Original Article

Sonographic Caval/Aorta Diameter And Inferior Vena Cava Collapsibility Indices For Assessment Of Preoperative Intravascular Volume Status In Elective Surgery Patients

Sushila Lama Moktan, Mona Sharma

Abstract

Introduction: The assessment of preoperative intravascular volume status is crucial for optimizing fluid management in patients undergoing elective surgery. Inaccurate volume status estimation can lead to complications related to hypovolemia or fluid overload. Traditional methods like central venous pressure monitoring are invasive and may not be readily available or accurate. The advances in non-invasive sonographic techniques offer an alternative approach. Two indices, the Caval/aorta diameter index (IVC/Ao) and inferior venacava collapsibility index (IVCCI), have shown a promise in evaluating intravascular volume status.

Methods: This observational study included adult patients undergoing elective non-cardiac surgery. Ultrasonographic measurement of the IVC maximum and minimum diameter and aortic diameter were obtained before the induction of anesthesia. The IVCCI and IVC/Ao index were then calculated. IVCCI of >50% and Caval/Ao index of <1.0 was considered as hypovoalemic state.

Results: Hundred and twenty-six patients were analyzed from whom the means of maximum IVC diameter, abdominal aorta diameter, IVC/Ao index, and IVCCI were 1.686 ± 0.44 cm, 1.41±0.32 cm, 1.2±0.33, and 42.98 ±7.2 respectively (mean±S.D.). Of the 126 patients, 27.77% of the patient had IVC/Ao index of <1.0, and 17.46% had IVCCI of >50%.

Conclusion: Using sonographic IVC/Ao and IVCCI indices appears to be easy, quick, reliable and non-invasive way to determine the fluid status of the patients who have fasted before surgery. These indices show a promising technique for identifying hypovolemia in early stages, which should be investigated further in the near future.

Keywords: Caval aorta index; inferior venacava collapsibility index; intravascular volume status; ultrasound.

Author affiliations:

Department of Anesthesia and Intensive Care,
Kathmandu Medical College Teaching Hospital, Sinamangal, Kathmandu, Nepal

Correspondence:

Dr. Sushila Lama Moktan,
Department of Anesthesia and Intensive Care, Kathmandu Medical College Teaching Hospital, Sinamangal, Kathmandu, Nepal.

Email: moktansushi@gmail.com

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Introduction

Assessing preoperative intravascular volume status is crucial in elective surgery patients to optimize fluid management and minimize complications. The effect of hypotension is more pronounced in patients who already have an intravascular fluid deficit because of nil per oral status along with the usage of anesthetic agents leading to many unwanted side effects.[1] Although most of risk factors for post-anaesthetic hypotension are not modifiable, hypovolemia is the most alterable factor to avoid hypotension.[2-4] While majority of the patients have minor deficit, some with clinically significant deficit may have worse outcome.[5,6]

Ultrasonography is simple, non-invasive technique that can precisely detect hypovolemia before proceeding with anesthesia and subsequently preventing post-anesthetic hypotension by using two key sonographic measurements of inferior venacava and abdominal aorta.[8-10]

This study aims to assess the convenient, quick and effective way of evaluating preoperative hydration status with the ultrasound derived parameters like caval/aorta diameter ratio and inferior venacava collapsibility index.

Methods

This cross-sectional observational study was conducted in the operation theatre of Kathmandu Medical College Teaching Hospital over a period of eight months after receiving approval from Institutional Review Committee (ref no.: 01122023/03). An informed written consent was obtained after thoroughly explaining the study's purpose and methodology in terms that they were as comprehensible as possible to the participants.

We included 130 adult patients(18-60 years of age) with American society of anesthesiologists-physical status (ASA-PS) I and II scheduled elective non-cardiac/ non-neuro surgeries. Individuals who exhibited cardiac comorbidities, such as significant arrhythmia, severe valvular disease, unstable angina, ejection fraction <50%, systolic blood pressure >180 and <90 mmHg, patients on diuretics, pulmonary hypertension, heart failure, and emergency cases were exculded. Patients with agitation, trauma, dyspnea, BMI>30kg/m^2, elevated intra-abdominal/ intra-cranial pressure, intra-abdominal mass compressing the IVC, pregnant women, patient in pain as well as subpar ultrasound examination (defined as inability to accurately visualize/measure the aorta and IVC) were also excluded. Due to inadequate visualization of IVC and abdominal aorta, four patients were excluded. So, total of 126 patients were taken for the analysis.

