Evaluation of Internal Jugular Vein Diameter and Cross-Sectional Area Measurements in Correlation with Central Venous Pressure (CVP) in Pediatric Patients Undergoing Cardiac Surgery


The Department of Anaesthesiology, Faculty of Medicine, Cairo University

The aim of this study was to assess the correlation between the sonographic measurement of diameter and cross sectional area of IJV to CVP during cardiac surgery in pediatric patients.

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 2/2014 to 6/2015. Sixteen patients having congenital heart disease was enrolled in the study after obtaining the approval of the Medical and Ethical Committees and an informed consent from parents.

Inclusion criteria were: Age group: 2 to 10 years, weight between: 10 to 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, infection at the site of CVP or generalized infection, dehydrated patients and congestive heart failure.

All patients were subjected to detailed history taking from the parents and thorough 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), Electrocardiogram (ECG), echocardiography and chest X-ray.

Premedication was in the form of intramuscular midazolam at a dose of 0.2mg/kg; atropine at a...
dose of 0.02mg/kg given 10 minutes before induction.

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

Induction was carried out by inhalational technique using sevoflorane at 2 MAC and fentanyl intravenous administration of 2µg/kg. Sevoflorane MAC could be increased till ensuring hypnosis and absence of response to external stimuli. Intubation was facilitated by pancuronium at 0.1 mg/kg. Mechanical ventilation was instituted as 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 extreme hypocarbia.

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

Anesthesia was maintained by giving Fentanyl at a dose of 1 µg/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.

CVP measurement: CVP was measured manually using a pressure manometer. It was 'zeroed' at the level of the right atrium by taking it at level of the 4th intercostal space in the mid-axillary line while the patient lying supine, each time at the same zero position. CVC patency was ensured by flushing the catheter. A 3-way tap was used to connect the manometer to an intravenous drip set on one side, and, via extension tubing filled with intravenous fluid, to the patient on the other.

The 3-way tap was then turned so that it is open to the fluid bag and the manometer but closed to the patient, allowing the manometer column to fill with fluid. Usually, the manometer would be filled up to a level higher than the accepted CVP. Then, turn off the flow from the fluid bag and the three-way tap from the manometer to the patient was opened. The fluid level within the manometer column would fall to the level of the CVP, the value of which could be read on the manometer scale which is marked in centimeters, therefore giving a value for the CVP in centimeters of water (cmH₂O).

Sonographic measurement of IJV: 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 liberally applied to the side of the neck contralateral 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. After obtaining an optimized II image, the vessel dimensions were recorded.

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 CVP with a power of 80%.

Parameters for the study:
• CVP (Central venous pressure).
• Sonographic measurement of IJV diameter of non canulated side.
• Sonographic measurement of IJV cross sectional area of non canulated side.

Timing for measurement:
T 1 - Immediately after induction (base line).
T2- Before the start of CPB.
T3- Immediately after weaning of CPB.
T4- At the end of Surgery before transfer to ICU.

Study outcome measures:
Primary outcome measure: Correlation of IJV cross sectional area to CVP.
Secondary outcome measures: Correlation of IJV diameter to CVP.

Statistical methods:
Data were coded and entered using the statistical package SPS S version 2 1. 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**

This study was observational study operated in Abuelrish educational pediatric hospital in cardiothoracic theater. 16 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 with SD of 4.7, the smallest weight was 10kg and the largest weight was 25kg. (Table 1).

As regards the role IJV diameter measured by ultrasound in detection of preload, there was a poor correlation between IJV diameter and CVP at the four time intervals (T1, T2, T3, and T4) *r*-values are: 0.199, 0.170, 0.475, 0.138 respectively (Table 2 & Fig. 1).

IJV cross sectional area measured by ultrasound in detection of preload showed that there was a poor correlation between IJV cross sectional area and CVP at the four time intervals (T1, T2, T3, and T4) *r*-values were: 0.189, 0.410, 0.458, and 0.088 respectively (Table 3 & Fig. 2).

### Table (1): Descriptive data.

<table>
<thead>
<tr>
<th></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>CVP 1</td>
<td>11.25 (2.8)</td>
<td>10.50 (6-19)</td>
</tr>
<tr>
<td>CVP 2</td>
<td>11.81 (2.2)</td>
<td>12.00 (9-17)</td>
</tr>
<tr>
<td>CVP 3</td>
<td>11.00 (1.2)</td>
<td>11.00 (9-13)</td>
</tr>
<tr>
<td>CVP 4</td>
<td>9.56 (2.9)</td>
<td>10.00 (4-13)</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>
</tbody>
</table>

CVP: Central Venous Pressure.  
IJV: Internal Jugular Vein.

### Table (2): Correlation between IJV diameter and CVP.

<table>
<thead>
<tr>
<th></th>
<th>r-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>0.199</td>
<td>0.459</td>
</tr>
<tr>
<td>T2</td>
<td>0.170</td>
<td>0.520</td>
</tr>
<tr>
<td>T3</td>
<td>0.475</td>
<td>0.063</td>
</tr>
<tr>
<td>T4</td>
<td>0.138</td>
<td>0.612</td>
</tr>
</tbody>
</table>

CVP: Central Venous Pressure.  
IJV: Internal Jugular Vein.

