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Research Article

STUDY OF CORRELATION OF IVC DIAMETER AND COLLAPSILIBILTY INDEX WITH SOMATIC PARAMETERS IN CHILDREN AGED 1-10 YEAR

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ABSTRACT

Background: A validated tool for accurate assessment of hydration status in the paediatric emergency population is to obtain inferior vena cava diameter (IVCD) by ultrasound (USG). Prior studies have focused on IVCD in dehydrated adults and have shown to provide accurate estimates of right atrial pressure and volume status. The normative data for assessment of IVCD and its Correlation with somatic parameters in children is not available and is needed for rapid assessment of variation in hydration of sick children.

Methods: we conducted an observational prospective study in children coming to OPD or admitted in wards requiring USG for various reasons in MVJ MC&RH. IVC diameter was measured in normal children between the age group of 1-10 years in sagittal and transverse view using USG and collapsibility index. Statistical analysis was done using SPSS 22 version software.

***Results*:** The mean age of study subjects was 5.7 y. Out of 380 subjects, 200(52.6%) were boys and 180(47.4%) were girls. Correlation was studied between physical parameters and IVCD which revealed a positive correlation with both maximum and minimum IVCD with P value of <0.001, however there is no positive correlation of collapsibility index with respect to age and other somatic parameters with mean Collapsibility index of 0.37.

Conclusions: This study provides reference values of IVCD for Indian children of different age group

Keywords*: Inferior Vena Cava Diameter, Collapsibility Index, Ultrasonography*

INTRODUCTION

Inferior vena cava (IVC) is the largest vein in the body, receives all the blood from below the diaphragm. Inferior vena cava diameter (IVCD) reduces with inspiration and expands with expiration due to falling intra-thoracic pressures and vessel 'collapse' due to the increase in the difference in transmural pressure. IVCD is noted to become flat during dehydration and remains dilated in case of venous occlusion or fluid overload. Due to this unique feature of IVC and its collapsibility, it can be used to measure the fluid status of the body and used as non-invasive surrogate for central venous pressure (CVP) measurement. Measurement of CVP for intravascular volume status is an invasive procedure and is associated with complications, this can be replaced by IVCD and IVC collapsibility index by ultrasonography as a tool to measure intravascular volume as it is less time consuming, safe and non-invasive procedure, can be done bedside. Prior studies have focused on IVCD in dehydrated patients and have shown that it provides accurate estimates of right atrial pressure and volume status. The normative data for assessment of IVC diameter and its Correlation with somatic parameters is studied in western population and very few studies are done in Indian population.

In practice, using IVC ultrasound to guide fluid resuscitation has significant advantages. The subcostal longitudinal view is readily obtainable in > 90% of patients; it is one of the easiest point-of-care ultrasound techniques to master and the entire examination takes < 3 min and can be repeated at will (eg, after each fluid bolus or clinical change) (da, 2015). Assessment of IVC diameter in different phases of respiratory cycle is a consistent guide for assessment of volume status in the hemodynamically stable individuals. We conducted this study to find normal IVC diameter and its based on age, height, weight, body surface area (BSA) and body mass index (BMI), by M-mode USG in normal children between age

of 1-10 years. Availability of baseline data of IVC diameter in normal children shall be of great help in rapid assessment of variations in sick children.

MATERIALS AND METHODS

Method of collection of Data

This study was conducted on children coming to OPD requiring USG for various reasons over a period two years from October 2018 to September 2020. It was a hospital based observational prospective study. The study was approved by the Ethical committee of M.V.J. Medical College and Research Hospital and the study subjects included 380 children between 1 to 10 years of age based on clinical examination and hydration status. Children with altered hydration status like dehydration or diseases affecting intravascular volume or fluid overload status were excluded.

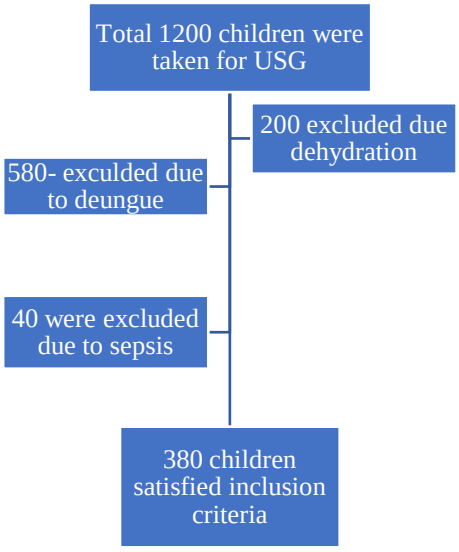
Various parameters like age, weight, height was obtained along with demographic data of the children at the time of the examination. Infants were weighed on an infant digital weighing scale and older children on a digital weighing machine to the nearest of 10 g. Percentage of expected weight for age was calculated using WHO growth charts as standard for 1-5 years and IAP charts for 5-10 years. Children with weight for age 2 standard deviation below the mean were excluded. The supine length was measured on an infantometer in a child below 2 years and the standing height was measured on a stadiometer in children above 2 years to the nearest 1 mm.

