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

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Abstract

Aim: The aim of this study is to compare the ultrasound estimation of the cross-sectional area (CSA) and diameter of internal jugular vein (IJV) with left ventricular end diastolic area (LVEDA) for the assessment of intravascular volume in pediatric patients during cardiac surgery.

Patients and Methods: The CSA and diameter of the left IJV were defined, using ultrasound machine, and compared with LVEDA, estimated by transesophageal echo, in four times intervals (immediately after induction [T1], before the start of cardiopulmonary bypass [CPB] [T2], immediately after weaning of CPB [T3], and at the end of surgery before transfer to the Intensive Care Unit [T4]) as a tool for intravascular volume assessment in 16 pediatric patients undergoing cardiac surgery. Results: There was a poor correlation between IJV CSA and diameter with LVEDA. r values were 0.158, 0.265, 0.449, and 0.201 at the four time intervals (T1, T2, T3, and T4), respectively. Conclusion: Estimation of the CSA and diameter of the left IJV using ultrasound is not reliable and cannot be used alone to decide further management.

Keywords: Internal jugular vein diameter and cross-sectional area, left ventricular end diastolic area, volume status

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 further deterioration in myocardial function with the development of acute heart failure. Therefore, the assessment of the volume status during cardiac surgery is mandatory to optimize hemodynamics to guide fluid therapy.[1]

Traditionally accepted methods for perioperative volume assessment include the measurement of central venous pressure (CVP). However, this method is invasive and can subject the patient to complications. Therefore, it is not applicable in all surgical populations.[2]

Left ventricular end-diastolic area (LVEDA) is also a good predictor of preload. One major disadvantage of this parameter is that 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 noninvasive method to predict CVP as a method for determination of intravascular volume status in spontaneously breathing pediatric patients undergoing cardiac surgery. The aim of this study was to compare the ultrasound estimation of the cross-sectional area (CSA) and diameter of internal jugular vein (IJV) with left ventricular end-diastolic area (LVEDA) for the assessment of intravascular volume in pediatric patients during cardiac surgery.
critical care patient. There was a positive correlation between sonographic measurement of IJV diameter and CVP.\(^5\)

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

**Patients and Methods**

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**

Inclusion criteria included age between 2 and 10 years, weight between 10 and 30 kg, and simple congenital heart lesions, e.g., atrial septal defect, ventricular septal defect, both sexes.

**Exclusion criteria**

Exclusion criteria included 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 (complete blood count, prothrombin time, prothrombin concentration (PC), international normalized ratio, 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 0.2 mg/kg, atropine at a dose of 0.02 mg/kg will be given 10 min before the induction of anesthesia.

Standard monitors were applied (ECG, pulse oximeter, noninvasive blood pressure, and temperature probe) before induction of anesthesia.

Induction was carried on by inhalational technique using sevoflurane at 2 minimum alveolar concentration (MAC) and fentanyl intravenous administration of 2 μg/kg. Sevoflurane MAC was increased till ensuring hypnosis as shown by immobilization and absence of response to external stimuli.

Intubation was facilitated by pancuronium at 0.1 mg/kg, then mechanical ventilation was instituted on pressure mode giving a tidal volume of 5–7 ml/kg and rate adjusted 20–30 according to age maintain adequate oxygenation at the lowest possible FiO\(_2\) and avoiding hypercarbia or extreme hypocarbia adjusted by arterial blood gases.

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

Anesthesia was maintained by giving fentanyl at a dose of 1 μg/kg/h, sevoflurane at 1 MAC, and pancuronium at 0.02 mg/kg every 40 min till initiation of cardiopulmonary bypass (CPB) where anesthesia will be maintained by sevoflurane 2% connected to CPB machine and 0.01 mg/kg pancuronium for every 30 min.

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

IJV measurements were obtained at the level of the cricoid cartilage. First, ultrasound gel was liberally 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 IJV was identified. Manual pressure was used to collapse the internal jugular vein (IJV), 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 IJ image, a 10-s B-mode cine loop was obtained and reviewed frame by frame to identify the largest CSA (during expiration), and vessel dimensions were recorded.

Transesophageal echocardiography was performed using an Omni Plane III probe (SONOS 5500, GE Medical Systems, WI, USA). LVEDA 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 CSA 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 CPB, and (T4) at the end of surgery before transfer to the Intensive care unit (ICU).

**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 CSA measurement and LVEDA with a power of 80%.

**Statistical methods**

Data were coded and entered using the statistical package SPSS version 21 (SPSSInc, Chicago, IL, USA). Data were 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. \(P <0.05\) was considered statistically significant.

- \(r\): Pearson’s correlation coefficient:
  - 0.01–0.19: Very weak; negligible correlation
  - 0.20–0.39: Weak correlation
  - 0.40–0.69: Moderate correlation

\(\mu\): Mean
\(\sigma\): Standard deviation
\(\sigma^2\): Variance
\(\beta\): Power
\(\alpha\): Significance level
\(\rho\): Pearson’s correlation coefficient.
• 0.70–0.89: Strong correlation
• 0.90–1.00: Very strong correlation.
• *P* value: *P* < 0.05 is considered statistically significant.

**RESULTS**

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 February 22, 2014 to June 11, 2015. Sixteen pediatric patients with congenital heart disease undergone cardiac surgery were included in this study. 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 with SD of 4.7, the smallest weight was 10 kg, and the largest weight was 25 kg [Table 1].