### Table (3): Correlation between IJV cross sectional area and CVP.

<table>
<thead>
<tr>
<th></th>
<th>r-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>0.189</td>
<td>0.482</td>
</tr>
<tr>
<td>T2</td>
<td>0.410</td>
<td>0.11</td>
</tr>
<tr>
<td>T3</td>
<td>0.458</td>
<td>0.074</td>
</tr>
<tr>
<td>T4</td>
<td>0.088</td>
<td>0.746</td>
</tr>
</tbody>
</table>

CVP: Central Venous Pressure.  
IJV: Internal Jugular Vein.

![Fig. (1): Relationship between Internal Jugular Vein (IJV) diameter and Central Venous Pressure (CVP) at T1. Linear correlation: r=0.199, p-value=0.459.](image1)

![Fig. (2): Relationship between Internal Jugular Vein (IJV) cross sectional area and Central Venous Pressure (CVP) at T1. Linear correlation: r=0.189, p-value=0.482.](image2)
Discussion

This study aimed to evaluate IJV cross dimensions (diameter and cross sectional area) as a reliable noninvasive tool to assess intravascular volume status in pediatric patients undergoing cardiac surgery. IJV dimensions were compared to (CVP) which is a common tool for assessment of intravascular volume.

As regards the role IJV cross sectional area in detection of preload, there was a poor correlation between IJV cross sectional area and CVP at the four time intervals (T1, T2, T3, and T4). \( r \)-values were: 0.189, 0.410, 0.458, 0.088 respectively. There was also a poor correlation was reported between IJV diameter and CVP, \( r \)-values were: 0.199, 0.170, 0.475, 0.138 respectively.

In the issue of IJV cross sectional area and CVP, the results of the current study generally conform to Maratea E literature. He had a similar study operated on thirty-seven patients presented for cardiac surgery to determine factors which increase cross sectional area of right internal jugular vein to facilitate central venous line insertion. The findings of E Maratea were consistent with our findings as they showed that there was no correlation between central venous pressure and cross sectional area of right internal jugular vein [5].

The results agreed with the findings reported by Prekker ME et al., in 67 medical ICU patients. They reported a weak correlation between CVP and IJV dimensions \( (r=0.21) \). However Prekker et al., were comparing CVP to IJV aspect ratio and not to IJV diameter nor cross sectional area \([6]\).

Kent et al., considered that Inferior Vena Cava Collapsibility Index (IVC-CI) is an accurate tool for intravascular volume assessment. He wanted to detect another noninvasive tool for intravascular volume assessment. It was an observational study in 39 medical ICU patients comparing Inferior Vena Cava Collapsibility Index (IVC-CI) and Internal Jugular Vein Collapsibility Index (IJV-CI). 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 \([7]\).

Another study with the same aim of our study to detect noninvasive tool for intravascular volume assessment by comparing IVC diameter with the CVP, similar results confirmed that bedside sonographic 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 \( (r=0.19, p=0.22) \) \([8]\).

On the other hand, there were studies showed good correlation between CVP and other parameters related to internal jugular vein such as IJV collapsibility \( (r=0.408) \) \([9]\), the ratio between IJV and CCA \([10]\), the vertical height of IJV \([11-13]\), IJV diameter \( (r=0.82) \), \([1]\), and IJV cross sectional area \([5]\). These findings are different from the current study that showed poor correlation of IJV dimensions and CVP. This difference might be attributed to the different type of patients (the patients of the current study are pediatric patients undergoing cardiac surgery differ from all the aforementioned studies in which patients are either volunteers or patients in the Emergency Department without specification) and also might be because we measured different parameters than these studies. Future research is needed to correlate all these parameters together in the different groups of patients.

Uthoff et al., had a study to evaluate the accuracy of noninvasive Central Venous Pressure (CVP) assessment by Internal Jugular Vein Collapsibility (IJV-C) compared to invasive CVP measurement (invCVP) as the gold standard. IJV-C was performed in a random sequence in 81 intensive care patients with simultaneous invCVP monitoring. The Spearman correlation coefficient between invCVP and IJV-C was 0.408 which mean that the overall ability of IJV-C to assess invCVP was moderate \([7]\).

The ratio between Internal Jugular Vein and Common Carotid Artery (IJV/CCA ratio) was reported in a pilot study to be a useful indicator for CVP of pediatric burn patients, this differs from the current results; however there are many differences between the current study and the aforementioned study. One of these differences is the type of patients, another difference that the aforementioned study compared CVP to IJV/CCA ratio while in our study we compared CVP to IJV cross dimensions. In that study, it proven a strong correlation between IJV/CCA ratio and CVP and revealed that
a ratio of 2 or greater was associated with a CVP of at least 8mmHg ($p<.001$). These results suggest that if the cross-sectional area of the vein is at least twice that of the artery, then the CVP seems to be 8mmHg.

