (MAP)] for a period of 10 minutes after endotracheal intubation. Ten ml/kg/hr of crystalloid infusion was started. Throughout the analysis period, patients were in the supine position; only minimal stimulation, such as skin preparation was permitted. Once the surgery started, hemodynamic data collection was stopped. Oxygen + nitrous oxide and sevoflurane, an inhalational volatile anesthetic, was used at varying concentrations for maintenance of anesthesia. Blood and fluid replacements were made as needed. At end point of procedure patients were reversed with glycopyrrolate (0.01 mg/kg) and neostigmine (0.05 mg/kg) and extubated when regular spontaneous breathing pattern was seen and when patient started responding to pain stimuli. Patient was shifted to recovery room.

Sample size calculation

The incidence of intra-operative hypotension is 46.9 % [3]. The prevalence rate-based formula for the minimal sample size is

$$n = \frac{Z_\alpha^2 P\,(1\text{-}P)}{d^2}$$

Where, P = percentage of prevalence and d = percentage likely difference in the prevalence. The significance level is related to z_α. For 5% level of the significance $z_\alpha = 1.96$. With P = 46.9% and d = 25% of P = 11.73%, sample size came out to be 70. Since this was an observational study, 70 consecutive patients posted for surgery under general anaesthesia who met the inclusion and exclusion criteria were included in the study. The mean and standard deviation for the continuous quantitative variables were determined. The categorical data was expressed in terms of rates, ratios and percentages. The Chi- square test, test of proportion, or Fisher's exact test were used to determine whether there was a correlation between the result, clinical, and demographic factors. For discrete variables nonparametric tests were used. Apart from the above suitable tools like ANOVA, correlation, regression etc., were used according to the need.

The value of p less than 5% (0.05) was deemed significant for all tests.

Results

In this study involving 70 patients, 37 were males (52%) and 33 were females (48%). Age was found to be 37.74 ± 13.06 years. Mean collapsibility values of IVC during spontaneous and deep breathing were 30.86 ± 16.59 and 38.00 ± 15.40, respectively. Mean collapsibility values of subclavian vein during spontaneous and deep breathing were 23.92 ± 13.33 and 39.42 ± 18.05, respectively. In our study the SBP, DBP, and MAP reduced significantly ($p < 0.05$) compared to baseline at 2 min, 4 min, 6 min, 8 min after induction and endotracheal intubation. Karl Pearson's co-relation coefficients of MAP at 2, 4, 6 and 8 minutes with respect to collapsibility indices of subclavian vein on deep inspiration was highly significant with values of 'p' being 0.0010, 0.0020, 0.0007, 0.0012, respectively.

Table 1: Trends of collapsibility index of inferior vena cava during spontaneous breathing

	Inferior venacava spontaneous breathing (Mean ± S.D)	Inferior venacava deep breathing (Mean ± S.D)	Subclavian vein spontaneous breathing (Mean ± S.D)	Subclavian vein deep breathing (Mean ± S.D)
Maximum diameter (cm)	1.32 ± 0.53	1.53 ± 2.80	0.37 ± 0.25	0.31 ± 0.19
Minimum diameter (cm)	0.86 ± 0.27	0.69 ± 0.27	0.28 ± 0.20	0.17 ± 0.08
Collapsibility Index	30.86 ± 16.59	38.00 ± 15.40	23.92 ± 13.33	39.42 ±18.05

Table 2: Systolic, diastolic and mean blood pressure measurements at mentioned time intervals after endotracheal intubation

	Mean systolic blood pressure (mm Hg)	Mean diastolic blood pressure (mm Hg)	Mean arterial pressure (mm Hg)
Baseline	126.33	78.71	93.60
Induction	121.14 (0.012)*	75.70 (0.037)*	90.57 (0.0418)*
2 mins	107.87 ($p < 0.0001$)**	66.90 ($p < 0.0001$)**	80.79 ($p < 0.0001$)**
4 mins	97.56 ($p < 0.0001$)**	60.13 ($p < 0.0001$)**	72.83 ($p < 0.0001$)**
6 mins	91.20 ($p < 0.0001$)**	55.17 ($p < 0.0001$)**	67.66 ($p < 0.0001$)**
8 mins	87.63 ($p < 0.0001$)**	53.03 ($p < 0.0001$)**	64.76 ($p < 0.0001$)**
Incision	99.60 ($p < 0.0001$)**	62.00 ($p < 0.0001$)**	74.30 ($p < 0.0001$)**

In our study the systolic, diastolic and mean blood pressure at the time interval of induction showed significant p values compared to baseline, whereas at 2 min, 4 min, 6 min, 8 min, interval it showed highly significant p values compared to the baseline.

