Original Article

Correlation of Sonographic Inferior Vena Cava and Aorta Diameter Ratio with Dehydration in Nigerian Children

AA Adewumi, KT Braimoh, OAM Adesiyun, HT Ololu-Zubair, BM Idowu[1]

Department of Radiology, University of Ilorin Teaching Hospital, Ilorin, Kwara State, [1]Department of Radiology, Union Diagnostics and Clinical Services, Yaba, Lagos State, Nigeria

ABSTRACT

Background: Accurate assessment of the degree of dehydration is essential in the management and fluid therapy of dehydrated children. The invasiveness of central venous pressure limits its routine clinical use. Fortunately, some studies have suggested that ultrasonographic measurement of inferior vena cava (IVC) diameter: aorta diameter ratio (IADR) is an objective method of assessing intravascular volume. **Objectives:** To determine the clinical usefulness of ultrasound measurement of IADR in assessment of children with dehydration. **Methodology:** This was a cross-sectional study which compared dehydrated children to age- and sex-matched euvolemic healthy children as controls. The maximum anteroposterior diameter of the abdominal aorta (at peak systole) and maximum IVC diameter (in expiration) were measured. **Results:** A total of 120 subjects and 120 controls were evaluated. The mean age was 21.73 ± 20.89 months for subjects and 21.19 ± 22.13 months for control. The mean IADR for children with mild, moderate, and severe dehydration was 0.75 ± 0.07, 0.55 ± 0.07, and 0.33 ± 0.05, respectively. The mean IADR for controls was 0.99 ± 0.06. IADR had an inverse relationship with the degree of dehydration in the subjects. A cut-off point of 0.86, with a sensitivity and specificity of 96.7% in predicting dehydration, was derived, with the sensitivity and specificity increasing with increasing level of dehydration. **Conclusion:** IADR is sensitive and specific for assessing moderate and severe dehydration in Nigerian children.

Keywords: *Collapsibility index, dehydration, diarrheal disease, euvolemia, IVC: aorta diameter ratio, pediatrics*

Date of Acceptance:
25-Mar-2019

Introduction

Dehydration is a common condition encountered frequently in the Emergency Paediatric Unit. According to a World Health Organization (WHO) report, acute diarrheal alone accounts for 1.8 million deaths annually in children under 5 years of age or roughly 17% of all pediatric deaths worldwide, making it the second most common cause of childhood deaths worldwide.[1] Over half of these deaths occur in just five countries: India, Nigeria, Afghanistan, Pakistan, and Ethiopia.[1,2]

The most common cause of dehydration is diarrhea from rotavirus, enterotoxigenic *Escherichia coli*, and epidemics of *Vibrio cholerae*. The most severe threat posed by diarrhea is dehydration which could lead to child mortality.[3,4] Accurate assessment of the degree of dehydration is necessary for the management of these patients in whom delay may result in acute kidney injury and death while overestimation of the deficit may result in fluid overload which can precipitate heart failure.

Dehydration is usually assessed clinically which leaves room for error because it takes into account a

Access this article online

Quick Response Code:

Website: www.njcponline.com

DOI: 10.4103/njcp.njcp_591_18

Address for correspondence: Dr. BM Idowu, Union Diagnostics and Clinical Services, Yaba, Lagos State, Nigeria.
E-mail: ibmcontacts@gmail.com

How to cite this article: Adewumi AA, Braimoh KT, M Adesiyun OA, Ololu-Zubair HT, Idowu BM. Correlation of sonographic inferior vena cava and aorta diameter ratio with dehydration in Nigerian children. Niger J Clin Pract 2019;22:950-6.

combination of symptoms and signs which may be subjective or unreliable.[5] Levine *et al.*[6] and Jauregui *et al.*,[7] in separate studies, examined three clinical scales used for evaluating dehydration. Levine *et al.*[6] examined the WHO severe dehydration scale, Center for Disease Control scale, and Clinical Dehydration Scale (CDS) and concluded that accuracy varied based on provider training and age of child. Jauregui *et al.*[7] opined that the Gorelick scale and CDS scale were fair predictors of dehydration in children with diarrhea or vomiting, but that the WHO scale and physician's clinical judgment were not helpful predictors of dehydration. Kinlin and Freedman[8] also evaluated CDS and found it moderately reliable with weak association with objective measures.

