Original Article

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Paediatrics Section

Correlation of Baseline Inferior Vena Cava Diameter and Collapsibility with Age and Sex in Normovolaemic Children: A Cross-sectional Study

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ABSTRACT

Introduction: Ultrasound measurement of Inferior Vena Cava (IVC) diameter and collapsibility is increasingly used for volume status assessment and fluid responsiveness in paediatric and adult population. There is a wide variation in the age specific IVC diameters in paediatric population, whereas age specific variation in IVC collapsibility in euvolaemic children is not much known.

Aim: To analyse the correlation of baseline IVC diameter and collapsibility with age and sex in euvolaemic children.

Materials and Methods: This cross-sectional study was conducted at Kerala Institute of Medical Sciences, a tertiary care hospital in south Kerala, India, over a study period from June 2014 to May 2016. A total of 80 children in the age group of one month to 15 years, who presented without evidence of volume depletion were enrolled. The IVC was assessed approximately 2 cm distal to IVC-hepatic vein junction, Motion mode (M-mode) measurement of maximum (expiratory) and minimum (inspiratory) width of IVC diameter was measured. Collapsibility Index was also calculated for each subject by measuring difference between the maximum and minimum IVC diameters divided by the maximum diameter. The statistical data was analysed using the statistical software Statistical Package for Social Sciences (SPSS) version 16. All the numerical data was expressed as mean±Standard Deviation (SD). Quantitative analysis was performed using Analysis of Variance (ANOVA) and t-test. The correlation of IVC parameters were assessed using Karl Pearson correlation coefficient. The p-value less than 0.05 was considered as significant.

Results: Eighty euvolaemic children between the age one month and 15 years were enrolled in the study. The mean age of study group was 5±4 years. Males 41 (51.3%) and females 39 (48.8%) were almost equally distributed. A significant strong positive correlation was found between IVC expiratory and inspiratory diameter with age using Karl Pearson correlation, r=0.912, p<0.001; r=0.876, p<0.001, respectively. No significant correlation was found between IVC collapsibility and age, Karl Pearson correlation, r=0.079, p=0.485. No correlation was found between sex and the IVC parameters.

Conclusion: According to the present study results, IVC diameter showed a positive correlation with age but not with sex. The IVC collapsibility had no correlation with either age or sex.

Keywords: Diagnosis, Measurement, Paediatric, Ultrasonography

INTRODUCTION

Ultrasonographic (USG) assessment of the IVC has been used as a non invasive diagnostic tool for the assessment of intravascular volume [1,2]. Specifically, IVC diameter and collapsibility have been used as methods of assessing intravascular volume [3,4]. Changes in the volume status are reflected as change in diameter of IVC, which is a thin walled compliant vessel [5]. The IVC contracts with inspiration and expands with expiration [6]. During inspiration, negative pressure creates increased venous return to the heart, briefly collapsing the IVC. During expiration, venous return decreases and the IVC returns to its baseline diameter [7]. Changes in volume status are reflected in sonographic evaluation of the IVC. Fluid management is very crucial in the management of children with fluid deficit and fluid overload; as sonographic IVC parameters are increasingly used in volume status assessment, establishing normative data for IVC parameters is very essential. Although a positive correlation is observed in sonographic measurements between IVC diameter and age, there is a lack of universally accepted cut-off of IVC diameter in healthy paediatric population [8-10]. In adult population, IVC diameter at inspiration ranges from 0-14 mm at rest, and expiratory diameter of 15-20 mm at rest [11]. Most of the previous studies focused on correlation of sonographic measurement of IVC diameter with various body parameters [8-12], and only few studies compared IVC collapsibility and age [8,10].

In healthy subjects breathing spontaneously, cyclic changes in thoracic pressure, result in collapse of the IVC diameter of approximately 50% [7].

The aim of the present study was to analyse the correlation of IVC diameter and collapsibility with age and sex in euvolaemic paediatric population.

MATERIALS AND METHODS

This was a cross-sectional study conducted in the emergency room of Kerala Institute of Medical Sciences, Trivandrum, a tertiary care hospital in Kerala, India. After obtaining Institutional Ethical Committee clearance (ECR/284/284/KIMS/Inst/Ker/2013), over the study period of two years from June 2014 to May 2016. Written informed consent was obtained from parents of eligible children.

Inclusion criteria: During the study period all children who presented to emergency room without any signs and symptoms of volume depletion and consented for study were included in the study.