Table 3: Karl Pearson's correlation coefficients of map at 2 minutes with collapsibility indices

	r at 2 min	r at 4 min	r at 6 min	r at 8 min
Subclavian/Axillary vein (Spontaneous breathing)	-0.0839*	-0.0277*	-0.0291*	-0.0158*
Subclavian/Axillary vein (Deep Inspiration)	-0.3854**	-0.3643**	-0.3944**	-0.3804**
Inferior Vena cava (Spontaneous breathing)	-0.0578*	0.0021*	0.0098*	-0.0546*
Inferior Vena cava (Deep Inspiration)	0.0330*	0.1522*	0.1629*	0.1545*

The correlation of mean arterial pressure at 2, 4, 6 and 8 minutes with respect to collapsibility index of subclavian vein on deep inspiration was very significant with *p* value 0.0010, 0.0020, 0.0007, 0.0012 respectively.

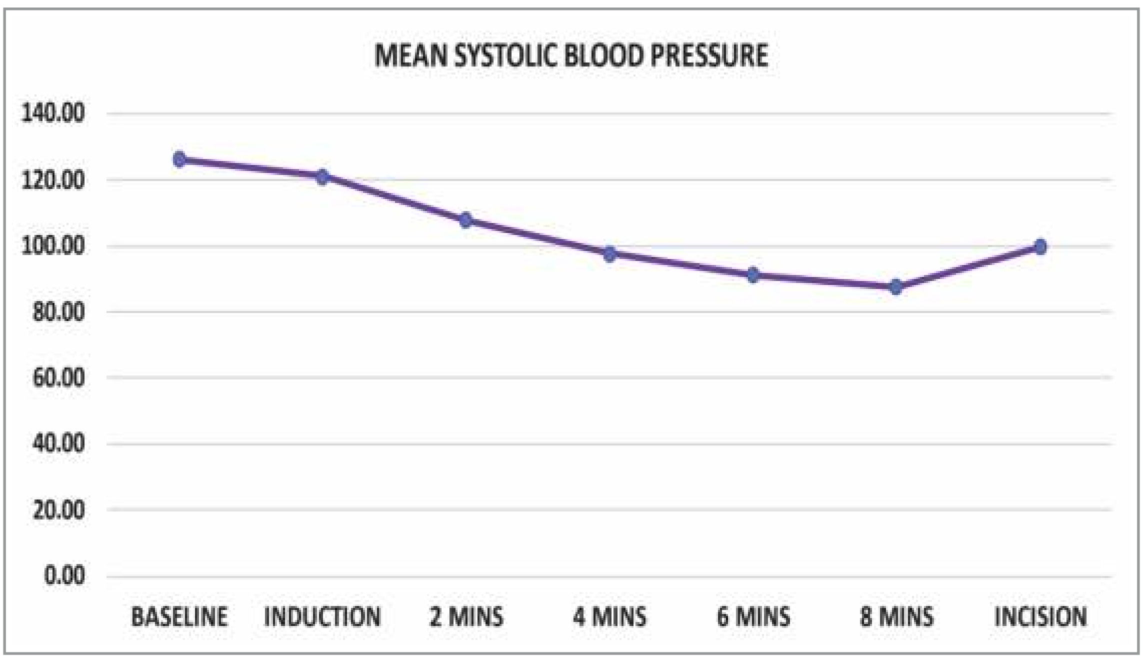

Figure 1: Depicting the values of mean systolic blood pressure at below mentioned time intervals