All the patients were instructed to fast at least two hours for clear fluid and six hours for solid food. Only the patients scheduled for the day's first surgeries were assessed in order to attain the fluid equivalent status.

Basic monitors, including an electrocardiogram, non-invasive blood pressure, and pulse oximetry were attached to the patients in the operating room. After five minutes of rest, baseline measurements of Heart rate(HR), systolic and diastolic blood pressure(SBP, DBP), mean arterial pressure (MAP) were recorded. The average of three measurements were taken for analysis. Using the portable GE LOGIQ e ultrasound (US) device, the measurements were taken once the patient was relaxed and well-rested. None of the patients received intravenous fluid before the USG examination.

During quiet passive respiration with the patient in supine position, one of the researchers with USG training in anesthesia assessed the measurements of the IVC and abdominal aortic diameter. As per the American Society of echocardiography's methodology, the IVC was visualized through a subcostal approach with a curvilinear (3.5 to 5 MHz) ultrasound transducer probe in a paramedian long-axis view.[11] A two-dimensional image of IVC as it entered right atrium was obtained first. The methods used to distinguish the IVC from the aorta were pulsatile nature, pulse wave doppler, compressibility and phasic collapse with respiration.Using M-mode imaging, variation in the IVC diameter with respiration was measured approximately 2-3 cm down to IVC- right atrium junction.[12] During the same respiratory cycle, the internal anteroposterior (AP) diameter of IVC at the end of expiration and inspiration was measured as maximum ($dIVC_{max}$) and minimum ($dIVC_{min}$) respectively. The average of the three measurements was taken for analysis. To the left of IVC, abdominal aorta was visualized and the maximum internal diameter was measured during systole 5-10 mm above coeliac trunk. The IVC/Ao index was derived by taking the ratio of dIVCmax IVC during expiration and maximal abdominal aortic diameter during systole. A cutoff of 1 was established for IVC/Ao index, with values <1 being considered hypovolaemic.[13] The equation [($dIVC_{max}$ in mm – $dIVC_{min}$ in mm)/$dIVC_{max}$ diameter in mm]X100 was used to determine the percentage collapse of the IVC (IVCCI). Patients with IVCCI of >50% was considered as hypovolaemic.[14]

The sample size was calculated using the standard deviation of 0.1715, obtained from previous study with confidence interval of 1.96 and five percent margin of error. With 5% drop out rate, total sample calculated was 130. All the statistical analyses were performed using using Statistical Package for Social Sciences version 22. Continuous data was expressed as mean with standard deviation according to distribution of data and categorical data expressed as number of occurrences (frequencies and percentages). The reported P-values were two-tailed, with those <0.05 considered to be statistically significant.

Results

The measured individual characteristics of the 126 patients are shown in **Table 1**. Four patients were excluded due to inadequate visualization of IVC. The average age was 40 years, where 67(53.17%) were female. The mean body mass index (BMI) and body surface area (BSA) were 24.6±3.3 kg/m^2 and 1.6±0.1m^2, respectively (mean±S.D.). Nil per oral (NPO) in minutes, oral clear fluid intake in milliliters(ml) preoperatively, and associated co-morbidities like hypertension, diabetes, hypothyroidism, are summarized in **Table 1**.

Table 1. Patient characteristics in mean ±standard deviation, and percentages.

Variables	Value
Age in years	39.89±12.88
Gender, Male:Female	59:67 (53.17% male)
ASA grade, I:II	65:61(51.58% ASA I)
BMI in Kg/m^2	24.61±3.37
BSA in m^2	1.67±0.17
NPO in minutes	225±33
Preoperative volume of oral fluid intake in millilitres	256.74±70.81
Co-morbidities (hypertension, diabetes, hypothyroidism)	52(41.26%)

ASA: American society of anesthesiologists, BMI: Body mass index, BSA: body surface area

The baseline hemodynamic data taken during the scan is shown in **Table 2**.