Exclusion criteria: Children who were having dehydration or shock were not included in the study. Children with congenital heart disease and those who have not consented were also excluded from the study.

Sample size calculation: According to the study by Kathuria N et al., considering the correlation between IVC diameter and age as

0.79 at 95% confidence interval with 95% power, the sample size was calculated as [9]:

N={(Z 1-α/2+Z 1-β) 2*4/(ln(1+r/1-r))2}+3.

(Z1-α/2- two tailed probability for 95% confidence interval=1.96, Z1-β-two tailed probability for 95% power=1.64, r-Correlation between diameter and age=0.79)

N= {(1.96 + 1.64)^ 2*4/(ln(1+ 0.79/1-0.79))^2}+3=14.32

Thus the total minimum sample size required for the study is 14.32. Non response rate of 50% was added to get a minimum sample size of 22.

Study Procedure

Eighty children in age group 1 month to 15 years, who were not having signs and symptoms of volume depletion and clinically judged to be euvolaemic were enrolled for study. For clinical judgement of euvolaemia focused history obtained included absence of diarrhoea, vomiting, decreased oral intake/feeding difficulty, lethargy and focused examination included measurement of heart rate, respiratory rate, blood pressure, temperature and capillary refill time.

After taking focused history and examination, one measurement of IVC was obtained.

Method of IVC measurement: Portable sonosite micromax machine (Brand–Fujifilm, Model-M-Turbo) was used to perform the necessary measurements during this study. With the child in supine position, the standard curvilinear low frequency abdominal ultrasound probe (3.5-5 MHz) was placed on the patient's midline, in the subxiphoid region angling to right and a longitudinal view of images were recorded over several respiratory and cardiac cycles. The IVC was assessed approximately 2 cm distal to IVC-hepatic vein junction [13], where it's anterior and posterior walls are clearly visualised. The M-mode measurement of maximum and minimum width of IVC diameter was measured. The maximum IVC diameter was obtained during the expiratory phase of the respiratory cycle and the minimum during the inspiratory phase. The IVC collapsibility index was calculated using formula [14]:

$$\frac{\text{IVC Expiratory Diameter-IVC inspiratory Diameter}}{\text{IVC Expiratory Diameter}} \times 100$$

Ultrasound measurements were performed by either of the two principal investigators (either a paediatric emergency attending consultant who underwent formal emergency ultrasound training with Indian Academy of Paediatrics, workshop on paediatric critical care imaging, and or a paediatric resident who underwent training under the above consultant).

STATISTICAL ANALYSIS

Data was collected using a structured proforma which was filled by the principal investigators. The proforma was used to collect essential demographic and clinical data along with the measurements of IVC of the study population. The statistical data was analysed using the statistical software SPSS version 16. All the numerical data was expressed as mean±standard deviation. Quantitative analysis was performed using ANOVA and t-test. The correlation of IVC diameter and collapsibility with age and sex was calculated using Karl Pearson correlation, a p<0.05 was considered significant.

RESULTS

The present study evaluated 80 children, for correlation between sonographic measurement of IVC parameters with age and sex in children.

Of the total population enrolled in the study, one-third (33.8%, n=27) were less than 2 years of age, majority (42.5%, n=34) were between more than 2-7 years of age and others (23.8%, n=19) were older than 7 years of age. In this study, males and females were almost equally distributed (51.3%, n=41 vs 48.8%, n=39) [Table/Fig-1].

Age group	Males (n=41) n (%)	Females (n=39) n (%)	Total (n=80) n (%)
1 month-2 years	13 (31.7)	14 (35.9)	27 (33.8)
>2-7 years	16 (31.0)	18 (46.2)	34 (42.5)
>7-15 years	12 (29.3)	7 (17.9)	19 (23.8)

[Table/Fig-1]: Baseline demographic characteristics of study participants.

The mean IVC expiratory diameter among study participants was 8.2±2.8 mm. In children less than 2 years of age, mean IVC expiratory diameter was 5.7±0.9 mm, between more than 2-7 years of age, it was 8.9±1.8 mm and in more than 7 years of age, it was 11.9±1.8 mm. The mean inspiratory IVC diameter among study population was 5.1±1.7 mm. In children less than 2 years of age mean IVC inspiratory diameter was 3.4±0.6 mm, between more than 2-7 years age 5.3±1.1 mm and in more than 7 years 7.0±1.0 mm.