Central venous pressure (CVP) is regarded as the objective measure of intravascular volume, with CVP of <8 mmHg indicating a significant reduction in intravascular volume.[9,10] However, placement of central venous line for CVP is invasive, time-consuming, and further predisposes the patient to infection, thrombosis, and arterial puncture. Therefore, it is not used routinely especially in pediatric patients. On the other hand, ultrasonography is devoid of the complications associated with measuring CVP.

Studies have shown a correlation between sonographic inferior vena cava (IVC) diameter/IVC collapsibility index (IVC CI) and CVP.[11] Contraction of the intravascular volume results in sonographically measurable decrease in IVC diameter and an increase in its CI.[12,13] However, respirophasic variation in IVC diameter, the need for a nomogram to interpret results, and so on limit the use of IVC diameter in isolation for assessing intravascular volume.[14,15] These limitations triggered the quest for a better method of assessing the intravascular volume by increasing the usefulness of the IVC diameter.

The abdominal aortic diameter correlates with body surface area (BSA), age, and sex just like IVC diameter, and there is no statistically significant change in aortic size with hydration status.[16] Consequently, the IVC: aorta diameter ratio (IADR) seems more reliable and can be used without a nomogram for each age group or calculation of BSA.[17,18] The IADR has also been found to be more applicable in pediatric patients. Studies which compared the IADR to the IVC CI, CVP, and WHO scale concluded that IADR is a valuable and better alternative to IVC CI.[17,18]

Ultrasonographically measured IADR has been evaluated in pediatric patients in other parts of the world[17,18] but not in Nigerian children. The purposes of this study were to appraise the value of IADR for assessing hydration status in Nigerian children and to correlate IADR with various degrees of dehydration (mild, moderate, and severe). Our hypotheses were dehydration is associated with low IADR and that IADR is inversely proportional to the severity of dehydration.

Materials and Methods

This cross-sectional study was done at the Emergency Paediatric Unit (EPU) of the University of Ilorin Teaching Hospital (UITH) from January 2015 to August 2015. The study was approved by the Ethics Review Committee of the hospital (approval no. ERC PAN/2014/08/1334). Parental consent was obtained for children <10 years old while both parental consent and assent were obtained for children older than 10 years after explaining the aim and objectives of the study to them in their language. The EPU is a 30-bed unit that cares for children between 29 days and 14 years of age who require beyond ambulatory care. It admits about 1700–2000 cases per year with an average monthly admission of 147.5 ± 46.4 in 2013.[19]

The study population comprised dehydrated patients (as assessed by at least a senior registrar in pediatrics) between the ages of 1 month and 14 years presenting at the EPU of UITH. Age- and sex-matched euvolemic children with no clinical evidence of dehydration who presented with minor complaints at EPU, Paediatric Outpatient Department (POPD) and General Outpatient Department (GOPD) of UITH were enrolled as controls. The subjects and controls were recruited consecutively.

The sample size was calculated using Leslie–Fisher formula[20] with a prevalence rate of 7.3%,[19] yielding a sample size of 104 which was rounded off to 120 to allow for attrition. Since dehydration is a clinical assessment and not recorded as a case, the prevalence of diarrheal disease in UITH (7.3%), which is the major cause of dehydration, was used to calculate the sample size for this study. An equal number (120) of controls were also recruited. Children with history of congenital heart disease or heart failure from any cause, patients on hemodialysis, acute blood loss, connective tissue disease, for example, Marfans' syndrome, and uncooperative children were excluded from the study.