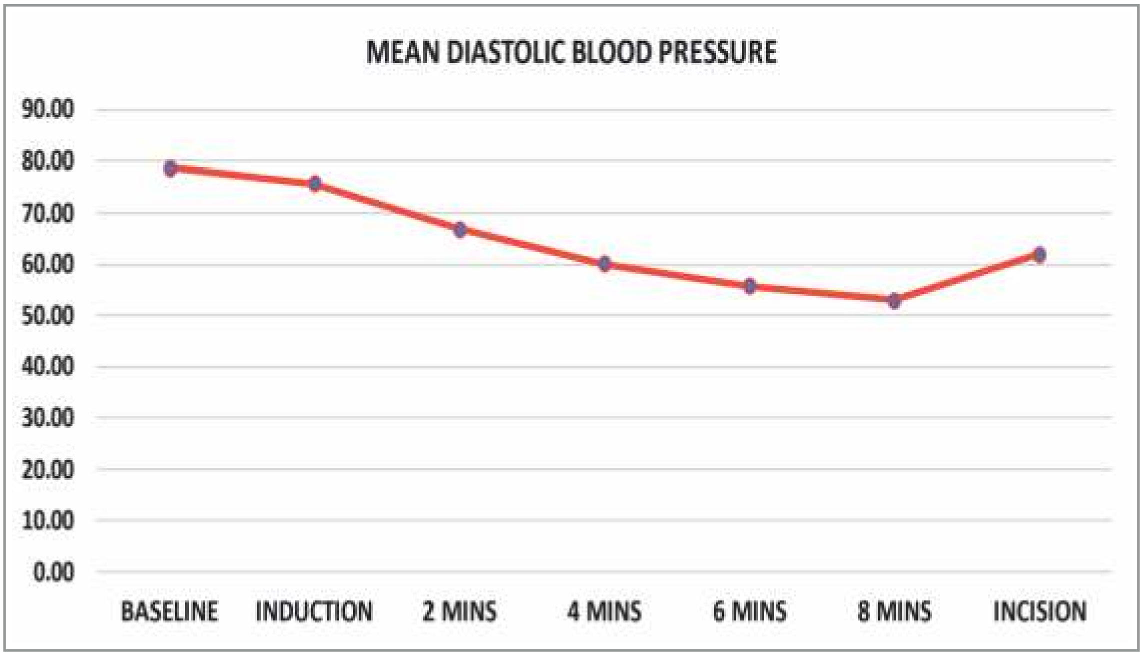

Figure 2: Depicting the values of mean diastolic blood pressure at below mentioned time intervals

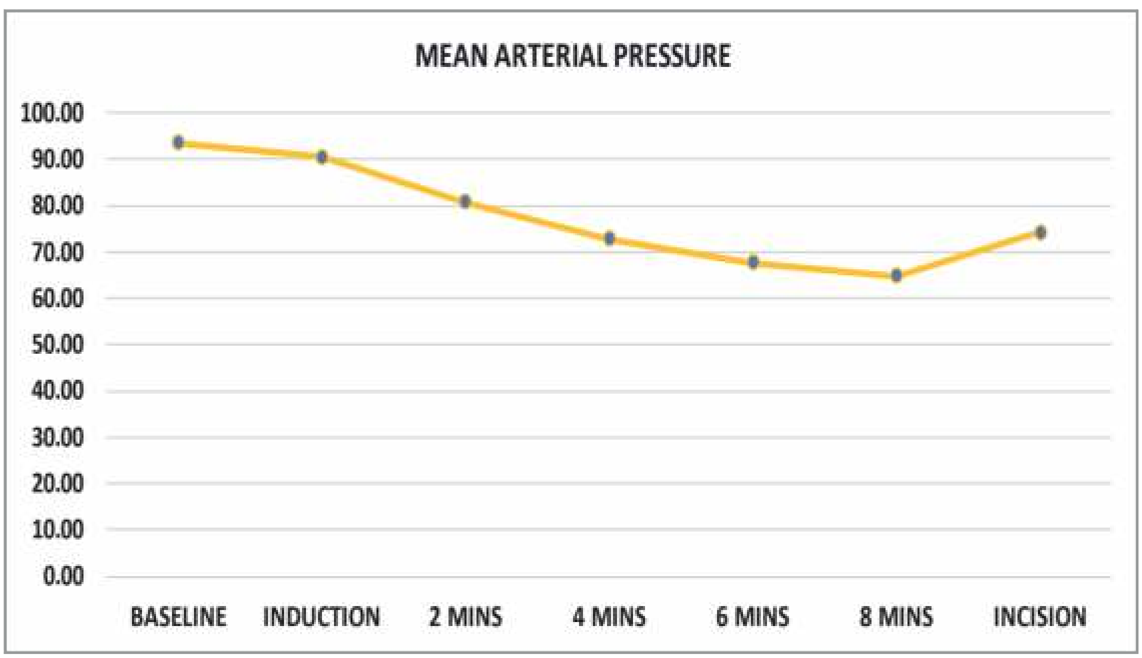

Figure 3: Depicting the values of mean arterial blood pressure at below mentioned time interval