The difference in mean IVC expiratory and inspiratory diameter in three age groups were statistically significant (p<0.001 for both expiratory and inspiratory diameters), but the difference IVC diameters among males and females were not statistically significant. (p=0.332 expiratory and p=0.404 inspiratory) [Table/Fig-2,3].

Age group	IVC expiratory diameter	IVC inspiratory diameter	IVC collapsibility
1 month-2 years	5.7±0.9 mm	3.4±0.6 mm	40.7±6.4%
>2-7 years	8.9±1.8 mm	5.3±1.1 mm	39.9±5.4%
>7-15 years	11.9±1.8 mm	7.0±1.0 mm	40.9±5.1%
p-value	<0.001	<0.001	0.786

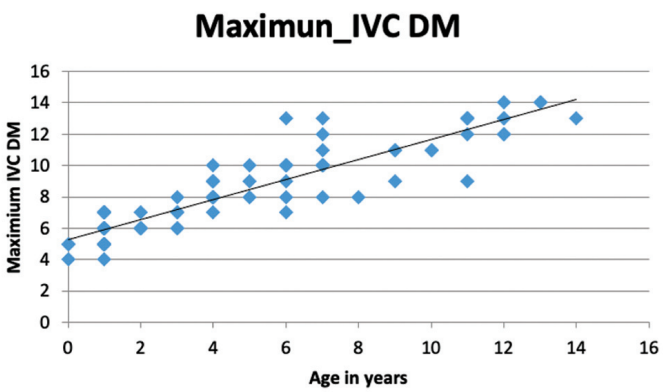
[Table/Fig-2]: The mean IVC parameters among different age groups. ANOVA

Gender	IVC expiratory diameter	IVC inspiratory diameter	IVC collapsibility
Males	8.83±2.7 mm	5.2±1.6 mm	40.8±5.6%
Females	8.23±2.8 mm	4.9±1.6 mm	39.0±5.8%
p-value	0.332	0.404	0.161

[Table/Fig-3]: The mean IVC parameters among males vs females. Student's t-test

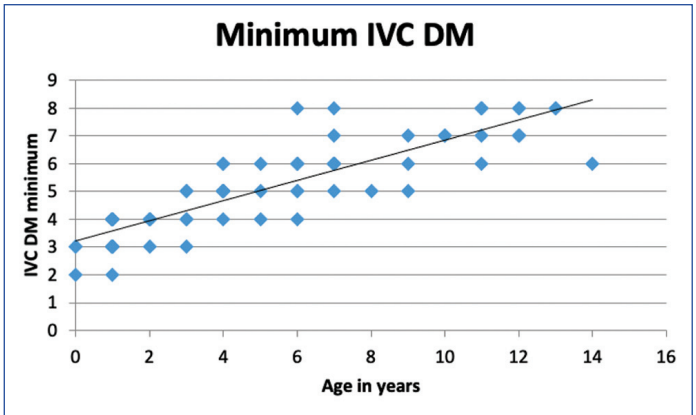
The mean collapsibility index of IVC among the study population was 39.5±5.7%. The IVC collapsibility showed no statistically significant variation with age or sex; p=0.786 for age vs p=0.161 for sex [Table/Fig-2,3].

A strong positive correlation which was statistically significant was found between IVC expiratory diameter with age using Karl Pearson correlation, r=0.912, p<0.001[Table/Fig-4].



[Table/Fig-4]: IVC maximum (expiratory) diameter as function of age. Karl Pearson correlation r=0.912, p<0.001, IVCDM (IVC Diameter)

Similarly, strong positive correlation was found between IVC inspiratory diameters and age. The baseline IVC inspiratory diameter measured by ultrasonography, in longitudinal view, increased with increasing age. Karl Pearson correlation was r=0.876, p<0.001 [Table/Fig-5].



[Table/Fig-5]: IVC minimum (inspiratory) diameter as function of age.
Karl Pearson correlation r=0.876, p<0.001 (inspiratory)

Karl Pearson correlation with gender for expiratory diameter was r=-0.108 p=0.340 and for inspiratory diameter was r=-0.090, p=0.426 [Table/Fig-6].

Correlation of IVC collapsibility with age and sex was negligible. Karl Pearson correlation coefficient for IVC collapsibility and age was, r=0.079, p=0.485; and for sex r=-0.071, p=0.530 [Table/Fig-6].