Weighing scale and a standiometer or tape rule were used to measure the weight and height of the participants, respectively, using standard techniques,[5] with the body mass index (BMI) calculated in kilograms per meter square therefrom.[5] The BSA was calculated in meter square using Mosteller's formula $\left(\sqrt{\frac{\text{Height(cm) xWeight(Kg)}}{3600}}\right)$.[5] The mid-upper arm circumference (MUAC) was also measured using a tape rule.[5]

Clinical assessment of hydration status

The degree of dehydration was assessed by the pediatrician, who was blinded to the result of sonographic scan, as mild, moderate, or severe using the following clinical signs as follows: [5] (a) mild dehydration (<5% in an infant; <3% in an older child): normal or increased pulse, decreased urine output, thirsty normal physical findings; (b) moderate dehydration (5%–10% in an infant; 3%–6% in an older child): tachycardia, little or no urine output, irritable/lethargic, sunken eyes and fontanelle, decreased tears, dry mucous membranes, mild delay in elasticity (skin turgor), delayed capillary refill (>1.5 s), cool, and pale; and severe dehydration (>10% in an infant; >6% in an older child): rapid and weak or absent peripheral pulses, decreased blood pressure, no urine output, very sunken eyes and fontanel, no tears, parched mucous membranes, delayed elasticity (poor skin turgor), very delayed capillary refill (>3 s), cold and mottled, limp, and depressed consciousness.[5]

Sonographic examination

A portable Mindray DP-2200 ultrasound machine (Shenzhen Mindray Biomedical Electronics, Nanshan, Shenzhen, China) with variable frequency (2.5–5 MHz) curvilinear probe was used due to a wide range of pediatric body habitus to be scanned (higher frequency for smaller and younger children and lower frequency range for older and bigger children). Coupling gel was also used to expel air and reduce the difference in acoustic impedance between the probe and skin.

The controls were scanned on the examining couch in the POPD and GOPD. The patients were scanned at their bedside while lying supine on the bed. The cooperation of younger children was secured using pacifiers like snacks and colorful toys. After exposing the abdomen and applying a coupling gel, the transducer was placed longitudinally on the subject's abdomen in the midline, 1 cm from the xiphoid process during normal respiration. (The intrahepatic segment of the IVC was seen on this view.) The probe was then oriented in the transverse plane with the probe marker pointed to the patients right; both the IVC and upper abdominal aorta are visible above the vertebral body shadow at this point just caudal to the insertion of the left renal vein into the IVC [Figure 1]. In this view, the liver is used as an acoustic window and care is taken not to compress the abdomen. The image was frozen on the screen and scrolled backward frame by frame to find the aorta at its maximal width (in peak systole).[21] The calipers were then used to measure the anteroposterior (AP) aortic diameter (inner wall to inner wall). The images were scrolled back a few more frames to find the IVC at its largest width (in expiration)[22] and the calipers were again used to measure the AP IVC diameter (inner wall to inner wall). The measurements were taken three times and the average was recorded. All sonographic examinations were done by one sonologist before the commencement of fluid therapy (as much as possible, within 10 min of patients' arrival). The sonologist (first author) was a fourth-year radiology resident under the supervision of two consultant radiologists with 20–22 years' experience.

Data analysis

The demographic parameters (age and sex), weight, height/length, BMI, MUAC, BSA, maximum IVC diameter, maximum aortic diameter, brief clinical history and physical examination, as well as clinical grading of dehydration were recorded. Data analysis was done using the Statistical Package for Social Sciences version 20.0 (SPSS Inc., Chicago, IL, USA) and MedCalc for Windows version 12.5 (MedCalc software, Ostend, Belgium). Test of normality was performed using Kolmogorov–Smirnov's test. Continuous variables were expressed as mean ± standard deviation and categorical variables as frequencies. Tests of significance were done using Student's *t*-test or analysis of variance (ANOVA) as appropriate. Pearson's and/or Spearman's correlation were determined as applicable. Statistical significance was $P \leq 0.05$. Receiver operating characteristic (ROC) curves where plotted to determine the diagnostic cut-offs.