Discussion

Many factors contribute for post induction hypotension, which involves anesthetic agents that causes vasodilation, myocardial depression, low baseline MAP, low pre induction blood pressure, volume status, etc. The most vulnerable period after inducing general anesthesia is from the time of induction till 20 minutes, because that time period is free from surgical stimulus [9].

Assessment of intravascular volume status includes dynamic and static parameters. Central venous pressure is a static cardiac filling pressure which helps to guide the fluid administration. Variations in pulse pressure and stroke volume are examples of dynamic parameters [10]. Cherpanath *et al*., reviewed the basic concepts of fluid responsiveness, and observed that the dynamic parameters of fluid responsiveness like variations in stroke volume and pulse pressure were better predictors than static parameters [10]. Bowdle *et al*., discussed the complications related to invasive monitoring which included infection at punctured site, pneumothorax, damage to veins and arteries, catheter, wire, and air embolism [11]. Assessment of IVC diameter was found to be a reliable indicator to ascertain the status of intravascular volume and fluid response in critically sick patients. According to Zhang *et al*., ultrasound measurements of IVC collapsibility index recorded prior to the induction of general anesthesia were highly predictive of hypotension, with a cut off value of 43% [4].

The study conducted by Patil *et al*., concluded that correlation between collapsibility indices of IVC with femoral and internal jugular vein were weak [12]. To overcome the mentioned limitations, in our study, we examined the collapsibility indices of subclavian vein and IVC during spontaneous and deep breathing.

In the present study, the SBP at the time intervals of induction showed significant fall ($p = 0.0124$) compared to baseline, whereas at 2 min, 4 min, 6 min, 8 min before incision it showed highly significant fall in SBP ($p < 0.0001$) compared to the baseline. At time interval of 8 minutes after induction of general anesthesia, the SBP dropped to the lowest value of 80 mmHg.

The DBP at the time interval of induction showed significant decrease ($p = 0.0379$) compared to baseline, whereas at the time intervals of 2 min, 4 min, 6 min, 8 min, incision it showed highly significant decrease ($p < 0.0001$) compared to the baseline. At time interval of 8 minutes after induction after general anesthesia, the DBP dropped to the lowest value of 50 mmHg.

In the present study the MAP at the time interval of induction showed significant decrease ($p = 0.0416$) compared to baseline, whereas at time intervals of 2 min, 4 min, 6 min, 8 min, incision it showed highly significant decrease ($p < 0.0001$) compared to the baseline. The percentage reduction in MAP after induction showed significant correlation compared to baseline blood pressure with the mean value of 90.57 ($p = 0.0416$). These findings were in line with the study conducted by Zhang *et al*. where the baseline mean blood pressure had a significant positive association with the percentage decrease in mean blood pressure after induction ($p = 0.0001$) [4].

The collapsibility of blood vessel depends on a physiological principle of decrease in intrathoracic pressure upon inspiration, which increases right ventricular diastolic filling, which rises the right side of the heart's caval outflow and cardiac output. In these circumstances central veins such as IVC and SVC tend to collapse. It was presumed that on deep inspiration it might aggravate this phenomenon, thus it is assessed to predict a decrease in MAP. During expiration this process is altered, accompanied by reduction of right atrial filling which leads to an increase in IVC diameter. To overcome the limitations of IVC ultrasonography, subclavian vein was considered to predict intravascular volume status [13]. The subclavian vein is one of the most compliant blood vessels, its size and diameter vary with respiration and intravascular volume status. In contrast to the internal jugular and femoral veins, it is guarded from inadvertent external compression by the surrounding tissues and clavicle. Due to this property of subclavian vein, measurements are less likely to be affected by collapsible variables such as manipulations by ultrasonography probe. Thus, these factors further credit the use of subclavian vein ultrasonography in predicting intravascular volume status [10].

