Sonographic Evaluation of Internal Jugular Vein Diameter and Cross-Sectional Area Measurements in Correlation with Left Ventricular End Diastolic Area (LVEDA) as a Tool for Perioperative Assessment of Volume Status and Fluid Therapy in Pediatric Patients Undergoing Cardiac Surgery


The Department of Anaesthesiology, Faculty of Medicine, Cairo University

Abstract

Aim: The aim of this study is to compare the ultrasound estimation of the cross sectional area and diameter of Internal Jugular Vein (IJV) with Left Ventricular End Diastolic Area (LVEDA) for assessment of intravascular volume in pediatric patients during cardiac surgery.

Material and Methods: The cross sectional area and diameter of the left internal jugular vein were defined, using ultrasound machine, and compared with LVEDA, estimated by Trans-ESophaggeal Echo (TEE), in four times intervals (immediately after induction (T1), before the start of CPB (T2), immediately after weaning of Cardio-Pulmonary Bypass CPB (T3) and at the end of surgery before transfer to ICU (T4)) as a tool for intravascular volume assessment in 16 pediatric patients undergoing cardiac surgery.

Results: There was poor correlation between IJV cross sectional area and diameter with LVEDA. r-values were: 0.158, 0.265, 0.449, 0.201 at the four time intervals (T1, T2, T3, and T4) respectively.

Conclusion: Estimation of the cross sectional area and diameter of the left internal jugular vein using ultrasound is not reliable and cannot be used alone to decide further management.

Key Words: Sonographic evaluation – Internal jugular vein – Left ventricular end diastolic area – Volume status – Fluid therapy – Pediatric patients – Cardiac surgery.

Introduction

FLUID administration is one of the maneuvers to augment cardiac output. Volume expansion is essential to improve the outcome in patient undergoing cardiac surgery. However, unnecessary volume load may cause deterioration in myocardial function with the development of acute heart failure. Therefore, assessment of the volume status during cardiac surgery is essential to optimize hemodynamics to guide fluid therapy [1].

Left Ventricular End-Diastolic Area (LVEDA) is a good predictor of preload. One major issue with this parameter is that in the absence of baseline echocardiographic data of absolute levels of LVEDA which varies from patient to patient, depending upon baseline cardiac anatomy and physiology [3]. Another issue that it requires anesthetists with specialized experience who have undergone rigorous training in these techniques [4].

A pilot study reported the successful utilization of ultrasonography of Internal Jugular Vein (IJV) as a non-invasive method to predict central venous pressure as a method for determination of intravascular volume status in spontaneously breathing critical care patient [5].

The aim of the present study is to evaluate the correlation between the ultrasonographic assessment of cross sectional area and diameter of IJV to LVEDA as tools used to assess the volume status in pediatric patients undergoing heart surgery.

Patients and Methods

This study was an observational study carried out in the Cardiothoracic Unit of the Children's Hospital of the Faculty of Medicine, Cairo University over the period from 2/20 14 – 6/2015. Sixteen patients having congenital heart disease were enrolled in the study after obtaining the approval of
the Medical and Ethical Committees and an informed consent from parents.

Inclusion criteria were: Age between 2 and 10 years, weight between 10 and 30kg, simple congenital heart lesions, e.g. ASD, VSD, both sexes. Exclusion criteria were: Abnormal laboratory findings (liver functions, kidney functions), associated right-sided and pulmonary artery lesions, concurrent endocrine abnormality, complex congenital lesions, dehydrated patient, and congestive heart failure.

All patients were subjected to detailed history taking from the parent and preoperative assessment in the form of clinical assessment (temperature, chest condition and associated anomalies), laboratory assessment (CBC, PT, PC, INR, liver functions, kidney functions and random blood sugar) and imaging (Electrocardiogram (ECG), Echocardiography, Chest X-ray).

In the preparing room premedication was given in the form of intramuscular administration of midazolam at a dose of 0.2mg/kg, atropine at a dose of 0.02mg/kg given 10 minutes before induction of anesthesia.

Standard monitors were applied (ECG, pulse oxymeter, non-invasive blood pressure and temperature probe) before induction of anesthesia.

Induction was carried on by inhalational technique using sevoflorane at 2 MAC and Fentanyl intravenous administration of 2µg/kg. Sevoflorane MAC was increased till ensuring hypnosis as shown by immobilization and absence of response to external stimuli. Intubation was by panceuronium at 0.1mg/kg then mechanical ventilation was instituted on pressure mode giving a tidal volume of 5-7ml/kg and rate adjusted 20-30 according to age maintain adequate oxygenation at the lowest possible FiO₂ and avoiding hypercarbia or hypocarbia adjusted by arterial blood gases.