Results

A total of 120 clinically dehydrated children were enrolled for this study between January and August,

Table 1: Demographic and anthropometric parameters' distribution of all participants

Variable	Subject (*n*=120) *n* (%)	Control (*n*=120) *n* (%)	*P*
Age (years)			
≤5	113 (94.2)	113 (94.2)	
>5	7 (5.8)	7 (5.8)	>0.99
Mean±SD (months)	21.73±20.89	21.19±22.13	
Median (months)	16.00	14.00	0.55
Range (min-max)	2-114	2-120	
Sex			
Male	69 (57.5)	69 (57.5)	
Female	51 (42.5)	51 (42.5)	>0.99
Weight (kg)			
Mean±SD	9.01±3.94	9.66±4.27	0.23
Height (cm)			
Mean±SD	78.45±13.51	76.69±15.69	0.35
MUAC			
Mean±SD	13.33±1.68	13.51±1.64	0.41
BSA			
Mean±SD	0.44±0.13	0.45±0.14	0.53

SD: Standard deviation; MUAC: Mid-upper arm circumference; BSA: Body surface area

Table 2: Comparison of sonographic parameters of subjects and controls

Variable	Dehydration	Control	*T*	*P*
	Mild dehydration			
Maximum IVC diameter (mm)				
Mean±SD	5.93±1.15	7.84±1.57	−8.136	<0.001*
Maximum aorta diameter (mm)				
Mean±SD	7.96±1.34	7.94±1.38	0.062	0.950
IADR				
Mean±SD	0.75±0.07	0.99±0.07	−20.876	<0.001*
	Moderate dehydration			
Maximum IVC diameter (mm)				
Mean±SD	3.93±0.72	7.30±1.07	−14.976	<0.001*
Maximum aorta diameter (mm)				
Mean±SD	7.21±1.29	7.27±1.01	−0.212	0.833
IADR				
Mean±SD	0.55±0.07	1.00±0.04	−33.858	<0.001*
	Severe dehydration			
Maximum IVC diameter (mm)				
Mean±SD	2.28±0.46	6.61±1.09	−15.509	<0.001*
Maximum aorta diameter (mm)				
Mean±SD	6.94±0.80	6.94±1.43	0.000	1.000
IADR				
Mean±SD	0.33±0.05	0.96±0.07	−31.019	<0.001*

IVC: Inferior vena cava; SD: Standard deviation; IADR: IVC: Aorta diameter ratio *Independent samples *T*-test

Table 3: Comparison of sonographic parameters between different grades of dehydration

Variable	Grade of dehydration			*F*	*P*
	Mild	Moderate	Severe		
Maximum IVC diameter (mm)					
Mean±SD	5.93±1.15[a]	3.93±0.72[b]	2.28±0.46[c]	120.934	<0.001*
IADR					
Mean±SD	0.75±0.07[a]	0.55±0.07[b]	0.33±0.05[c]	313.350	<0.001*

IVC: Inferior vena cava; SD: Standard deviation; IADR: IVC: Aorta diameter ratio; *F*: Analysis of variance (ANOVA); *Statistically significant (i.e., *P*<0.05); NB: Different alphabets (a, b, c) indicate statistically significant difference using least significant difference

2015. Also, 120 age- and sex-matched controls were enrolled making 120 pairs of subjects and controls. There were 69 (57.5%) male and 51 (42.5%) female subjects compared with 69 male and 51 female controls. The demographic and anthropometric parameters of all participants are shown in Table 1.

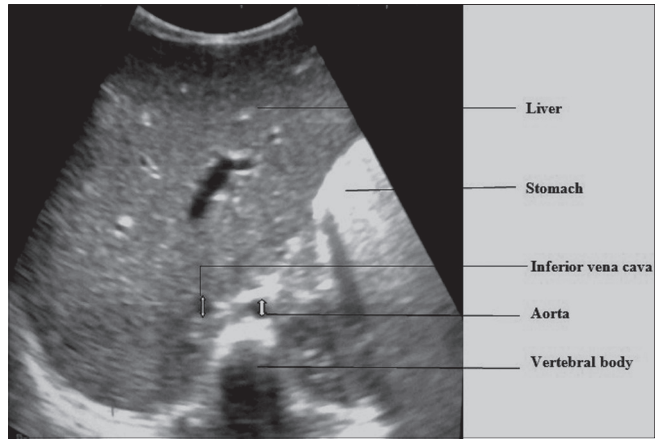

Figure 1: B-mode transverse sonogram of the epigastrium showing the anteroposterior plane for measuring the IVC and upper abdominal aorta diameters