With regard to the role IJV diameter measured by ultrasound, it was 9.88 ± 1.17 mm in T1, then it became 8.5 ± 102 mm in T2, it increased again to 9.61 ± 1.5 mm in T3, then finally was 9.11 ± 1.5 mm. On the other hand, LVEDA in T1 was 10.74 ± 0.93 cm² in T1 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 and Figure 1].

IJV CSAs 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), finally it became 66 ± 17.5 cm² in T4.

There was also a poor correlation between IJV CSA and LVEDA, *r* values are: 0.163, 0.230, 0.485, and 0.259 in T1, T2, T3, and T4, respectively [Table 3 and Figure 2].

**DISCUSSION**

This study aimed to evaluate IJV cross dimensions (diameter and CSA) 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 the assessment of intravascular volume. [3]

Regarding the role of IJV CSA in the detection of preload, there was a poor correlation between IJV CSA and LVEDA, *r* values were 0.163, 0.230, 0.485, and 0.259. Moreover, there was a poor correlation between IJV diameter and LVEDA, *r* values were 0.158, 0.265, 0.449, and 0.201 in T1, T2, T3, and T4, respectively [Table 2 and Figure 1].

| Mean(SD) | Median(range) |
|----------|---------------|
| Age      |               |
| 4.93 (2.5)| 4.00 (2-9)    |
| Weight   |               |
| 16.25 (4.7)| 15.00 (10-25)|
| IJV diameter |         |
| 1        | 9.88 (1.17)   |
| 2        | 8.5 (1.2)     |
| 3        | 9.61 (1.5)    |
| 4        | 9.11 (1.2)    |
| IJV cross-sectional area |     |
| 1        | 77.12 (18.2)  |
| 2        | 55.56 (16.3)  |
| 3        | 74.31 (21.7)  |
| 4        | 66.00 (17.5)  |
| LVEDA    |               |
| 1        | 10.74 (0.93)  |
| 2        | 11.91 (2)     |
| 3        | 11.36 (2.6)   |
| 4        | 10.33 (1.19)  |

SD=Standard deviation, IJV=Internal jugular vein, LVEDA=Left ventricular end diastolic area

| Table 2: Correlation between internal jugular vein diameter and traditional parameters for volume status left ventricular end diastolic area |
|----------------------------------------------------------------------------------------------------------------------------------|
| **r** | **P** |
| T1   | 0.158 | 0.560 |
| T2   | 0.265 | 0.321 |
| T3   | 0.449 | 0.081 |
| T4   | 0.201 | 0.454 |

**Figure 1:** Relationship between internal jugular vein diameter and left ventricular end diastolic area at T1. Linear correlation: *r* = 0.158, *P* = 0.560

**Figure 2:** Relationship between internal jugular vein cross-sectional area and left ventricular end diastolic area at T1. Linear correlation: *r* = 0.163, *P* = 0.467
Table 3: Correlation between internal jugular vein cross-sectional area and traditional parameters for volume status left ventricular end diastolic area

|        | r     | P    |
|--------|-------|------|
| T1     | 0.163 | 0.547|
| T2     | 0.230 | 0.392|
| T3     | 0.485 | 0.057|
| T4     | 0.259 | 0.333|

values were 0.158, 0.265, 0.449, and 0.201 in T1, T2, T3, and T4, respectively.

CVP and pulmonary artery systolic pressure failed to be reliable indicators for preload fluid assessment. However, transthoracic echo (TEE), as a semi invasive tool, showed a great reliability in this aspect.\(^6\)

There were many trials to find a noninvasive 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 transthoracic echo through sub-costal window. It has the advantage of not being affected by the intrathoracic pressure, on the contrary it is affected by the intra-abdominal pressure, it has sensitivity and specificity of 90\%.\(^{[7-9]}\)

Moreover, superior vena cava diameter variability has been tested using the TEE window with good sensitivity and specificity, but with the limitation of being affected by the intrathoracic 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.\(^{[11,12]}\) Twelve percent increase in stroke volume with PLR is a positive test. It has the disadvantage in that it gives false negative with increase intra-abdominal pressure.\(^{[13]}\)

Other studies that agree with this one show also no correlation such as Kent et al. study, who considered that IVC collapsibility index (IVC-CI) is an accurate tool for intravascular volume assessment. They wanted to detect another noninvasive tool for intravascular volume assessment. It was a prospective, observational study in 39 medical ICU patients comparing IVC-CI and IJV 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 the 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 similar aim to our study but with different results. He wanted to detect a reliable noninvasive tool for the detection of right atrial pressure (RAP). He studied 67 patients undergoing right heart catheterization and compared the CSA of IJV during Valsalva maneuver with the direct measurement of RAP. He found that a >17% increase in right IJV CSA with Valsalva predicted elevated RAP (≥12 mmHg) (P < 0.001).\(^{[16]}\)

In another observational pilot study, over 18 patients scheduled for cardiac surgery. There were significant correlations between left ventricular end diastolic diameter and CSA using ultrasound as noninvasive tool to identify changes in the volume status of surgical patients. However, the sample size was very small, only ten were included in the study analysis of IJV diameter and CSA.\(^{[17]}\)

**CONCLUSION**

Assessment of volume status in pediatric patients undergoing cardiac surgery is a multi-factorial issue; it needs multi-model tools and measurements including clinical point of views. IJV diameter and CSA 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.

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.

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