Original Contribution

Impact of individual characteristics on sonographic IVC diameter and the IVC diameter/aorta diameter index

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Background: The inferior vena cava (IVC) parameters, including its diameter and collapsibility index have been evaluated for fluid status for over 30 years, but little is known about the impacts of patient characteristics on IVC parameters. The purpose of this study was to explore the relationships between individual patient characteristics and IVC parameters in healthy Chinese adult volunteers.

Methods: From February 2012 to May 2012, 216 healthy volunteers older than the age of 18 years were consecutively enrolled in our study. The individual characteristics and presence or absence of hypertension of each participant were recorded. Sonographic measurements of IVC and abdominal aorta diameter (Ao) were performed (DP-6900; Mindray, Shenzhen, China).

Results: Volunteers ranged in age from 18 to 84 years (43.7 ± 7.8 years), and 50.5% were males. In univariate analyses, maximum IVC diameter (IVCmax) was negatively correlated with age (years) (r = −0.171, P = .012) and positively correlated with sex (men) (r = 0.174, P = .011), height (centimeters) (r = 0.281, P < .001), and body surface area (square meters) (r = 0.173, P = .011). The IVC/Ao index was negatively correlated with age (years) (r = −0.326, P < .001), waist circumference (centimeters) (r = −0.176, P = .01), body mass index (r = −0.173, P = .011), and hypertension (r = −0.186, P = .006). None of the patient characteristics were significantly correlated with percentage collapse of the IVC. Height (centimeters) was the sole significant predictor of IVCmax (R² = 0.079, P < .001). Age (years) and body mass index (kilogram/square meter) were independent predictors of the IVC/Ao index (R² = 0.123; P < .001 and P = .046, respectively).

Conclusions: The percentage collapse of IVC and the IVCmax are not substantially influenced by patient characteristics. In contrast, the IVC/Ao index is more susceptible to patient characteristics than IVC.

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1. Introduction

Many different conditions can cause hypovolemia in patients who are receiving emergency care, including blood loss, vomiting, diarrhea, urorrhagia, vasodilatation, transudation of fluid into the extravascular compartment, increased insensible fluid loss, and decreased oral intake. Early detection and correction of hypovolemia may limit and/or reverse tissue hypoxia and improve patient outcomes [1]. However, multiple studies have demonstrated that approximately 50% of hemodynamically unstable patients respond to a fluid challenge [2]. In contrast, overzealous resuscitation can lead to increased morbidity and mortality [3,4].

Funds: none.

Conflict of interests: All authors declare that they have no any conflict of interests.

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http://dx.doi.org/10.1016/j.ajem.2015.06.047
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them had a history of hypertension. They may not have been representative of a healthy population. In addition, an ideal tool for measuring volume status should have an established normal reference range. However, to our knowledge, the data available on the normal sonographic values of IVC are sparse [10,13,14]. A study conducted by Rein et al [10] in 1982 enrolled only 10 healthy subjects and has been cited 19 times since 2006.

To mitigate the effects of individual characteristics on IVC diameter and its use as a diagnostic test, Kosiak et al [15] introduced a new tool to evaluate volume status in children and young adults, the IVC diameter/aorta diameter (IVC/Ao) index. The authors reported that the IVC/Ao index was superior to IVC diameter for predicting volume status [15]. However, there has been little subsequent investigation of the utility of the index in evaluating volume status in either children or adults [16].

The aims of the present study were to (1) establish reference ranges for the sonographic measurement of IVC parameters and the IVC/Ao index and (2) assess the effects of individual characteristics on IVC parameters in healthy Chinese adult volunteers.

2. Material and methods

2.1. Study design

This was a cross-sectional descriptive US study conducted in our hospital. Our institutional ethical committee approved the study protocol without requiring participant consent forms; however, the oral consent of participants was required and obtained.

2.2. Study setting and population

From February 2012 to May 2012, we enrolled 228 physically active, healthy volunteers older than the age of 18 years into this study. The volunteers were residents of China who were visiting the Department of US for routine comprehensive health checkups during the study enrollment period. Exclusion criteria included age younger than 18 years, history of symptomatic cardiovascular or cerebrovascular disease, pregnancy, cirrhosis, ascites, moderate-to-severe tricuspid insufficiency, and a BMI above 35 kg/m². The volunteers received no remuneration for their participation.

We initially recruited 228 volunteers for this study. We excluded 12 volunteers from the study because their IVC could not be adequately visualized.