Diarrhea was the most common cause of dehydration in this study (76 cases = 65%). Other causes include 27 gastroenteritis (22.5%), 9 protein energy malnutrition (7.5%), 8 gastritis (6.7%), 8 sepsis (6.7%), 3 upper respiratory tract infection (2.5%), and one case of malaria (0.8%). Sixty-nine (57.5%) subjects had mild dehydration, 33 (27.5%) had moderate dehydration, while 18 (15%) had severe dehydration.

There were statistically significant differences between the mean maximum IVC diameter and IADR of subjects and those of controls [Table 2]. ANOVA and *post hoc* test also showed significant differences between the mean maximum IVC diameter and the mean IADR for mild, moderate, and severe dehydration, respectively [Table 3].

There was a strong negative correlation (i.e., an inverse relationship) between the mean maximum IVC diameter ($\rho = -0.820$; $P < 0.001$) and mean IADR ($\rho = -0.918$; $P < 0.001$), on one hand, and the degree of dehydration, on the other hand.

Using the clinical assessment of dehydration as the gold standard, the test characteristics of IADR were calculated, and an ROC curve to determine the overall performance of IADR in diagnosing dehydration (all degrees) was plotted. It had an area under the curve of 0.9920, $P < 0.001$ at 95% confidence interval. This gave a cut-off point of 0.86 with sensitivity of 96.67% and specificity of 96.67% in predicting dehydration [Table 4]. Similarly, separate ROC curves of IADR in predicting mild, moderate, and severe dehydration individually were also plotted after careful age and sex match of each subgroup. The following cut-off values were derived for the different grades of dehydration: mild ≤0.86, moderate ≤0.71, and severe ≤0.43.

The relationship between the clinical diagnosis and IADR cut-off values for diagnosing dehydration derived

Table 4: Sensitivity and specificity of IADR for predicting all grades of dehydration collectively (criterion values and coordinates of the ROC curve)

Criterion	Sensitivity	95% CI	Specificity	95% CI
≤0.78	90.00	83.20-94.70	99.17	95.40-100.00
≤0.78	90.83	84.20-95.30	99.17	95.40-100.00
≤0.79	91.67	85.20-95.90	99.17	95.40-100.00
≤0.80	92.50	86.20-96.50	99.17	95.40-100.00
≤0.83	95.00	89.40-98.10	98.33	94.10-99.80
≤0.86	**96.67**	**91.70-99.10**	**96.67**	**91.70-99.10**
≤0.88	99.17	95.40-100.00	90.83	84.20-95.30
≤0.89	99.17	95.40-100.00	89.17	82.20-94.10
≤0.90	99.17	95.40-100.00	87.50	80.20-92.80
≤1.00	100.00	97.00-100.00	7.50	3.50-13.80
≤1.09	100.00	97.00-100.00	6.67	2.90-12.70

ROC: Receiver operating characteristic; IADR: IVC: Aorta diameter ratio; CI: Confidence interval Youden index (J): 0.9333; association criterion: ≤0.86

Table 5: Association between IADR cut-offs and clinical diagnosis of various degrees of dehydration

Clinical diagnosis	Dehydration *n* (%)	Normal *n* (%)	Total *n* (%)	χ^2	*P*
		IADR ≤0.86			
Mild dehydration	65 (94.2)	4 (3.3)	69 (36.5)	156.063	<0.001*
Normal	4 (5.8)	116 (96.7)	120 (63.5)		
Total	69 (100.0)	120 (100.0)	189 (100.0)		
		IADR ≤0.71			
Moderate dehydration	33 (100.0)	0 (0.0)	33 (21.6)	153.000	<0.001*
Normal	0 (0.0)	120 (100.0)	120 (78.4)		
Total	30 (100.0)	110 (100.0)	153 (100.0)		
		IADR ≤0.43			
Severe dehydration	18 (100.0)	0 (0.0)	18 (13.0)	138.000	<0.001*
Normal	0 (0.0)	120 (100.0)	120 (87.0)		
Total	16 (100.0)	110 (100.0)	138 (100.0)		