Body surface area (BSA), body mass index (BMI) were calculated using weight and height. BSA was calculated using Mosteller's formula that is $\sqrt{}$ [(height in cm × weight in kg)/3600. BMI was calculated using CDC formula that is weight (kg)/[height (m)]^2.

Statistical analysis

Data was entered into Microsoft excel data sheet and was analyzed using SPSS 22 version software. Categorical data was represented in the form of frequencies and proportions. Statistical analyses were performed using chi-square test for categorical variables and t-test for continuous variables' p values less than 0.05 will be considered significant. Continuous data was represented as mean and SD. Independent t test was used as test of significance to identify the mean difference between two quantitative variables. ANOVA (Analysis of Variance) was the test of significance to identify the mean difference between more than two groups for quantitative data. Pearson correlation was done to find the correlation between two quantitative variables.

RESULTS



Total of 1200 children coming to OPD who needed USG were enrolled, out of which 580 children were excluded due to positive dengue serology, 200 were excluded due to dehydration and 40 were excluded due to positive septic screen. Other obvious causes of deranged hydration status like shock, cardiovascular malformation, congestive cardiac failure, pneumothorax and other children requiring critical care were excluded at the beginning of the study. Among 380 children, 200 were male and 180 were female with a mean age of 5.79 ± 2.91years. the average age in boys (5.86 ± 3.02) and girls (5.72 ± 2.81) was comparable (the baseline characteristic of all the subjects are given in Table 1)

In our study there was significant difference in mean weight, height, BSA and BMI with respect to age groups with p value of <0.001 in all the above parameters, which is normal

according to Indian standards. There was increase in weight, height, BMI and BSA with increase in age but there no significant difference in mean Max IVC, min IVC with respect to sex.
There was no significant difference in maximum and minimum IVCD in transverse plane and sagittal plane. There was no significant difference in IVC collapsibility index in all the age groups with mean collapsibility index of 37.5 ± 5.4 %.

Table 1: Baseline characteristics of all the subjects in the study

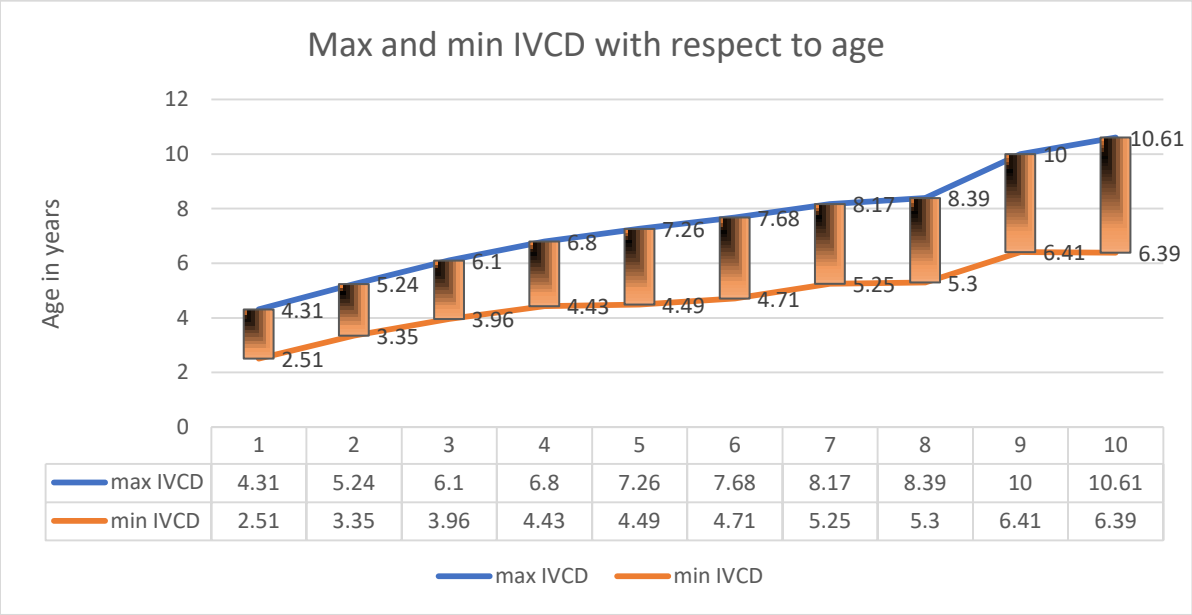
Age	1-2 years	3-4 years	5-6 years	7-8 years	9-10 years	Total
Gender (M/F)	37/30	29/35	50/44	27/36	57/35	200/180
Weight	9.83 ± 1.97	14.16 ± 1.18	17.74 ± 1.47	23.27 ± 2.12	30.47 ± 3.4	20.30 ± 8.16
Height	78.28 ± 8.71	96.77 ± 4.24	107.89 ± 4.08	119.24 ± 7.19	131.03 ± 5.21	108.90 ± 20.5
BSA	0.46 ± 0.07	0.62 ± 0.04	0.73 ± 0.04	0.88 ± 0.06	1.05 ± 0.07	0.78 ± 0.23
BMI	16.17 ± 2.90	15.12 ± 0.87	15.25 ± 1.15	16.44 ± 1.79	17.72 ± 1.52	16.39 ± 1.92
Mean max IVCD	4.75 ± 0.98	6.48 ± 0.69	7.43 ± 0.42	8.31 ± 0.31	10.38 ± 0.9	7.74 ± 2.15
Mean min IVCD	2.92 ± 0.80	4.22 ± 0.52	4.58 ± 0.39	5.28 ± 0.43	6.4 ± 0.78	4.81 ± 1.4
IVC-CI	39.32 ± 7.3	34.8 ± 4.24	38.37 ± 4.39	36.4 ± 4.61	38.38 ± 5.24	37.91 ± 5.51