Table 2. Hemodynamic parameters

Variables	Mean±SD
HR bpm	79.03±12.87
SBP mm of Hg	128.69±12.57
DBP mm of Hg	80.11±7.93
MAP mm of Hg	95.80±9.03

HR: heart rate, Bpm: beats per minute, SBP: systolic blood pressure, DBP: diastolic blood pressure, MAP: mean arterial pressure, mm of Hg: millimeter of mercury.

Table 3. Ultrasonographic measurements of IVC and Aorta

Variables		Mean±SD
IVCD minimum in cm		0.96 ± 0.28
IVCD maximum in cm		1.68 ± 0.44
Aorta diameter maximum in cm		1.41± 0.32
IVC/Aomax		1.2 ± 0.33
<1	35 (27.77%)	
>1	91 (72.22%)	
IVCCI in %		42.98 ± 7.2
>50%	22 (17.46%)	
<50%	104(82.53%)	

A summary of the minimum and maximum IVC diameters, the abdominal aorta diameter, IVC/Ao index and IVCCI is provided in **Table 3**. The means of maximum IVC diameter, abdominal aorta diameter,IVC/Ao index, and IVCCI were 1.686 ± 0.44 cm, 1.41±0.32 cm, 1.2±0.33, and 42.98 ±7.2 respectively (mean±S.D). Of the 126 patients, 27.77% of the patient had IVC/Ao index of <1, and 17.46% had IVCCI of >50%.

Table 4. Distribution of study subjects based on IVCCI <50% and >50%.

Variables	IVCCI <50%	IVCCI >50%	p-value
BMI	24.45 ± 3.18	25.36 ± 4.2	0.25
BSA	1.66 ± 0.17	1.69 ± 0.19	0.54
NPO	220.8 ± 33	243.6 ± 22.8	0.0025**
Preoperative oral Fluid intake	254.32 ±71.09	268.18 ±69.94	0.40
HR	78.47 ± 12.06	81.68 ±14.09	0.28
SBP	128.94 ± 12.45	127.54 ±13.36	0.63
DBP	79.97 ± 8.14	80.81 ± 7.01	0.65
MAP	95.73 ± 9.14	96.18 ±8.72	0.83
IVC/Ao	1.22 ± 0.33	1.12± 0.35	0.20

*** significant p-value*

The study subjects were compared and distributed based on the IVCCI <50% and >50% (**Table 4**). In the group with IVCCI >50%, the minutes for nil per oral was statistically significant (p-value: 0.0025) when compared with a group of IVCCI <50% whereas other parameters were not statistically significant.

Table 5. Distribution of study subjects based on IVC/Ao <1 and >1

Variables	IVC/Ao <1	IVC/Ao >1	p-value
BMI	24.2 ± 3.35	24.76 ± 3.39	0.39
BSA	1.63 ± 0.15	1.68 ±0.18	0.20
NPO	224.4 ± 35.4	225 ± 31.8	0.92
Fluid intake	255.71 ±61.56	257.14 ±74.37	0.91
HR	80.11 ± 12.96	78.61 ± 12.88	0.56
SBP	127.45 ±13.95	129.17 ± 12.05	0.49
DBP	80.88 ±7.77	79.82 ± 8.02	0.50
MAP	95.71 ± 9.65	95.84 ± 8.84	0.94
IVCCI	43.42 ± 8.33	42.77± 6.78	0.65

All the variables were similar in the two groups without any significant intergroup difference(**Table 5**).

Discussion

The pre-operative ultrasound measurements of the IVCCI and IVC/Ao index in this study were 1.2±0.33, and 42.98 ±7.2 (mean±S.D) respectively. Similarly, in a study performed on 102 Indians, the mean IVC/Ao measured in subcostal long-axis view was 1.108± 0.076.[16] Kosiak et al determined that the normal value of IVC/Ao was 1.2 ± 0.34 and established that IVC/Ao was a handy tool and could be assessed reliably by sonographers with little ultrasound experience. For the healthy young population, they recommended the IVC/Ao index reference value of 1.2 ± 2 SD for SD = 0.17.[15,16] Rahman et al established the

IVC/Ao index cut-off point for hypovolemic shock class I as 1.14 through mathemathical computation. Any reading that was less than the specified value was regarded as fluid deprived and in the early stages of hypovolemic shock i.e class I shock.[17] IVC/Ao cutoff ratio of 1.0 was chosen for our study based on the findings of Rahman and Shakya's research.[13,18]