IADR: IVC: Aorta diameter ratio; χ^2: Chi-square; *: Statistically significant (i.e. $P<0.05$)

Table 6: Evaluation of the cut-off points for determining dehydration

Evaluation	Mild	Moderate	Severe	Overall dehydration
Sensitivity	94.20	100.00	100.00	96.70
Specificity	96.70	100.00	100.00	96.70
Positive predictive value	94.20	100.00	100.00	96.70
Negative predictive value	96.70	100.00	100.00	96.70
False-positive rate	3.30	0.00	0.00	3.30
False-negative rate	5.80	0.00	0.00	3.30
Accuracy	95.77	100.00	100.00	96.67

from the ROC curves was subsequently analyzed using Chi-square test of association and a statistically significant relationship was found between clinical and sonographic diagnosis [Table 5].

Table 6 shows the specificity, sensitivity, positive predictive value, negative predictive value, false-positive rate, false-negative rate, and accuracy of the derived IADR cut-off points for determining dehydration in this study.

Discussion

This study evaluated the use of ultrasound in diagnosing and grading dehydration in an attempt to make the evaluation of the dehydrated child more objective and reliable. This study shows a similar distribution pattern in the types of dehydration with a previous study by Ojuawo *et al*. (mild 61.25%, moderate 27.8%, and severe 11%) compared with mild 57.5%, moderate 27.5%, and severe 15.0% in this study.[23] Acute diarrhea alone accounted for 65% of cases of dehydration in this study which is in agreement with previous WHO reports.[3,4]

The mean IADR for controls in this study was 0.99 ± 0.06. This is close to that of a similar study by Chen *et al.* (1.01 ± 0.15).[24] Three other studies by Sridhar *et al.*,[18] Son *et al.*,[25] and Kosiak *et al.*[26] got slightly higher values which are 1.2 ± 0.12, 1.26 ± 0.17, and 1.2 ± 0.17, respectively.

Analysis of the maximum aorta diameter in subjects with different grades of dehydration revealed no variation in the aortic diameter with hydration status in this study. This is in agreement with a previous study by Pearce *et al.*[16] Maximum IVC diameter was, however, consistently low in the dehydrated patients with the fall in the diameter increasing with worsening degree of dehydration (mean IVC diameters for different grades of dehydration were mild: 5.93 ± 1.15 mm, moderate: 3.93 ± 0.72 mm, and severe: 2.28 ± 0.46 mm. This showed that IVC diameter reduces significantly with diminishing intravascular volume. Other studies also reported a similar finding which is the basis of the use of ultrasound in assessment of hydration status.[12,13,27] However, this cannot be used to diagnose or assess hydration status in isolation in the clinical setting without a nomogram to calculate the expected IVC diameter for the child.

Another parameter used in assessing hydration status which was not evaluated in this study is the IVC CI which takes into account the change/variation in IVC diameter, that is, difference between maximum and minimum IVC diameter. An individual is said to have a low intravascular volume when the IVC CI is high. However, this method relies solely on IVC measurements and the use of IVC alone in intravascular volume assessment is associated with several reported limitations like the need for a nomogram for normal IVC diameter,[28] change in IVC diameter with position,[29] and respirophasic displacement of IVC resulting in nonconstant measuring points.[14,28,29] Consequently, the IADR was proposed by other researchers which proved superior to the use of IVC alone for assessing intravascular volume.[17,18]

The IADR of subjects in this study was significantly lower than that of controls. In addition, it had an inverse relationship to the degree of dehydration. It also consistently showed a stronger difference between its value and that of the control compared with maximum IVC diameter.