Under complete aseptic technique central venous catheter was inserted sonar guided using. Arterial cannula was inserted and a sample of arterial blood gases was obtained as a base line.

Maintenance of anesthesia was by giving Fentanyl at a dose of 1µg/kg/h, sevoflorane at 1 MAC and pancuronium at 0.02mg/kg every 40 minutes till initiation of CPB where anesthesia will be maintained by sevoflorane 2% connected to CPB machine and .01mg/kg pancuronium every 30 minutes.

A SonoSite M-Turbo handheld ultrasound machine (SonoSite, Bothell, WA) was used for all examinations. A vascular transducer for internal jugular vein imaging (5-10MHz, 38-mm linear array) was used.

Internal jugular vein measurements were obtained at the level of the cricoid cartilage. First, ultrasound gel was applied to the side of the neck contra lateral to the central line. A vascular transducer was then placed lightly on the neck and the internal jugular vein was identified. Manual pressure was used to collapse the II, distinguishing it from the less compressible and pulsatile carotid artery. Next, small adjustments in probe position were made to ensure that the image plane was perpendicular to the vein and that no pressure was applied to the probe-skin interface (as either could influence the vessel dimensions). After obtaining an optimized II image, the vessel dimensions were recorded.

Transesophageal echocardiography was performed using an Omni plane III probe (SONOS 5500, GE Medical Systems). Left ventricular end-diastolic area was determined by manual planimetry of the area circumscribed by the leading edge technique at the mid esophageal four chamber view.

Study outcome measures: Correlation of IJV cross sectional area and diameter to LVEDA in the following times: (T1) immediately after induction (base line), (T2) before the start of CPB, (T3) immediately after weaning of CPBT and (T4) at the end of surgery before transfer to ICU.

Statistical methods:

Sample size: Power analysis based on alpha=0.05, beta=0.8, a sample size of 16 patient will be required to detect a statistically significant correlation \( r = 0.6 \) between IJV cross sectional area measurement and LVEDA with a power of 80%.

Data were coded and entered using the statistical package SPSS version 21. Data was summarized using mean, Standard Deviation (SD), minimum and maximum for quantitative variables and frequencies (number of cases) and relative frequencies (percentages) for categorical variables. Correlations were done to test for linear relations between quantitative variables by Pearson correlation coefficient. A probability value \( p \)-value less than 0.05 was considered statistically significant.

- \( r \): Pearson's coefficient:
  - 0.01-0.19: Very weak; negligible correlation.
  - 0.20-0.39: Weak correlation.
- 0.40-0.69: Moderate correlation.
- 0.70-0.89: Strong correlation.
- 0.90-1.00: Very strong correlation.

*p*-value; *p*<0.05 is considered significant.

**Results**

Sixteen pediatric patients with congenital heart disease undergone cardiac surgery were included. The mean age of the group was 4.9 years with SD of 2.5, the youngest was 2 years, and the oldest was 9 years. The mean weight of the group was 16.25 kg with SD of 4.7, the smallest weight was 10 kg and the largest weight was 25 kg. (Table 1).

As regards the role IJV diameter measured by ultrasound it was 9.88±1.17 mm in T1 then it became 8.5±1.2 mm in T2, it increased again to 9.61±1.5 mm in T3 then finally was 9.11±1.2 mm. On the other hand, LVEDA in T1 was 10.74±0.93 cm² then increased to 11.91±2 cm² in T2 and almost maintained the same in T3 (11.36±2.6 cm²) finally it decreased to 10.33±1.19 cm² in T4 (Table 1).

There was a poor correlation between IJV diameter and LVEDA as *r*-values were: 0.158, 0.265, 0.449, and 0.201 in T1, T2, T3 and T4 respectively [(Table 2) & Fig. (1)].

IJV cross sectional areas measured by ultrasound were 77.12±18.2 cm² in T1 and then decreased markedly to become 55.56±16.3 cm² in T2 then it increased again to become 74.31±21.7 cm² (T3), lastly it became 66±17.5 cm² in T4. There was also a poor correlation between IJV cross sectional area and LVEDA, *r*-values are: 0.163, 0.230, 0.485, and 0.259 in T1, T2, T3 and T4 respectively [(Table 3) & Fig. (2)].