2.3. Study protocol

At the study site, trained nurses asked volunteers their age, sex, and if they had a history of hypertension. Each subject wore light clothes without shoes during anthropometric measurements. Waist circumference was measured midway between the lower rib and the iliac crest. Blood pressure was measured after 5 minutes of rest on 2 occasions 30 minutes apart using a random zero mercury sphygmomanometer on the right arm with the participant in a seated position. Hypertension was defined as systolic blood pressure greater than or equal to 140 mm Hg and/or diastolic blood pressure greater than or equal to 90 mm Hg at 2 different times and/or having a history of hypertension. The IVC diameter was measured approximately 2 cm distal to the IVC-hepatic vein junction, where the anterior and posterior walls of the IVC are visible and parallel to each other (Figure). All images were recorded in 6-second B-mode (gray scale) video clips to ensure that the images captured the full range of respiratory variation and the maximal and minimal IVC diameters rather than an oblique view of the IVC. The maximum and minimum IVC dimensions were obtained by measuring the vein lumen during a regular breathing cycle from one interior wall to the opposite interior wall. The abdominal Ao was measured in a similar manner during systole, 5 to 10 mm above the celiac trunk, from one interior wall to the opposite interior wall. The percentage collapse of the IVC (ΔIVC) was calculated using the following equation:

\[ \text{ΔIVC} = \left( \frac{\text{IVC}_{\text{max}} - \text{IVC}_{\text{min}}}{\text{IVC}_{\text{max}}} \right) \times 100 \]

The IVC/Ao index was calculated as \( \left( \frac{\text{IVC}_{\text{max}}}{\text{Ao}_{\text{diameter}}} \right) \) in millimeters/centimeters.

2.4. Data analysis

Data were expressed as means ± SD (2 SD range) or as proportions. The distributions of the continuous variables were evaluated for normality through histograms and 1-sample Kolmogorov-Smirnov tests. For the latter, \( P > .05 \) indicated a normal distribution. Pearson coefficients were obtained from correlation tests between continuous variables, with transformations used before analysis as necessary. To assess the independent effects of the explored variables on IVCmax, min-

imum IVC diameter, ΔIVC, diameter of the abdominal aorta, and the IVC/Ao index, we used multivariate linear regression models with a forward stepwise inclusion strategy. F statistics with \( P = .05 \) as the criterion level were used to identify variables retained in the model. All statistical analyses were performed using Statistical Package for Social Sciences version 19.0 (SPSS, Inc, Chicago, IL). All the reported \( P \) values are 2 tailed, with those \( < .05 \) considered to be statistically significant.

3. Results

3.1. Demographic data

The measured individual characteristics of the 216 volunteers are shown in Table 1. The mean age was 43.7 ± 7.8 years, the mean height was 163.3 ± 7.9 cm, the mean weight was 59.0 ± 9.9 kg, and the mean waist circumference was 76.9 ± 8.7 cm (mean ± SD). The mean BMI and BSA were 22.1 ± 3.1 kg/m² and 1.6 ± 0.2 m², respectively (mean ± SD).

3.2. Inferior vena cava diameter, abdominal Ao, ΔIVC, and the IVC/Ao index

A summary of the minimum and IVCmax, the abdominal Ao, ΔIVC, and the IVC/Ao index is provided in Table 2. The means of IVCmax, ΔIVC, abdominal Ao, and the IVC/Ao index were 14.9 ± 3.2 mm, 47.3 ± 8.5%, 17.8 ± 2.3 mm, and 0.8 ± 0.2, respectively (mean ± SD). The distribution of minimum IVC diameter was not normal (1-sample Kolmogorov-Smirnov test, \( P = .002 \)); therefore, we report the median, which was 8.0 (6.0-9.9) mm. Square root transformation of minimum IVC diameter was performed to approach normality.

Table 3 shows the correlations between individual characteristics and IVCmax, minimum IVC diameter, ΔIVC, abdominal Ao, and the IVC/Ao index. All of the individual characteristics showed significant positive correlations with abdominal Ao, and none were correlated with ΔIVC. Maximum IVC diameter was negatively correlated with age (years) (\( r = -0.21 \), \( P = .012 \)) and positively correlated with sex (men) (\( r = 0.174, P = .01 \)), height (centimeters) (\( r = 0.281, P < .001 \)), and BSA (square meters) (\( r = 0.173, P = .011 \)). Minimum IVC diameter was positively correlated with height (millimeters) (\( r = 0.176, P = .01 \)) and negatively correlated with age (years) (\( r = 0.21 \), \( P = .001 \)).
The IVC/Ao index was negatively correlated with age (years) \(r = -0.326, P < .001\), waist circumference (centimeters) \(r = -0.176, P = .01\), BMI \(r = -0.173, P = .011\), and hypertension \(r = -0.186, P = .006\).

