Caval Aortic Index: A Novel Tool for Fluid Assessment in Obstetric Emergencies

Lakshmi Priya Menon, Jayaraj Mymbilly Balakrishnan, William Wilson, Mariam Koshi Thomas

Department of Anaesthesiology and Critical Care, Aster Medcity, Cochin, Department of Anesthesiology, Jubilee Mission Medical College and Research Institute, Thrissur, Kerala, Department of Emergency Medicine, Kasturba Medical College, Manipal, Manipal Academy of Higher Education, Manipal, Karnataka, India

Abstract

Background: Uncorrected maternal hypotension occurring during obstetric emergencies may result in maternal and fetal morbidity. Fluid status of the pregnant mother is a major variable which affects the maternal hemodynamics during patient management, and there is no objective assessment tool for the same. A relatively new sonographic parameter, the inferior vena cava aorta (IVC/Ao) diameter index or caval aortic index, showed promise in this regard, and its application was studied in obstetric patients. Methodology: A prospective analytical study was conducted involving 50 pregnant and 50 nonpregnant women of reproductive age group. Using both subxiphoid and transhepatic views, their normal fasting caval aortic indices were determined from the ratio of mean IVC diameter to the mean aortic diameter. Descriptive and inferential statistical analyses were carried out accordingly. Results: Normal IVC/Ao diameter index for nonpregnant healthy women of reproductive age was 1.11 ± 0.29 in the subxiphoid view and 1.21 ± 0.33 in the transhepatic view. The difference between the two views was not statistically significant. IVC/Ao diameter index for a normal term pregnant woman was 1.03 ± 0.26, and term pregnancy does not significantly cause variation in the index. Conclusions: Caval aortic index is a useful noninvasive tool to assess volume status and guide fluid management in pregnant women presenting to the emergency department, and the transhepatic view is comparable to the traditional subxiphoid view for the measurement of the same.

Keywords: Caval aortic index, fluid assessment, obstetric emergencies, ultrasound

Introduction

Ultrasound has rapidly gained popularity in the emergency medicine setting because it is safe, rapid, and noninvasive and can be brought to the bedside. It plays a key role in fluid management, with protocols such as BLUE, RUSH, and FALLS forming the cornerstone of emergency medicine assessment and treatment. One key indicator of fluid status which has been identified and well studied is the inferior vena cava (IVC).[1-3] The size and shape of the IVC are correlated to the central venous pressure (CVP) and circulating blood volume; sonographic evaluation of the IVC is an instantaneous noninvasive measure of volume status[4,5] and has been studied in varied populations such as dialysis, trauma, and sepsis patients.[6,7]

However, some serious problems limit the usefulness of IVC diameter assessment. There is a problem of equipment and appropriately trained staff and, more importantly, lack of clear IVC diameter reference values for the pediatric and adult population. The correlation among IVC diameter, body height, and body surface area (BSA) has already been proven.[8] With critically ill patients, assessing BSA is difficult and time-consuming. The usefulness of this method would significantly increase if IVC diameter was compared with a parameter independent of body fluid status correlating with body growth and surface area similarly to IVC diameter.

Durajska et al. have introduced a new parameter for body fluid status assessment, the IVC aorta (IVC/Ao) diameter index.[9] They proved that the diameter of this largest artery changes with hydration status, but not statistically significant when

Address for correspondence: Dr. Jayaraj Mymbilly Balakrishnan, Department of Emergency Medicine, Kasturba Medical College, Manipal, Manipal Academy of Higher Education, Manipal - 576 104, Karnataka, India. E-mail: jayaraj.mb@manipal.edu

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comparing with BSA. Therefore, comparing IVC diameter with Ao diameter could be a promising method of estimating body water status without the necessity of looking for reference values for each age group or calculating per BSA, which would save the time needed for setting a final diagnosis.

Minimal fluid loss in pregnant patients can result in increased morbidity and mortality. Maternal hypotension if uncorrected will jeopardize the well-being of the fetus and cause morbidity or mortality in the acutely ill.\textsuperscript{[10]} Intravascular fluid status of the pregnant mother is a major variable which affects the maternal hemodynamics. Hence, it would be clinically useful if we can noninvasively assess the intravascular volume status in pregnant patients presenting to the emergency department (ED). This can be used to predict the occurrence of and treat maternal hypotension.

There is a paucity of literature in this context about pregnant patients. Hence, we planned to compare the two groups of patients, namely healthy nonpregnant women of reproductive age group and pregnant women to assess the effect of pregnancy on the variables in the study and to get a nomogram in this group. We also planned to determine the IVC/Ao index in healthy nonpregnant volunteers of reproductive age group and fasting term pregnant women in the study population.