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**Table (1): Descriptive data (IJV: Internal jugular vein, LVEDA: Left ventricular end diastolic area).**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (SD)</th>
<th>Median (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>4.93 (2.5)</td>
<td>4.00 (2-9)</td>
</tr>
<tr>
<td>Weight</td>
<td>16.25 (4.7)</td>
<td>15.00 (10-25)</td>
</tr>
<tr>
<td>IJV diameter 1</td>
<td>9.88 (1.17)</td>
<td>9.75 (8.6-12.5)</td>
</tr>
<tr>
<td>IJV diameter 2</td>
<td>8.5 (1.2)</td>
<td>8.60 (6.8-11)</td>
</tr>
<tr>
<td>IJV diameter 3</td>
<td>9.61 (1.5)</td>
<td>9.55 (7.1-12.4)</td>
</tr>
<tr>
<td>IJV diameter 4</td>
<td>9.11 (1.2)</td>
<td>9.20 (7.2-11.1)</td>
</tr>
<tr>
<td>IJV cross sectional area 1</td>
<td>77.12 (18.2)</td>
<td>74.50 (58-122)</td>
</tr>
<tr>
<td>IJV cross sectional area 2</td>
<td>55.56 (16.3)</td>
<td>56.50 (33-92)</td>
</tr>
<tr>
<td>IJV cross sectional area 3</td>
<td>74.31 (21.7)</td>
<td>70.50 (44-120)</td>
</tr>
<tr>
<td>IJV cross sectional area 4</td>
<td>66.00 (17.5)</td>
<td>65.50 (41-93)</td>
</tr>
<tr>
<td>LVEDA 1</td>
<td>10.74 (0.93)</td>
<td>10.90 (8-12.3)</td>
</tr>
<tr>
<td>LVEDA 2</td>
<td>11.91 (2)</td>
<td>11.35 (8.8-15.8)</td>
</tr>
<tr>
<td>LVEDA 3</td>
<td>11.36 (2.6)</td>
<td>11.10 (8-2-16.5)</td>
</tr>
<tr>
<td>LVEDA 4</td>
<td>10.33 (1.19)</td>
<td>10.35 (8.6-12)</td>
</tr>
</tbody>
</table>

**Table (2): Correlation between IJV diameter and traditional parameters for volume status LVEDA.**

<table>
<thead>
<tr>
<th>T</th>
<th>r-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>0.158</td>
<td>0.560</td>
</tr>
<tr>
<td>T2</td>
<td>0.265</td>
<td>0.321</td>
</tr>
<tr>
<td>T3</td>
<td>0.449</td>
<td>0.081</td>
</tr>
<tr>
<td>T4</td>
<td>0.201</td>
<td>0.454</td>
</tr>
</tbody>
</table>

IJV: Internal Jugular Vein.
LVEDA: Left Ventricular End Diastolic Area.

**Table (3): Correlation between IJV cross sectional area and traditional parameters for volume status LVEDA.**

<table>
<thead>
<tr>
<th>T</th>
<th>r-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>0.163</td>
<td>0.547</td>
</tr>
<tr>
<td>T2</td>
<td>0.230</td>
<td>0.392</td>
</tr>
<tr>
<td>T3</td>
<td>0.485</td>
<td>0.057</td>
</tr>
<tr>
<td>T4</td>
<td>0.259</td>
<td>0.333</td>
</tr>
</tbody>
</table>

IJV: Internal Jugular Vein.
LVEDA: Left Ventricular End Diastolic Area.

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**Fig. (1):** Relationship between Internal Jugular Vein (IJV) diameter and Left Ventricular End Diastolic Area (LVEDA) at T1. Linear correlation: *r* = 0.158, *p*-value = 0.560.

**Fig. (2):** Relationship between Internal Jugular Vein (IJV) cross sectional area and Left Ventricular End Diastolic Area (LVEDA) at T1. Linear correlation: *r* = 0.163, *p*-value = 0.467.
Discussion

This study aimed to evaluate IJV cross dimensions as a reliable noninvasive tool to assess intravascular volume status in pediatric patients undergoing cardiac surgery. IJV dimensions were compared (LVEDA) which is considered the gold standard for assessment of intravascular volume [3].

As regards the role IJV cross sectional area in detection of preload there was a poor correlation between IJV cross sectional area and LVEDA, \( r \) values were: 0. 163, 0.230, 0.485, 0.259. Also, there was a poor correlation was between IJV diameter and LVEDA, \( r \)-values were: 0. 158, 0.265, 0.449, 0.201 in T1, T2, T3 and T4 respectively.

Central Venous Pressure (CVP) and Pulmonary Artery Systolic Pressure (PASP) failed to be reliable indicators for preload fluid assessment. However, TEE, as a semi invasive tool, showed a great reliability in this aspect [6].

There were many trials to find a non invasive method to estimate fluid status, one of them is Inferior Vena Cava (IVC) diameter variability with breathing was tested as an indicator for fluid responsiveness and volume status using TEE or Trans-thoracic Echo (TTE) through sub-costal window. It has the advantage of not being affected by the intra-thoracic pressure, on contrary it is affected by the intra-abdominal pressure, it has sensitivity and specificity of 90% [7-9].