Table 4 shows the results of multiple linear regression analyses of IVCmax, minimum IVC diameter, abdominal Ao, and the IVC/Ao index with candidate individual characteristics. Height (centimeters) was the sole significant predictor of both IVCmax and minimum IVC diameter \((r = 0.079, P < .001\) and \(r = 0.031, P = .01\), respectively). Age (years) and BSA (square meters) independently predicted diameter of the abdominal aorta \((r = 0.256, P < .001\) and \(P < .001\), respectively). Age (years) and BMI (kilogram per square meter) were independent predictors of the IVC/Ao index \((r = 0.123, P < .001\) and \(P = .046\), respectively).

**4. Discussion**

Our study explores the relationships between participant characteristics and sonographic measurements of IVC and abdominal Ao and the IVC/Ao index in physically active, healthy Chinese adult volunteers. Volunteers in the study were aged 18 to 84 years (43.7 ± 7.8 years). The percentages of men and women were similar (50.5% vs 49.5%, respectively). We found that the IVC/Ao index was not influenced by any of the individual characteristics investigated. In addition, the IVC/Ao index appeared to be more sensitive to individual characteristics than was IVCmax, although the R-squared value of the regression analysis of the IVC/Ao index was only 0.12, compared with the value of 0.08 for the regression analysis of IVCmax. However, none of the tested variables were useful for predicting IVC diameter or any of the other evaluated IVC parameters.

In the present study, the IVC/Ao index was more strongly influenced by individual characteristics than was IVCmax in adults. It appears that the correlations between the predictors and the IVC/Ao index were driven by Ao, which was more susceptible to individual characteristics than were any of the IVC parameters. Therefore, we conclude that the IVC/Ao index does not outperform the IVC parameters in predicting volume status in adult patients.

Our study also establishes the reference ranges for IVCmax (8.5-21.3 mm), minimum IVC diameter (4-13.58 mm), ΔDIVC (29.5%-65.1%), abdominal Ao (13.2-22.4 mm), and the IVC/Ao index (0.4-1.2) in healthy Chinese adults.

Our results are generally in agreement with several previous surveys that have found that IVC diameter varies greatly between individuals and is not substantially influenced by individual characteristics [10,11].

In contrast to our findings, Masugata et al[12] found that age was accompanied by an increase in ΔDIVC in Japanese people in 2010. The authors suggest that low right atrial pressure and decreased IVC compliance in the elderly may have led to their results. However, there were no data available in their study to support this interpretation. Our study was based on healthy Chinese volunteers with an average age of 43.7 ± 7.8 years (range, 18-84 years), whereas their study consisted of elderly Japanese patients with an average age of 66.6 ± 14.7 years. In addition, the prevalence of hypertension in our study was lower than that in their study (19% vs 63%). Therefore, our results are less likely than theirs to be affected by disease and likely more accurately indicate the influence of age on IVC size in healthy adults. In contrast, Krumpe et al [18] demonstrated that aging is associated with an increase in the resting values of right atrial pressure, pulmonary artery pressure, and wedge pressure. Furthermore, elderly subjects breathe with smaller tidal volumes than do younger adults at rest [18], which may also decrease ΔDIVC in the elderly.

Our study found that age was negatively correlated with IVCmax, which is similar to the result in a description of the specific study. However, we also found that age was negatively correlated with height (centimeters) \((r = -0.267, P < .001)\). Multiple linear regression analysis showed that height (centimeters) was the sole independent predictor of IVCmax.

Interestingly, Kathuria et al [19] found a statistically significant positive correlation between age and IVC diameter in healthy pediatric patients. However, the relationship between IVC diameter and other individual characteristics, such as height and weight was not evaluated in the study. There remains a need to further study the relationships between IVC diameter and individual characteristics in children.

### 4.1. Limitations

There are some limitations to our study. First, the volunteers enrolled in our study were physically active, healthy residents who were

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**Table 1**

Demographic characteristics of the study volunteers (n = 216)

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>43.7 ± 14.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-44 (%)</td>
<td>116 (53.7)</td>
</tr>
<tr>
<td>45-59 (%)</td>
<td>63 (29.2)</td>
</tr>
<tr>
<td>≥ 60 (%)</td>
<td>37 (17.1)</td>
</tr>
<tr>
<td>Male (%)</td>
<td>110 (50.5)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>163.3 ± 7.9</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>59.0 ± 9.9</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>76.9 ± 8.7</td>
</tr>
<tr>
<td>Hypertension (%)</td>
<td>41 (19)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>22.1 ± 3.1</td>
</tr>
<tr>
<td>BSA (m²)</td>
<td>1.6 ± 0.2</td>
</tr>
</tbody>
</table>

Values are expressed in mean ± SD or the number of subjects (percent of the total).