Xing et al., needed an investigation pointed on create another noninvasive technique for quantification about CVP by ultrasonography. Seventy-six patients who required their CVP monitored for intraoperative or postoperative management were recruited. By accurate location of the collapse point of the internal jugular vein by ultrasound and the center of the right atrium using echocardiography, the height of the fluid column between those 2 points was measured as the noninvasive CVP (CVPn). Measurements were performed and compared with the invasive CVP (CVPi). The study revealed a significant correlation between CVPi and CVPn (preoperative measurements, $r=0.90$; $p<0.01$ and postoperative measurements, $r=0.93$; $p<0.01$) [11].

Muhamad et al., had a study included 25 patients from the Emergency Department (ED). The study showed a significant correlation between IJV height measured by sonar and CVP using central venous access ($r=0.64$ $p<0.001$) [12].

Muhamad et al., used sonographic measurement of Internal Jugular Vein (IJV) height to assess volume status while we used diameter and cross sectional area of IJV as non-invasive tool for volume assessment. His study group was above 18 years old while my study group was between 2 years and 10 years. Our study was intraoperative in pediatric patient intubated and ventilated while his study was in ED excluding intubated and ventilated patient.

Siva et al., compared ultrasound estimation of the height of the right internal jugular vein (CVP-IJV) with direct estimation of Central Venous Pressure (CVP) (CVP-CVC) in 44 critical ill patients. They found strong correlation between CVP-IJV and CVP-CVC, $p$-value=0.004 in overloaded patients, $p$-value 0.001 in hypovolemic patients. In our study we used IJV diameter and area to compare with CVP while in Siva study excluded patient below 18 years, while our study was in pediatric patient (2 to 10) [13].

Simon et al., had a study with the same aim of our study but with different results. The study included 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. They found that a 17% increase in RIJV CSA with Valsalva predicted elevated RAP ($>or =12$mmHg) ($p$-value <.001) [14].

A pilot study reported the successful utilization of ultrasonography of internal jugular vein as non-invasive tool to predict CVP. It showed high correlation coefficient ($r=0.82$) between end expiratory diameter of internal jugular vein with the direct measurement of the CVP when the patient was in supine position. It was operated on 34 spontaneously breathing critical ill patients with monitored CVPs [1].

In another similar study operated by Zhu et al., had proven that subclavian vein diameter measured by sonar correlate with Central Venous Pressure (CVP). He had two groups patient group and volunteer group. In the patient group, SCV diameters, during both expiration (dSCVe) and inspiration (dSCVi), were measured with ultrasonography before and after fluid resuscitation. In the volunteer group, baseline measurements were conducted without liquid therapy and the subsequent measurement. His results showed that the average diameters of the SCVe and SCVi in hypovolemic patients were significantly lower as compared with the SCVe and SCVi diameters of healthy volunteers. After fluid resuscitation, the SCVe and SCVi diameters in hypovolemic patients significantly increased. The pre-SCVe and the post-SCVe were closely correlated to the CVP ($r=0.612$ and $r=0.547$, respectively). Similarly, the pre-SCVi and the post-SCVi were correlated to the CVP ($r=0.452$ and $r=0.507$, respectively) [15].

However there are many differences between the current study and the Zhu P study. One of these differences is the type of the patients and age of the patients, Zhu P study was on forty patients with mean age 46y (American Society of Anesthesiologists I-II) who underwent elective gastrointestinal surgery and 40 healthy volunteers with mean age 43y were enrolled in the study while our study was on 16 pediatric patients with mean age 4.9y undergoing cardiac surgery. Another difference was that in our study we compared CVP with IJV dimensions while in the other study comparison was between CVP and subclavian vein diameter.

**Conclusion:**

IJV diameter and cross sectional area measurements by ultrasound in those patients are not reliable and cannot be used alone to replace CVP.
References


الملخص العربي

الهدف من هذه الدراسة هو إيجاد وسيلة بسيطة غير متاحة لتقدير حالة سوائل الجسم في الأطفال أثناء عمليات القلب وذلك عن طريق إيجاد علاقة بين قياسات الس汉语 للقطر والمساحة العرضية من الوريد الودائي الداخلي مع قياسات الضغط الوريدي المركزى.

القياسات التي يتم اخذها في الدراسة:
- الضغط الوريدي المركزى.
- قياسات الس汉语 لقطر الوريد الودائي الداخلى.
- قياسات الس汉语 المساحة العرضية من الوريد الودائي الداخلى.

مواعيد اخذ هذه القياسات في هذه الدراسة:
- قبل الدخول على ميكة القلب.
- بعد الخروج من ميكة القلب.
- بعد اتمام العملية وقبل نقل المريض للرعاية المركزى.

وأثبت النتائج وجود علاقة ضعيفة بين أبعاد الوريد الودائي الداخلى وبين ضغط الوريدي المركزى.

الخلاصة: أبعاد الوريد الودائي الداخلى مقاسة بالس汉语 لا يمكن أن يتم تفسيرها بشكل صارم للتحديد حالة سوائل الجسم.