Also, Superior Vena Cave (SVC) diameter variability has been tested using the TEE window with good sensitivity and specificity but with the limitation of being affected by the intra-thoracic pressure and the need of TEE [10].

Another noninvasive method to assess the volume status using the venous system is the passive leg raising PLR test [11,12]. 12% increase in stroke volume with PLR is a positive test [13].

Other studies that agree with this one show also no correlation such as Kent, et al., study, who considered that Inferior Vena Cava Collapsibility Index (IVC-CI) is an accurate tool for intravascular volume assessment. He wanted to detect another non invasive tool for intravascular volume assessment. It was a prospective, observational study in 39 medical ICU patients comparing Inferior Vena Cava Collapsibility Index (IVC-CI) and Internal Jugular Vein Collapsibility Index (IJV-CI). Concurrent M-mode measurements of IVC-CI and IJV-CI were collected during each sonographic session. Their results showed that correlations between IVC-CI/IJV-CI (\( r=0.38 \)) were weak. These results indicate that IJV-CI should not be used as a primary intravascular volume assessment tool for clinical decision support in the ICU [14].

Another study with the same aim of this study to detect noninvasive tool for intravascular volume assessment by comparing IVC diameter with the CVP, similar results confirmed that bedside ultrasonographic measurements of the IVC diameter were inaccurate tool for assessment of intravascular volume as determined by CVP in critical ill children. They used a convenience sample of children <21 years-old who were admitted to the pediatric Critical Care Unit and required CVP monitoring had bedside ultrasound measurements of both IVC and aortic diameters with simultaneous CVP measurement. IVC/Aorta ratio (transverse view) was calculated from these measurements. Their results suggested IVC/Aorta has no correlation with CVP in assessing intravascular volume in the study population (\( r=0.19, p=0.22 \)) [15].

Simon, et al., had a study with the same aim of our study but with different results. He wanted to detect a reliable noninvasive tool for detection of right atrial pressure. He studied 67 patients undergoing right heart catheterization and compared the cross sectional area of internal jugular vein during Valsalva maneuver with the direct measurement of right atrial pressure. He found that a 17% increase in RIJV CSA with Valsalva predicted elevated RAP (>or=12mmHg) (\( p \)-value <.001) [16].

In another observational pilot study over 18 patients scheduled for cardiac surgery. There were significant correlations between left ventricular end diastolic volume measured by transeosophageal echo using simpson’s formula with internal jugular vein antro-posterior diameter (\( r:0.71 \)), internal jugular vein transverse diameter (\( r:0.51 \)), internal jugular vein cross sectional area (\( r:0.76 \)). This study offers insight into the possibility of using ultrasound as non-invasive tool to identify changes in the volume status of surgical patients. However the sample size was very small, only 10 were included in the study analysis of IJV diameter and cross sectional area [17].

Conclusion:

Assessment of volume status in pediatric patients undergoing cardiac surgery is a multi-factorial issue; it needs multi model toools and measurements including clinical point of views. IJV diameter and cross sectional area measurements by ultrasound in those patients are not reliable and cannot be
used alone to decide further management. Future research is needed to correlate these parameters together in the different groups of patients.

References


تهدف هذه الدراسة إلى إيجاد وسيلة غير مجذوبة لإيصال حالة السوائل داخل جسم الأطفال الخاضعين لعمليات القلب وذلك عن طريق مقارنة بين قياسات السونار لقطر ومساحة المريج من الوريد الودائي الداخلي مع قياس مساحة البطين الأيسر في نهاية الارتخاء.

القياسات التي يتم اتخاذها:
• قياسات السونار لقطر الوريد الودائي الداخلي.
• قياسات السونار للمساحة المريجة من الوريد الودائي الداخلي.
• قياسات ايكو المريج لمساحة البطين الأيسر في نهاية الارتخاء.

مواضيع بعد هذه القياسات في هذه الدراسة:
• فورا بعد تخدير المريض.
• قبل الخروج من ميكة القلب.
• بعد الخروج من ميكة القلب.
• بعد انتهاء العملية وقبل نقل المريض للرعاية المركزية.

أثبتت النتائج وجود علاقة ضعيفة بين إعداد الوريد الودائي الداخلي وبين مساحة البطين الأيسر في نهاية الارتخاء.

الخلاصة: قطر ومساحة الوريد الودائي الداخلي مقياس بالسونار لا يمكن ان تستخدم وحدها لتحديد حالة سوائل الجسم ولكن بحاجة الى ابحاث مستقبلية لإيجاد علاقة بين هذه القياسات في مجموعات أخرى من المرضى.