We aimed to study the utility of IVC/Ao index as a fluid status assessment tool and generate a nomogram for pregnant and nonpregnant women of South India.

**Methodology**

This prospective study was done in the Emergency Medicine Department of Jubilee Mission Medical College and Research Institute, Thrissur, Kerala, India, between January 2014 and July 2014. Fifty pregnant women who were >37 weeks of gestation and 50 nonpregnant female volunteers were included in the study. The age for inclusion was between 15 and 45 years. Women with any preexisting comorbidities such as cardiorespiratory or renal disease, bleeding, infections, preterm and postterm pregnancies, multiple pregnancies, antenatal, diagnosed placental anomalies, uncorrected anemias, diagnosed preeclampsia and eclampsia, and hemoglobinopathies were excluded from the study. Participants were asked to have dinner by 10 pm the night before and maintain nil by mouth before the sonological evaluation to make sure that they were having standardized fasting status and that food or fluid would not influence the intravascular volume. We used SonoSite Max-Turbo ultrasound scanner and 3–5 MHz curvilinear probe for the study. Two sets of readings were taken for the IVC and Ao diameter at the subxiphoid and transhepatic regions in the supine position with the volunteer/patient in fasting. Three readings of IVC and Ao (including minimum and maximum diameters of each) in “M mode” were taken, and the mean of each was calculated. The mean IVC/Ao index was determined and compared between the two groups. The mean reference values for both the groups were assessed for the effects of confounding variables as well as the effect of pregnancy.

Informed written consent was obtained from all the individuals participating in the study. Data entry was done in Epi Info\textsuperscript{TM} database and statistics program version 7 (CDC, Atlanta, GA, USA, 2011), and statistical analyses were performed with IBM’s Statistical Package for Social Sciences version 20 (Armonk, NY: IBM Corp., USA, 2011). Descriptive and inferential statistical analysis was performed in the study. The results on continuous measurements are presented on mean ± standard deviation (SD) (minmax), and the results on categorical measurements are presented in number (%). Significance is assessed at 5% level of significance. Based on the outcome variable, with type I error of 5% level and power of 95%, the sample size of 100 (50 in each group) was found to be adequate.

**Results**

One hundred women were equally divided, 50 belonging to the nonpregnant group and 50 belonging to the pregnant group. The demographic variables in terms of mean age, height, and ethnicity for both the groups were comparable. Differences were seen in the mean weight, body mass index (BMI), and BSA, which can be attributed to the effect of pregnancy, the details of which are mentioned in Table 1.

Fifty nonpregnant healthy volunteers were subjected to the measurement of their IVC/Ao index, measured in both subxiphoid and transhepatic views in the supine position. The average values of IVC/Ao index were 1.11 ± 2 SD (SD = 0.29) in the subxiphoid view and 1.21 ± 2 SD (SD = 0.33) in the transhepatic view for 95% confidence intervals (CIs) [Table 2]. There was a difference of 0.1 between the mean values of both views, and when the Chi-square test was applied, it was found that the difference between the two views was not statistically significant ($P = 0.24$).

**Discussion**

Pregnant women presenting with obstetric emergencies require a reliable tool to assess intravascular volume status.

| Table 1: Comparison of demographic data of pregnant and nonpregnant group |
|--------------------------|----------|----------|----------|
| Variable                | Group    | n        | Mean± SD  |
| Age (years)             | Nonpregnant | 50      | 25.30±6.66 |
|                        | Pregnant   | 50      | 25.56±4.38 |
| Weight (kg)             | Nonpregnant | 50      | 51.92±9.98 |
|                        | Pregnant   | 50      | 54.94±19.28 |
| Height (m)              | Nonpregnant | 50      | 1.56±0.06  |
|                        | Pregnant   | 50      | 1.55±0.05  |
| BMI (kg/m\(^2\))       | Nonpregnant | 50      | 21.39±3.34 |
|                        | Pregnant   | 50      | 27.09±3.70 |
| BSA (m\(^2\))          | Nonpregnant | 50      | 1.49±0.16  |
|                        | Pregnant   | 50      | 1.67±0.13  |
| Hours of fasting        | Nonpregnant | 50      | 9.88±1.97 (median 10) |
|                        | Pregnant   | 50      | 10.72±3.12 (median 12) |

BMI: Body mass index, BSA: Body surface area, SD: Standard deviation
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We aimed to establish the usefulness of this index in the emergency obstetric setting. We independently determined the normal fasting IVC/Ao indices in reproductive age group women, 50 nonpregnant and 50 pregnant Indian women. Durajksa et al. first described this sonographic parameter using a mixed Polish population. We considered the possibility that the two patient populations in India and Poland may not be comparable.