An IADR cut-off of 0.86 was set in this study as diagnostic of hypovolemia with sensitivity of 96.67%, specificity of 96.67%, positive predictive value of 96.70% and accuracy of 96.67%. The study by Chen *et al.*[24] showed a sensitivity of 100% and a specificity of 39% at 0.72 cut-off value. Levine *et al.*[17] reported a sensitivity of 93% and specificity of 59% at a cut-off of 1.22 for severe dehydration. The index study, however, derived a sensitivity and specificity of 100% at 0.43 for severe dehydration.

The slightly higher cut-off points set by the previous studies may be responsible for the low sensitivity and specificity relative to this study. On the basis of the results in the controls of this study, it can be assumed that the IADR of 0.99 maybe taken as normal in Nigerian children.

Comparison of reference value of IADR of the controls to that of subjects confirmed the main hypothesis of this study. Also, the subhypothesis that IADR is inversely proportional to the severity of dehydration is consistent with our results. This study has been able to set IADR cut-off values for grading dehydration (mild dehydration ≤0.86, moderate dehydration ≤0.71, and severe dehydration ≤0.43). The study adds significantly to the body of knowledge because we are unaware of any study that attempted to sonographically grade dehydration into mild, moderate, and severe like was done in this study.

The advantages of IADR over previous methods of assessing hydration status include being fast and easy to perform, unaffected by respiratory excursions, eliminates the effects of anthropometric parameters, and not needing a nomogram chart for interpretation.

It is important to note that some studies reported that dehydration produces an increase in the aorta–IVC ratio. This variance is as a result of switching the numerator and denominator by these researchers, that is, calculating aorta: IVC diameters ratio instead of IVC: aorta diameter ratio as commonly done.

Conclusion

IADR promises to be a reliable addition to the diagnostic armamentarium for dehydration and its grading. However, it should be used with more caution in diagnosing mild dehydration. This is because the specificity and sensitivity derived for mild dehydration are not as high as those for moderate and severe. Probably, the change in IVC diameter is not much in mild dehydration giving more room for errors in measurement.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. World Health Organization. World Health Report 2005: Making Every Mother and Child Count: Statistical Annex3. Geneva: World Health Organization; 2005. p. 190.
2. United Nations Children's Fund, Progress for Children: A World Fit for Children: Statistical Review. No. 10. New York: UNICEF; December 2007. p. 18-25.
3. World Health Organization. The Treatment of Diarrhoea: A Manual for Physicians and Other Senior Health Workers. 4th rev. Geneva: World Health Organization; 2005. p. 6-8.
4. World Health Organization. Diarrhoea disease. WHO fact sheet No. 330; 2013.

