Effect of positional changes on inferior vena cava size

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Aim
To study the effect of positional change on inferior vena cava (IVC) diameter. The influence of positional change on IVC size is not well studied. Although the American Society of Echocardiography guidelines for chamber quantification recommend imaging the IVC in the left lateral position, many labs routinely image the IVC from the supine position.

Methods and results
Forty-three patients (age 39.5 ± 9.4) with normal echocardiographic findings were studied. Subcostal imaging was used to assess the IVC in the supine and left lateral positions. IVC dimensions, hepatic vein (HV) Doppler and tricuspid regurgitation (TR) jet velocity were measured. IVC systolic and diastolic dimensions were larger in the supine compared with the left lateral position (17.2 ± 4.1 vs. 10.9 ± 4.4 mm, P < 0.001; 16.2 ± 4.5 vs. 9.9 ± 4.4 mm, P < 0.001, respectively). Position had no influence on HV systolic and diastolic peak velocity. (35.4 ± 23.7 vs. 31.8 ± 35.0 cm/s, P = 0.461; 24.2 ± 19.5 vs. 25.4 ± 31.9 cm/s, P = 0.775, respectively).

Conclusions
The IVC dimension is larger in the supine position independent of the cardiac cycle. This may be due to increased intra-abdominal pressure and compression of the IVC by the liver in the left lateral position. HV systolic and diastolic peak Doppler velocities were not influenced by position.

Keywords
Inferior vena cava • Hepatic vein • Positional change

Introduction
The inferior vena cava (IVC) diameter as measured by echocardiography can be affected by tumour masses, respiration, and right atrial (RA) pressure.¹–³ The IVC has been studied in patients with congestive heart failure and particularly in patients with rightsided cardiovascular disease or pericardial disease.²,⁴ The IVC is commonly dilated in these patients with either an absent or reduced response to inspiration suggesting elevated right heart pressures. The influence of positional change on IVC size is not well studied. Although the American Society of Echocardiography (ASE) guidelines for chamber quantification recommend imaging the IVC in the left lateral decubitus position, many echocardiographic laboratories routinely image the IVC in the supine position. This study evaluates the effect of positional change on IVC diameter in a cohort of healthy young patients with an entirely normal echocardiographic study.

Methods

Subjects
Forty-three young healthy patients (27 females and 16 males, average age 39.5 ± 9.4 years) undergoing routine echocardiography at the Mayo Clinic Noninvasive Hemodynamic Laboratory had the IVC assessed after a complete echocardiogram was performed. Patients were included in the study after informed consent and Institutional Review Board (IRB) Approval was obtained. Only patients with an entirely normal study and no evidence of valvular heart disease, pericardial disease, or diastolic dysfunction were included in the study.

Echocardiography
Doppler echocardiographic study was performed according to the ASE guidelines in the left lateral decubitus with conventional parasternal long-axis views, parasternal short-axis, apical 2-, 3-, 4-, and 5-chamber views. Subcostal views were done subxiphoid in the...
supine position. The IVC dimensions were measured at end expiration. Subcostal assessment of the IVC was repeated with the patient in the left lateral position. Each subject underwent detailed transtracheal two-dimensional (2D), M-mode, Doppler and tissue Doppler echocardiography with a Sequoia 512 (Siemens Medical Solutions USA, Inc., Mountain View, CA, USA) with an ultrasound transducer operating at 3V2c (3.5 MHz) and Vivid 7 (GE Healthcare, Milwaukee, WI, USA) instrument using standardized techniques per ASE guidelines. Echocardiograms were uploaded digitally to online system (ProSolv Cardiovascular, Indianapolis, IN, USA) for off-line analysis. Echocardiograms were interpreted by experienced echocardiologists. IVC diameter was determined in the long- and short-axis views in the subcostal view 1–2 cm distal to the junction of the right atrium. Following the recommendations of ASE guidelines developed in conjunction with the European Association of Echocardiography (EAЕ), the IVC was described as small when the diameter was <1.2 cm, normal when the diameter measured between 1.2 and 1.7 cm, and dilated when it measured >1.7–2.5 cm, markedly dilated when it >2.6 cm. All measures reflect an average of three values taken at end expiration and three consecutive respiratory cycles. IVC Doppler and Hepatic vein (HV) flow velocities were obtained in the subcostal view at the same time. An estimation of RA pressure was done through the Caval index (IVC percent collapse) described by Kircher et al. namely a 50% reduction at end inspiration was considered equivalent to an RA pressure <10 mmHg. According to Nakao et al., the collapsibility index (CI) was measured in the supine position as well as the left lateral positions. Two independent readers blinded to the patient demographics and position performed IVC measurements during respiration and CI was estimated as described. A high correlation was found for both intra- and interobserver reliabilities (r = 0.98 and 0.96, respectively).

Statistical analysis
Data are expressed as means and standard deviations. Paired sample t-test was used for comparison between echocardiographic indices.