Table 2: Correlation of Max IVC, Min IVC and CI with Age, weight, Height, BSA and BMI

		Max IVC	**Min IVC**	**CI**
Age	Pearson Correlation	0.940**	0.884**	0.001
	P value	<0.001*	<0.001*	0.992
Weight	Pearson Correlation	0.921**	0.866**	-0.002
	P value	<0.001*	<0.001*	0.974
Height	Pearson Correlation	0.922**	0.875**	-0.034
	P value	<0.001*	<0.001*	0.505
BSA	Pearson Correlation	0.933**	0.881**	-0.020
	P value	<0.001*	<0.001*	0.696
BMI	Pearson Correlation	0.285**	0.261**	0.026
	P value	<0.001*	<0.001*	0.615
N		**380**	**380**	**380**

Correlations were also studied in this population (Table 2). There was a positive correlation between age and maximum IVC diameter which was statistically significant ($r = 0.940$, $p < 0.001$). Also, body weight was positively correlated with maximum IVC diameter which was also statistically significant ($r = 0.921$, $p < 0.001$). There was also a significant positive correlation between maximum IVC diameter and body surface area ($r = 0.933$, $p < 0.001$). Whereas, there was a weakly positive correlation between maximum IVC diameter and body mass index ($r = 0.285$, $p < 0.001$). Similarly, there was a significant positive correlation between minimum IVC diameter and age in the study population ($r = 0.884$, $p < 0.001$) and a statistically significant positive correlation between minimum IVC diameter and body weight ($r = 0.866$, $p < 0.001$). There was also a positive correlation between height and minimum IVC diameter which was

statistically significant (r = 0.875, p < 0.001). Body surface area was also positively correlated with minimum IVC diameter (r = 0.881, p < 0.001). Whereas, there was a weakly positive correlation between minimum IVC diameter and body mass index (r = 0.261, p < 0.001). Figures 1 shows nomograms of IVC diameters both maximum and minimum, for age.



	1	2	3	4	5	6	7	8	9	10
max IVCD	4.31	5.24	6.1	6.8	7.26	7.68	8.17	8.39	10	10.61
min IVCD	2.51	3.35	3.96	4.43	4.49	4.71	5.25	5.3	6.41	6.39

Figure 1: Normal maximum and minimum IVC diameter in different age group

DISCUSSION

Critical care of patients requires vigilant attention in initial hour to prevent mortality and morbidity. Most crucial part is played by fluid resuscitation in patients coming to emergency department and those admitted in PICU. To execute proper treatment and sufficient fluid replenishment it is vital for the clinician to know intravascular fluid status. Fluid management is very precarious in children and it is crucial to know the fluid deficit or overfill in the system prior to administering more fluids. There are some useful methods for assessment of fluid status but all have some limitations, especially when used in emergency.