5. Greenbaum LA. Nelson Textbook of Paediatrics. 19th ed. Deficit Therapy. Philadelphia, PA: Saunders Elsevier; 2011 p. 245-9.
6. Levine AC, Munyaneza RM, Glavis-Bloom J, Redditt V, Cockrell HC, Kalimba B, *et al*. Prediction of severe disease in children with diarrhea in a resource-limited setting. PLoS ONE 2013;8:82386.
7. Jauregui J, Nelson D, Choo E, Stearns B, Levine AC, Liebmann O, *et al*. External validation and comparison of three pediatric clinical dehydration scales. PLoS ONE 2014;9:95739.
8. Kinlin LM, Freedman SB. Evaluation of a clinical dehydration scale in children requiring intravenous rehydration. Pediatrics 2012;129:1211-9.
9. Rivers EP, Coba V, Whitmill M. Early goal-directed therapy in severe sepsis and septic shock: A contemporary review of the literature. Curr Opin Anaesthesiol 2008;21:128-40.
10. Jones AE, Focht A, Horton JM, Kline JA. Prospective external validation of the clinical effectiveness of an emergency department-based early goal-directed therapy protocol for severe sepsis and septic shock. Chest 2007;132:425-32.
11. Nagdev AD, Merchant RC, Tirado-Gonzalez A, Sisson CA, Murphy MC. Emergency department bedside ultrasonographic measurement of the caval index for noninvasive determination of low central venous pressure. Ann Emerg Med 2010;55:290-5.
12. Yanagawa Y, Nishi K, Sakamoto T, Okada Y. Early diagnosis of hypovolemic shock by sonographic measurement of inferior vena cava in trauma patients. J Trauma 2005;58:825-9.
13. Lyon M. Blaivas M, Brannam L. Sonographic measurement of the inferior vena cava as a marker of blood loss. Am J Emerg Med 2005;23:45-50.
14. Blehar DJ, Resop D, Chin B, Dayno M, Gaspari R. Inferior vena cava displacement during respirophasic ultrasound imaging. Crit Ultrasound J 2012;4:18.
15. Muller L, Bobbia X, Toumi M, Guillaume L, Molinari N, Ragonnet B, *et al*. Respiratory variations of inferior vena cava diameter to predict fluid responsiveness in spontaneously breathing patients with acute circulatory failure: Need for a cautious use. Crit Care 2012;16:R188.
16. Pearce WH, Slaughter MS, LeMaire S, Salyapongse AN, Feinglass J, McCarthy WJ, *et al*. Aortic diameter as a function of age, gender, and body surface area. Surgery 1993;114:691-7.
17. Levine AC, Shah SP, Umulisa I, Munyaneza RM, Dushimiyimana JM, Stegmann K, *et al*. Ultrasound assessment of severe dehydration in children with diarrhea and vomiting. Acad Emerg Med 2010;17:1035-41.
18. Sridhar H, Mangalore P, Chandrasekaran VP, Manikam R. Caval aorta index and central venous pressure correlation in assessing fluid status! Ultrasound bridging the gap. J Emerg Med 2012;828626.
19. Adedoyin OT, Abdulkadir MB, editors. Morbidity/mortality review for the emergency paediatric unit, University of Ilorin Teaching Hospital for the year 2013. In: Ilorin Annual Paediatric Digest. Ilorin: Department of Paediatrics and Child Health; 2013. p. 94-100.
20. Araoye MO. Research Methodology with Statistics for Health and Social Sciences. 2nd ed. Ilorin: Nathadex Publishers; 2004. p. 115-29.
21. Heerman JR, Segers P, Roosens CD, Gasthuys F, Verdonck PR, Poelaert JI. Echocardiographic assessment of aortic elastic properties with automated border detection in an ICU: *In vivo* application of the arc tangent Langewouters model. Am J Physiol Heart Circ Physiol 2005;288:H2504-11.
22. Feissel MM, Faller JP, Telboul JI. The respiratory variation in IVC diameter as a guide to fluid therapy. Int Care Med 2004;30:1834-7.
23. Ojuawo A, Njoku A, Adedoyin O. The impact of oral rehydration therapy on childhood diarrhoea disease in Ilorin. Niger J Paediatr 2003;30:23-6.
24. Chen L, Kim Y, Santucci KA. Use of ultrasound measurement of the inferior vena cava diameter as an objective tool in the assessment of children with clinical dehydration. Acad Emerg Med 2007;14:841-5.
25. Son KH, Kim MR, Kim YW, Yoon YS. The utility of the IVC/aorta diameter index in trauma patients. J Korean Soc Emerg Med 2010;21:35-43.
26. Kosiak W, Swieton D, Piskunowicz M. Sonographic inferior vena cava/aorta diameter index, a new approach to the body fluid status assessment in children and young adults in emergency ultrasound – Preliminary study. Am J Emerg Med 2008;26:320-5.
27. Sefidbakht S, Nabarizadeh A, Assadsangabi RHR, Abassi HR. Sonographic measurement of the IVC as a predictor of shock in trauma patients. Emerg Radiol 2007;14:181-5.
28. Kutty S, Li L, Hasan R, Peng Q, Rangamani S, Danford DA. Systemic venous diameters, collapsibility indices, and right atrial measurements in normal pediatric subjects. J Am Soc Echocardiogr 2014;27:155-62.
29. Mookadam F, Warsame TA, Yang HS, Emani UR, Appleton CP, Raslan SF. Effects of positional changes on Inferior vena cava size. Eur J Echocardiogr 2011;12:322-5.