Results
The IVC end-systolic and -diastolic dimension were significantly larger in the supine position compared with left lateral poison (17.2 ± 4.1 vs. 10.9 ± 4.4 mm, P < 0.001; 16.2 ± 4.5 vs. 9.9 ± 4.4 mm, P < 0.001, respectively) (Figure 1A and B). The HV systolic and diastolic peak velocity showed no significant difference when measured in either the supine or left lateral positions (35.4 ± 23.7 vs. 31.8 ± 35.0 cm/s, P = 0.461; 24.2 ± 19.5 vs. 25.4 ± 31.9 cm/s, P = 0.775, respectively). Echocardiographic measurements of IVC diameter in the supine position in systole and diastole are not different 17.2 ± 4.1 and 16.2 ± 4.5 mm, respectively. IVC diameters in the left lateral recumbent position in systole and diastole are also essentially not different at 10.9 ± 4.4 and 9.9 ± 4.4 mm, respectively. The mean peak tricuspid regurgitation (TR) velocity was 2.08 m/s (n = 27, range is 0–2.5 m/s). Echocardiographic data are displayed in Table 1.

Discussion
The IVC is a highly compliant vessel that changes its diameter and cross-sectional area in parallel with changes in blood volume and central venous pressure. Respiratory, intra-thoracic and intra-abdominal pressures may also influence the volume and diameter of the IVC. Accuracy in IVC measurement has clinical implications in the diagnosis and management of cardiac disorders because it affects the estimation of right-sided cardiac pressure, which is estimated semi-quantitatively by non-invasive ultrasound imaging. Kircher et al. describes a method for estimating RA pressure depending upon the magnitude of inspiratory reduction or collapse of the IVC on echocardiography. A ≥50% reduction in IVC calibre with inspiration suggests a normal RA pressure equal to 10 mmHg. Nakao et al. suggested that the CI can not be reliably measured in the left lateral position because of the small size of IVC in this position; they also mentioned that the CI is affected more by IVC size than by RA pressure. Himelman et al. showed that <50% reduction in IVC diameter after deep inspiration and is considered plethora in constrictive pericarditis and cardiac tamponade, where the RA pressure is usually >10 mmHg.

At end inspiration, with a negative intrathoracic pressure, the IVC collapses as it empties into RA facilitated by the inspiratory driven negative intrathoracic pressure. The degree of emptying is directly proportional to the IVC/RA pressure gradient. The inspiratory pressure required to decrease the IVC calibre ≥ 85% of the difference between its maximal and minimal values allows the assessment of RA pressure. IVC diameter is therefore a useful and sensitive marker of central venous pressure.

Echocardiographic dimensions (diameter and area) of the IVC performed in the left lateral position provide the best non-invasive estimation of RA pressures. Nakao et al. proved that the IVC dimensions in the left lateral position shows the best correlation with RA pressure with greater accuracy than those measured in the supine or right lateral positions. The reasons for the changes were not investigated nor the relation of those changes to cardiac cycle. In our study, measurements of the IVC diameter were made in both systole and diastole in both supine and left lateral positions. In both positions, there were no significant changes in calibre with regard to the cardiac cycle phase. These added measurements in systole and diastole further strengthens the concept that positional change influence IVC calibre, which might be attributed to increased intra-abdominal pressure and compression of the IVC by the liver in the supine position. Furthermore in instances where the IVC dimension may be large in the supine position in healthy subjects, HV systolic and diastolic Doppler estimated velocities remained normal in both inspiration and expiration.

None of the subjects in our study had any of the diseases that may be aetologically implicated in causing volume overload, nor were any of them highly trained athletes or pregnant at the time, yet an increase in IVC size was documented in the supine compared with the left decubitus position. In the absence of cardiac disease, it is presumed that reduction of the IVC diameter in the left lateral position is likely related to compression of the IVC by the liver.

HV dimensions, systolic and diastolic Doppler velocities did not show variation with postural change, this is likely because these structures are intra hepatic and not subject to compression.
**Study limitations**

A comparative study with athletes and mid-trimester pregnancy may be helpful; however, in the latter physiologic body volume expansion occurs and may influence IVC size as well.

**Conclusions**

The IVC dimension is larger in the supine position than in the left lateral position, this may be due to increased intra-abdominal pressure and compression of the IVC by the liver in the left lateral position. This increase in IVC diameter is normal in young

**Table 1  Echocardiographic data**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Left lateral</th>
<th>Supine</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVC dimension systole (mm)</td>
<td>10.9 ± 4.4</td>
<td>17.2 ± 4.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>IVC dimension diastole (mm)</td>
<td>9.9 ± 4.4</td>
<td>16.2 ± 4.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>HV velocity systole (cm/s)</td>
<td>31.8 ± 35</td>
<td>35.4 ± 23.7</td>
<td>0.461</td>
</tr>
<tr>
<td>HV velocity diastole (cm/s)</td>
<td>25.4 ± 31.9</td>
<td>24.2 ± 19.5</td>
<td>0.775</td>
</tr>
</tbody>
</table>

IVC, Inferior vena cava; HV, Hepatic vein.
healthy adults. HV diameter, systolic and diastolic Doppler flow, did not show significant variation, because these structures are intrahepatic and there is no compression with postural change. Hence, when estimating RA pressure from IVC calibre and a larger IVC size is noted in the supine position, careful assessment of the HVs is warranted. Furthermore, measuring the IVC in the left decubitus position will confirm normal vascular volumes. Comparative studies with trained athletes and pregnant women may be helpful in delineating other factors that influence a change in IVC diameter with a change in posture.

Conflict of interest: none declared.

References
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