In the present study we used Karl Pearson's correlation coefficients to correlate the MAP readings with the collapsible indices. The collapsibility indices of subclavian/infra clavicular axillary vein during deep inspiration had shown very significant correlation with decrease in mean arterial pressure at 2 minutes, 4 minutes, 8 minutes after induction ($p = 0.0010, 0.0020, 0.0012$) respectively and at 6 minutes it was found to be highly significantly correlated with decrease in MAP ($p = 0.0007$). These findings are in concordance with the study conducted by Min *et al*., where MAP decline during anesthesia induction was significantly predicted by the subclavian-axillary vein's collapsibility index during deep inspiration ($p < 0.001$) [3]. Thus, from the above observations we found that subclavian/ infraclavicular axillary vein collapsibility index on deep inspiration is a better preoperative predictor of IOH. In contrary to the present study, Zhu *et al.* found no correlation between the parameters of the SCV Sonography (diameters of subclavian vein during inspiration and expiration) and blood pressure [14].

Also, Patil *et al*. found the correlation between MAP and Venous Collapsibility Index (VCI) to be poor ($r = 0.130$) and the relationship had near statistical significance ($p = 0.06$) [15]. Nadia *et al*. conducted an observational clinical trial to compare pre-operative IVC collapsibility index with subclavian vein collapsibility index as a predictor of post-induction hypotension on 120 patients undergoing surgery under general anaesthesia and observed that subclavian vein collapsibility index in deep breathing was sensitive and reliable in predicting hypotension after induction of general anaesthesia but they did not consider IVC collapsibility index during deep breathing in their study [16]. A two part study was conducted by Wang *et al*. to observe the effect of Subclavian Vein (SCV) diameter combined with perioperative fluid therapy on preventing Post-induction Hypotension (PIH) in patients undergoing general anaesthesia. The study included patients aged 18 to 65 years, classified as ASA physical status I or II, and scheduled for elective surgery. The first part (Part I) included 146 adult patients, where maximum SCV diameter ($dSCV_{max}$), minimum SCV diameter ($dSCV_{min}$), SCV collapsibility index (SCV_{CI}) and SCV variability ($SCV_{variability}$) assessed using ultrasound and the incidence of post-induction hypotension was observed and a cut-off for hypotension was determined. In second part, 126 patients who met the criteria for cut-off value of post-induction hypotension were included and they received 6 ml/kg of colloid solution within 20 min before induction. The study evaluated the impact of SCV diameter combined with perioperative fluid therapy by comparing the observed incidence of PIH after induction of anaesthesia.

They concluded that both SCV_{CI} and $SCV_{variability}$ were non-invasive parameters capable of predicting PIH, and their combination with perioperative fluid therapy can reduce the incidence of PIH [17].

We found that the correlation of collapsibility indices of subclavian/infra clavicular axillary vein with the decrease in MAP during spontaneous breathing were not significant which were in concordance with the findings of the study performed by Choi *et al.* where the collapsibility index of subclavian / axillary vein, on spontaneous breathing was not a reliable indicator of the drop in MAP during induction of GA ($p = 0.127$) [3].

In the present study, significant correlation was not found between the percentage reduction in MAP and the IVC collapsibility index during spontaneous breathing and deep inspiration.

Kent *et al*. in his prospective comparative study of subclavian vein and IVC collapsibility index found that on linear regression analysis, the paired measurements of IVC and subclavian vein collapsibility index revealed an acceptable correlation over a wide range of venous collapsibility ($R^2 = 0.61$) [8].

Conclusion

Preoperative subclavian vein / infraclavicular axillary vein collapsibility index during deep inspiration is more effective in predicting IOH followed by induction of general anesthesia in comparison to subclavian vein/infraclavicular axillary vein collapsibility index during spontaneous ventilation and IVC Collapsibility index during spontaneous and deep breathing.

Limitations

Although there was significant hypotension during intraoperative period as predicted by preoperative ultrasound measurements, major interventions were not taken to correct the hypotension and ASA III and IV patients in whom invasive hemodynamic monitoring is required were not included.

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