In our study, the demographic variables for both the groups, nonpregnant and pregnant, were comparable. Both the groups constituted women from Kerala with a mean age of 25 years and mean height of 1.55 m. The nonpregnant group had a mean weight, mean BMI, and mean BSA of 51.92, 21.39, and 1.49, respectively, whereas the same mean parameters for the pregnant group were 64.94, 27.09, and 1.67 respectively. They varied in mean weight, mean BMI, and mean body surface index, which was attributed to pregnancy.

We found the normal IVC/Ao index in nonpregnant Indian women in the subxiphoid view to be 1.11 ± 2 SDs, where SD = 0.29 for 95% CIs. This is comparable with the normal values of IVC/Ao index established by Kosiak et al. of 1.2 ± 2 SD, where SD = 0.17 (both values with their standard deviations are within the same range). The subxiphoid view is the traditional acoustic window used to measure IVC/Ao index as per various studies in the emergency medicine setting. We measured IVC/Ao index in both the subxiphoid and transhepatic views, as we would need to use the transhepatic view in pregnant women. The subxiphoid view clinically appeared to be a poor acoustic window in term pregnant women, probably due to the effect of the gravid uterus on the normal architecture of the subxiphoid organs and blood vessels.

The normal IVC/Ao index in the transhepatic view in nonpregnant women was determined to be 1.21 ± 2 SD, where SD = 0.33 for 95% CIs. We found that although there was a difference of 0.01 in the mean IVC/Ao indices in both views, it was not statistically significant (P = 0.24). This difference may be due to the pressure effect of the ultrasound probe over the upper abdomen in the subxiphoid view, causing minimal compression over the IVC, resulting in a lower mean value, which leads to the conclusion that both the transhepatic and subxiphoid views can be used interchangeably for IVC/Ao index estimation.

Sridhar et al. attempted a study for studying the IVC/Ao index and comparing it with the CVP for fluid administration. They concluded that the sonographic IVC/Ao index assessment seems to be a quick, simple, noninvasive, and reliable method to access the fluid status in a busy setup like an emergency room. However, the afore mentioned study excluded pregnant patients from the study, which we have studied exclusively and found comparable results to the available literature. CVP being an invasive mode of monitoring, has its own list of complications which further makes it obsolete.

The longitudinal IVC/Ao index measured by Kosiak et al. and our study measurements were similar to the outcomes of the previous studies which for the first time were presented during the 18th European Ultrasound Congress – Euroson 2006 in Bologna and published in the American Journal of Emergency Medicine. The similarity of the results proves that measuring the diameters of the IVC and Ao as well as the calculation of the IVC/Ao index is an easy and fast examination tool for analyzing fluid requirements and fluid administration even in the vulnerable pregnant population and that subhepatic and transhepatic views can be used interchangeably.

The IVC/Ao index, provides as a valuable tool for analyzing fluid requirements and starting targeted therapeutic interventions in pregnant patients with variable hemodynamic status presenting to the ED.

**Conclusions**

We calculated the IVC/Ao index in nonpregnant healthy women in the subxiphoid and transhepatic views and found that the difference between the two views was not statistically significant. In pregnant women, transhepatic view was concluded to be the better acoustic window and pregnancy does not significantly cause variation in the IVC/Ao index. The IVC/Ao index is a simple but effective noninvasive tool which can be used in fluid assessment for obstetric emergencies where minimal hypotension can have disastrous consequences for the mother and the fetus. Further studies on a larger population including patients presenting to the ED are required to substantiate our findings.

**Limitations**

This study had several limitations. The most obvious was that ultrasound measurements were performed by only one

**Table 2: Comparison between inferior vena cava aorta diameter indices of subxiphoid and transhepatic views of the nonpregnant group**

| USG scan view | Mean ± SD | Significance, P |
|---------------|-----------|----------------|
| Subxiphoid    | 1.11±0.29 | 0.240          |
| Transhepatic  | 1.21±0.33 | NS             |

SD: Standard deviation, USG: Ultrasound, NS: Not significance
experienced emergency physician, which leads to doubts regarding the interuser variability of results. Second, the nomogram was generated in a fasting population, which in a clinical setting will not be achievable. Third, the sample size of the study is small and hence to generalize to the Indian population will require further studies.

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**Conflicts of interest**
There are no conflicts of interest.

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