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**Table 2**

Sonographic measurement of the IVC and abdominal aorta parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVCmax (mm)</td>
<td>14.9 ± 3.2</td>
</tr>
<tr>
<td>Median (IQR) IVCmax (mm)</td>
<td>8.0 (6.0-9.9)</td>
</tr>
<tr>
<td>ΔDIVC (%)</td>
<td>47.3 ± 8.9</td>
</tr>
<tr>
<td>Ao (mm)</td>
<td>17.8 ± 2.3</td>
</tr>
<tr>
<td>The “IVC/Ao index”</td>
<td>0.8 ± 0.2</td>
</tr>
<tr>
<td>The IVC/BSA (mm²/m²)</td>
<td>9.2 ± 2.0</td>
</tr>
</tbody>
</table>

Abbreviations: IQR, interquartile range; IVCmax, minimum IVC diameter. All values are the mean ± SD, median (interquartile range).
Table 3
Correlation between the IVCmax, minimum IVC diameter, ΔIVC, abdominal aorta, and the “IVC/Ao index” with individual characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>IVCmax</th>
<th>IVCmin</th>
<th>ΔIVC</th>
<th>Ao</th>
<th>The “IVC/Ao index”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>−0.171</td>
<td>.012</td>
<td>−0.134</td>
<td>.049</td>
<td>0.22</td>
</tr>
<tr>
<td>Sex (female, 0; men, 1)</td>
<td>0.174</td>
<td>.01</td>
<td>0.113</td>
<td>.097</td>
<td>0.013</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>0.281</td>
<td>&lt;.001</td>
<td>0.176</td>
<td>.01</td>
<td>0.037</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>0.093</td>
<td>.174</td>
<td>0.074</td>
<td>.276</td>
<td>−0.037</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>−0.064</td>
<td>.35</td>
<td>−0.011</td>
<td>.877</td>
<td>−0.092</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>−0.082</td>
<td>.23</td>
<td>−0.029</td>
<td>.669</td>
<td>−0.075</td>
</tr>
<tr>
<td>BSA (m²)</td>
<td>0.173</td>
<td>.011</td>
<td>0.12</td>
<td>.08</td>
<td>−0.013</td>
</tr>
<tr>
<td>Hypertension (no, 0; yes, 1)</td>
<td>−0.121</td>
<td>.076</td>
<td>−0.093</td>
<td>.075</td>
<td>0.025</td>
</tr>
</tbody>
</table>

Square root transformation of minimum IVC diameter was performed to improve normality.

Table 4
Multiple linear regression analysis of the association of the IVCmax, minimum IVC diameter, abdominal aorta, and the “IVC/Ao index” with candidate individual characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Variable</th>
<th>Coefficient</th>
<th>P</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>The IVCmax</td>
<td>Height (cm)</td>
<td>0.112</td>
<td>(.061 to .164)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>The IVCmin</td>
<td>Height (cm)</td>
<td>0.054</td>
<td>(.013 to .095)</td>
<td>.01</td>
</tr>
<tr>
<td>Ao</td>
<td>Age (y)</td>
<td>0.062</td>
<td>(.044 to .081)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>BSA (m²)</td>
<td>5.504</td>
<td>(3.766 to 7.243)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>The “IVC/Ao index”</td>
<td>Age (y)</td>
<td>−0.004</td>
<td>(−.006 to −0.003)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>BMI (kg/m²)</td>
<td>−0.009</td>
<td>(−0.017 to −0.002)</td>
<td>.046</td>
</tr>
</tbody>
</table>

Square root transformation of minimum IVC diameter was performed to improve normality.

visiting the Department of US for routine comprehensive health checkups. There may be some selection bias. Second, although participants with moderate-to-severe tricuspid insufficiency were excluded from our study, mild tricuspid insufficiency was not recorded or analyzed. Third, our study is only a cross-sectional study. A prospective cohort study should be performed to confirm the relationship between participant height and IVC diameter.

5. Conclusion

We conclude that height is an independent predictor of IVCmax. However, height only explained a small percentage (7.9%) of the variance in IVCmax. Similarly, age (years) and BMI (kilogram per square meter) were independent determinants of the IVC/Ao index, but, together, they explained only a small percentage (12.3%) of the variance in the IVC/Ao index. The values of the IVC parameters and Ao varied greatly among individuals but were not substantially influenced by participant characteristics. It appears that the correlations of predictors with the IVC/Ao index were driven by Ao, which was more susceptible to individual characteristics than were any of the IVC parameters. Therefore, we conclude that the IVC/Ao index did not perform better than the IVC parameters in predicting volume status for adult patients.

Acknowledgments

The authors appreciate all attending physicians working in our hospital for providing their full support for this study.

References