Normal range of IVC diameter is available for adults but such normative data is lacking for children. This study intends to derive the normative data for IVC diameter in paediatric age group. Prior studies have focused on IVCD in dehydrated patients and have shown that it provides accurate estimates of right atrial pressure and volume status. IVCD and IVC-CI can be used as guide in fluid resuscitation. The IVCD & IVC-CI is a good indicator of circulating blood volume and an accurate determinant of right atrial pressure. These techniques are reliable and relatively easy to perform as compared to other invasive methods.

Age and Gender distribution

Among them 200 were male and 170 were female with no significant difference in sex distribution. Additionally, these children were divided into 5 groups, 1-2 years, 3-4 years, 5-6 years, 7-8 years and 9-10 years respectively. Each age group had comparable number of male and female children with no statistically significant difference of sex in each age group as well as no statistically significant difference in number of children enrolled in each age group. In present study population the age group was 1-10 years with mean age of 5.79 ± 2.91 years. Mean age in our study was similar to the study conducted in New Delhi by Taneja *et al.*, (Taneja, *et al.*, 2018)compared to Kutty *et al.* (Kutty, *et al.*, 2014), Kathuria

et al., (Kathuria, *et al.,* 2015), Haines *et al.,* (Haines, *et al.,* 2012) and Mannarino *et al.,* (Mannarino, *et al.,* 2019) where the mean age group was 8.3 years, 11 years, 8.5 years, 7 years respectively. There studies included children with older age group and was conducted in western population.

The male and female subjects in our study in different age groups with 53% male and 47% female, which is similar to study conducted by Taneja *et al.,* (Taneja, *et al.,* 2018*)* with 60% male and 40% females.

Comparison of Anthropometric Values with Age

Children in present study population have lower height, weight and BSA compared to Mannarino et al (Mannarino, et al., 2019) as that study was conducted in Caucasian population. This difference can be attributed to difference in race.

The mean weight, height, BMI and BSA according to different age groups in our present study is similar to Taneja *et al.,* (Taneja, *et al.,* 2018) whereas the mean weight, height and BSA are higher in Kutty *et al.,* Kathuria *et al.,* (Kathuria, *et al.,* 2015), Haines *et al.,* (Haines *et al.,* 2012) and Mannarino et al. (Mannarino, et al., 2019) probably due to difference in body proportion between Indian Population compared to western population.

Inferior Vena Cava Diameter (IVCD)

The availability of this data will help us save time during emergency with the list of normal IVCD in different age groups will be available handy for the reference of clinician to decide on the fluid status and treatment required. Determination of IVCD and its collapsibility index have been studied by many researchers but a handful of them have considered IVCD in normal children and their correlation with other somatic parameters. In our study, we have derived a normal IVCD curve and correlated it with other somatic parameters like age height weight, BMI and BSA. In the present study, we have focused on finding the normal IVC diameter and collapsibility index, prior to noting the IVCD it is important to consider the facts and come to a conclusion whether IVCD is solely dependent on age or it varies with sex and other somatic parameters like weight, height, BMI and BSA. The mean maximum and minimum IVC diameter in the present study is 7.14mm, 4.81mm respectively similar to Taneja et al (Taneja, et al., 2018) with mean maximum IVCD of 6.84mm and mean minimum IVCD of 4.4mm in different age groups whereas the mean maximum and minimum IVCD in study conducted by Kutty et al is 12.1mm, 8.9mm respectively, In Kathuria *et al.,* () it is 11mm, 7mm respectively and in Mannarino *et al.,* (Mannarino, *et al.,* 2019) it is 10.1mm, 6.9mm respectively which are higher than the present study due to difference in body proportion. However, IVC diameter is noted to increases with increase in age, height, weight, BSA in all the above-mentioned studies.

Inferior Vena Cava Diameter Measurement in Two Different Planes

In our study we have measured IVCD in both sagittal view and in transverse view and found that there is no significant variation between sagittal view and transverse view. Measuring the diameter in both views has helped us to reduce the observer variability and sequentially has increased the sensitivity of the study. Kathuria et al[81] has also found the similar results with maximum IVCD in sagittal view and transverse view.

Inferior Vena Cava Diameter and Collapsibility Index and Its Correlation With Somatic Parameters

Inferior Vena Cava Diameter and Its Variation With Age

In our study, IVC diameter increases with increase in age which is similar to other studies like Kutty et al[80], Mannarino et al (Mannarino, et al., 2019), Taneja et al (Taneja, et al., 2018), Haines et al (Haines, et al., 2012) and Kathuria et al (Kathuria, et al., 2015).