	Age		Sex	
IVC parameters	Pearson r-value	p-value	Pearson r-value	p-value
Expiratory IVC diameter	0.912	<0.001	-0.108	0.340
Inspiratory IVC diameter	0.876	<0.001	-0.090	0.426
IVC collapsibility	0.079	0.485	-0.071	0.530

[Table/Fig-6]: The correlation between IVC diameters with age and sex.

DISCUSSION

Bedside ultrasound is a useful non invasive tool to estimate intravascular volume status by measuring IVC diameter and collapsibility index [15,16]. The present study presents the data regarding relationship between IVC parameters with age and sex in paediatric population.

This study enrolled 80 children in the age group 1 month to 15 years, who were not having clinical signs of volume depletion. The IVC diameters of all children, during inspiration and expiration were categorised as per age of children. A significant positive correlation was found between IVC expiratory and inspiratory diameter with age using Karl Pearson correlation; r= 0.912, p<0.001 for expiratory IVC diameter and r= 0.876, p<0.001 for inspiratory IVC diameter. Whereas negligible correlation was there between IVC collapsibility with age (r=0.079, p=0.485) and sex (r=-0.071, p=0.530). Similar positive correlation of IVC diameter with age was observed in previous studies also.

In the study by Ghosh V et al., enrolling 100 children in age group 6 months to 16 years, the mean expiratory IVC diameter was 7.6-13.5 mm and inspiratory diameter 5.6-10.5 mm [8]. The mean maximum and minimum IVC diameter increased significantly with age (r=0.738, p<0.001, r=0.789, p<0.001). Collapsibility index did not show significant correlation with age.

Similarly, study by Taneja K et al., also showed positive correlation of maximum (r=0.794, p<0.001) and minimum (r=0.752, p<0.001) IVC diameters with age, while collapsibility index was almost similar in all age groups [10]. The maximum IVC diameter was 7.24±2.97 mm, minimum IVC diameter 4.71±1.97 mm and collapsibility was 34±1.1%. This study was done by radiologist and had IVC diameter and collapsibility similar to the present study done by clinicians. Whereas in an adult study by Pail S et al., no correlation of IVC diameter with age of population was seen and with respect to gender r=-0.032, p=0.172 for females and r=-0.001, p=0.952 for males were found [17]. The IVC maximum diameter was 9.7-22.6 mm, minimum diameter was 4.6-15.4 mm and average collapsibility was 38% in the adult study by Pail S et al., [17]. In another study by Kutty S et al., where 120 healthy volunteer children were enrolled, the mean maximum and minimum IVC diameters were higher than the present study 12.1±3.8 mm and 8.9±3.8 mm, respectively [18]. But similar to the present study, they also showed correlation of these diameters with age while IVC collapsibility index was not correlated with age.

Haines EJ et al., derived an IVC dimension growth curve as a function of age among the children aged 4 weeks to 20 years and found linear correlation between IVC dimensions and age [12]. The mean IVC dimeter was 1.2 to 22.6 mm. The difference in mean IVC diameters observed in these studies may be due to difference in the age group enrolled in the studies.

Measurement of IVC diameter and collapsibility with respiration are increasingly being used to guide fluid management decisions in patients [19]. Fluid management is very precarious in children, and it is crucial to know the fluid deficit or fluid overload before administering more fluid. Literature suggests IVC diameter measurements as a useful tool in recognising patients who may get benefited from volume challenge [3,20-22]. On the other side, many studies suggest that changes in sonographic IVC measurement do not strongly predict fluid responsiveness [23,24]. As there was a strong positive correlation of IVC diameter with age and negligible correlation of IVC collapsibility with age, IVC collapsibility would be a better tool for volume status assessment in paediatric population.

Limitation(s)

Patients were assumed to be euvolaemic based on their clinical signs and symptoms at presentation to emergency room. Limitation of this study was inclusion of children from a specific region, which was not enough to extrapolate these measurements on the general population. Further multicentric studies with large sample size are required to derive IVC normogram based on age.

CONCLUSION(S)

This study established a wide variation in the absolute values of IVC diameter with age in paediatric population, hence relaying absolute IVC diameter for volume status assessment was difficult in paediatric population. The IVC collapsibility did not vary much with age or sex in euvolaemic children. There was a strong positive correlation between IVC diameter and age in paediatric population; whereas no positive correlation was established between IVC collapsibility and age.

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