In our study, 35 (27.77%) had IVC/Ao index of <1.0, so, we considered that these patients were hypovolaemic despite no significant changes in their vitals parameters. Baseline hemodynamic parameters in the groups IVC/Ao <1 and >1 was also with in normal range and not significant, much like Shakya's study. They came to the conclusion that patients with IVC: Ao index < 1.0 experienced post-induction hypotension after GA.[13]

Of the 96 patients that Shyma Fathy examined, 54(56%) experienced postinduction hypotension. Compared to the patients without hypotension, hypotensive patients had lower IVC/Ao and higher the IVCCI.[9] The non-invasive nature of ultrasound suggests that it will be more beneficial in routine clinical practice. Additionally, a linear correlation was found between IVC/Ao index and CVP.[7] Numerous studies have different cutoff values for the IVC/Ao, ranging from 0.8 to 1.1.[9,19] In a study by Fathy et al, the positive predictive value was 98% when the caval/aorta diameter index had a cut-off value of less than 0.84.[9] So, intravascular volume status may not always be adequately reflected by a set cut-off.

Of the 126 participants in our study, 22(17.46%) had IVCCI of >50% with hemodynamic parameters within the normal range. According to Szabó M et al's research, preoperative IVCCI ≥50% in spontaneously breathing patients has a high specificity (90%) and low sensitivity (45.5%) for predicting post-induction hypotension.[20]

Preoperative fasting duration was statistically signicant (p value 0.0025) in our study when comparing between the groups with IVCCI >50% and <50%. However, a study by Agrawal et al demonstrated that preoperative fasting does not cause appreciable hypovolaemia; nonetheless, a positive correlation between length of preoperative fasting and the post-induction drop in blood pressure was noted.[21] Additionally, the majority of anaesthetised patients had preoperative functional intravascular deficit, in the study by Bundgaard-Nielsen M et al. Despite the fact that deficit was generally mild, small percentage of patients had deficits that might be clinically significant, highlighting the importance of customized approach to goal-directed fluid therapy. To achieve the maximal stroke volume, 70% of the patients needed fluid therapy.[5]

In a systemic review and meta-analysis of the observational studies by Dana et al they concluded that preoperative IVCCI is a strong predictor of postinduction hypotension.

Prolonged preoperative fasting may cause a latent fluid deficiency that is difficult to identify in healthy and young people. However, in high-risk surgeries, elderly and comorbid patients, this deficit may become clinically significant.[22] Wrobe et al compared the mean IVCCI between inpatient and enhanced recovery after surgery (ERAS) groups, whose mean fasting durations were 13.7 hours and 2.56 hours respectively. Compared to the ERAS group (40.0%; $p<0.001$), the mean IVCCI in the inpatient group (56.8%) was found to be significantly higher.[23] IVCCI might be a safe, simple and practical method for predicting postanesthesia hypotension. However, a fixed cut-off may not always accurately reflect the intravascular volume status because IVC diameter and collapsibility depend on the interaction of several factors such as, intra-abdominal/intrathoracic pressure and venous compliance.[10]

There are some limitations to our study. First, it was a single centered, cross-sectional study. Second, only ASA-PS I-II patients undergoing elective, non-cardiac surgery were included. Third, a single operator performed ultrasound examination; however, prior research showed that the interrater variability was less for IVC/Ao and IVCCI. Fourth, postanesthesia hypotension was not noted.

Even though postanaesthetic hypotension was not noted in our study, it could serve as preliminary research as indices measure intravascular volume that are useful in detecting hypovolaemic or hypervolaemic states before surgery, which is critical for perioperative fluid management. Hypotension is undesirable adverse event of anesthesia and is associated with increased postoperative morbidity. In order to provide preventive measures, the anesthesiologist must anticipate patients who are at high risk of post anesthesia hypotension.

Conclusion

IVC/Ao and IVCCI might be promising non-invasive methods for assessing preoperative intravascular volume status. Their use in clinical practice could improve perioperative management and reduce the risk of complications associated with fluid imbalances. Further research should be directed on these indices to assess intravascular volume status to predict intraoperative hypotension and to establish whether ultrasound-guided preoperative optimization improves outcomes in high-risk patients.

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