Inferior Vena Cava Diameter and Its Variation With Sex

In present study, mean maximum IVCD in male is 7.7 ± 2.15 and mean maximum IVCD in female is 7.57 ± 1.88 with p value of 0.422, similarly, mean minimum IVCD in male is 4.81 ± 1.4 and mean minimum IVCD in female is 4.75 ± 1.21 with p value of 0.630 in sagittal view. At the same time the mean maximum and minimum IVCD in male is 7.7 ± 2.16 and 4.81 ± 1.39 respectively with p value of 0.449 and in female it is 7.55 ± 1.88 and 4.73 ± 1.20 respectively with p value of 0.587 in transverse view. That is both male and female IVCD are comparable with no significant statistical difference between them.

Although body proportion and rate of general somatic growth are outstandingly different between male and female, their IVC diameter did not display a significant difference in our study. Similarly, in study conducted by Kutty *et al.,* (Kutty, *et al.,* 2014), Haines *et al.,* (Haines, *et al.,* 2012), Taneja *et al.,* (Taneja, *et al.,* 2018) and Mannarino *et al.,* (Mannarino, *et al.,* 2019) no difference were noted in IVCD of male and female in respective age groups.

Inferior Vena Cava Diameter and Its Correlation with Somatic Parameters

In present study, we found that IVCD has maximum correlation with age followed by a strong positive correlation with BSA, height and weight with Pearson correlation of 0.933, 0.922, 0.921 respectively for maximum IVCD and 0.88, 0.87, 0.86 respectively for minimum IVCD. However, we have observed weak positive correlation with BMI of 0.285, 0.261 in maximum, minimum IVCD respectively. Our findings are consistent with Kutty *et al.,* (Kutty, *et al.,* 2014), Mannarino *et al.,* (Mannarino, *et al.,* 2019), Taneja *et al.,* (Taneja, *et al.,* 2018), Haines *et al.,* (Haines, *et al.,* 2012) and Kathuria *et al.,* (Kathuria, *et al.,* 2015).

Inferior Venacava Diameter and Its Collapsibility Index

Collapsibility index:

Collapsibility index is measured by the difference in maximum and minimum Inferior Vena Cava diameter during expiratory and inspiratory phase respectively divided by maximal inferior vena cava diameter. Mean collapsibility index in our study is 37 ± 5.5 %. Many studies conducted in adults show that the variety of reference value ranging from 35-50%. Collapsibility index is helpful in assessing the estimate of right atrial pressure. Optimum collapsibility in adults being 40% with sensitivity of 73% and specificity of 85%. Ginghina *et al.,* (Ginghina, *et al.,* 2009) has classified RAP based on IVC diameter and its collapsibility as follows-

1. High collapsibility with small or normal-sized IVCD; RAP is very likely low (<5 mm Hg)
2. High collapsibility with a large IVCD or normal collapsibility with a small or normal sized IVCD; RAP is probably between 0- and 10-mm Hg.
3. Normal collapsibility with large IVC; RAP is 10 to 15 mm Hg.
4. Low collapsibility with large IVC; RAP is high (10-20 mm Hg)
5. RAP in patients with low collapsibility and a normal-sized or small IVCD should be interpreted as indeterminate (Ginghina *et al.,* 2009).

Collapsibility index and its variation with age:

In present study we have observed that mean inferior vena cava collapsibility index is 37%. Correlation of collapsibility index with age is not statistically significant with p value of 0.992 and Pearson's correlation coefficient (r) of 0.001.

Collapsibility index and somatic parameters:

In our study we have found that there is no significant correlation of collapsibility index with weight (p value 0.974), height (p value 0.505), BMI (p value 0.696) or BSA (p value 0.615). Collapsibility index doesn't increase or decrease with age and other somatic parameters like weight, height, BSA and BMI. This is because the collapsibility of inferior vena cava depends only on hydration status and doesn't vary with weight, height, BMI and BSA. Collapsibility index of 37 ± 5.5% is independent of body proportion. Hence collapsibility index in present study is consistent with Taneja et al (Taneja, et al., 2018) Kutty *et al.,* (Kutty, *et al.,* 2014), Kathuria *et al.,* (Kathuria, *et al.,* 2015), Haines et al (Haines, *et al.,*2012) and Mannarino *et al.,* (Mannarino, *et al.,*2019).

CONCLUSION

This study provides reference values of IVCD for Indian children of age 1-10 years. IVCD measured by bedside ultrasonography can be used for determination of the intravascular volume status of patients with spontaneous respiration. USG of inferior vena cava can be substitute for invasive hemodynamic monitoring and offers the pediatrician a rapid, non-invasive way to guide fluid resuscitation in critically ill children. There is a positive correlation of maximum and minimum IVCD with somatic parameters like

age, weight, height, BSA, whereas a weakly positive correlation with BMI. Collapsibility index is independent of all these parameters and depends on hydration status of the patient.

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