American Journal of Emergency Medicine xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Comparison of sonographic inferior vena cava and aorta indexes during fluid administered in children

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ARTICLE INFO

Article history:
Received 15 November 2017
Received in revised form 3 January 2018
Accepted 3 January 2018
Available online xxxx

Keywords:
Aorta
Children
Fluid
Index
Inferior vena cava
Ultrasound

ABSTRACT

Objectives: This prospective, observational study evaluated changes in ultrasound measurements of the inferior vena caval index (IVCI), the aorta diameter/IVC diameter index (Ao/IVCD), and the aorta area/IVC area index (Ao/IVCA) during fluid administration in children requiring intravenous fluid administration.
Methods: Children who presented to the pediatric emergency department with symptoms of dehydration were enrolled between May 2015 and February 2016. The maximum diameter of the aorta, from inner wall to inner wall, and the long and short axis diameters of IVC were measured using a convex array transducer in the transverse view. Subsequently, we measured the diameter of the IVC at the subxiphoid area during inspiration and expiration in longitudinal view. We calculated IVCI, Ao/IVCD, and Ao/IVCA during administration of 10 ml/kg and 20 ml/kg normal saline boluses.
Results: IVCI and Ao/IVCA significantly changed immediately after administration of initial 10 ml/kg of NS. Ao/IVCA showed significant change during the additional administration of 10 ml/kg (total 20 ml/kg) normal saline boluses (1.43, IQR 1.12–1.86 vs. 1.08, IQR 0.87–1.45, p value < 0.001). No significant changes were observed for IVCI and Ao/IVCD. Ao/IVCA was significantly correlated with the volume of fluid administered. The coefficient between initial and administration of the 10 ml/kg normal saline bolus was −0.396 (p value = 0.010), and that between the 10 ml/kg and 20 ml/kg normal saline boluses was −0.316 (p value = 0.038).
Conclusions: Ao/IVCA showed better correlations with the volume of fluid administered than IVCI and Ao/IVCA. Ao/IVCA might be a promising index for assessing the effects of fluid administration.

1. Introduction

Accurate assessment of volume status in children remains one of the most challenging and important tasks for clinicians. Various individual clinical signs, symptoms, and laboratory markers such as body weight loss, capillary refill time, skin turgor, respiratory pattern, heart rate, urine output, serum bicarbonate help identify volume status in children [1]. However, none of these parameters are sufficient for accurately determining volume status and assessing the effects of fluid administration [2].

Ultrasound techniques have been used for assessing volume status in children [3]. Several studies used inferior vena cava diameter, and aorta diameter ratio, rather than inferior vena caval index (IVCI) [4-7]. A new parameter, aorta/IVC cross-sectional area index (Ao/IVCA) was recently suggested, for predicting volume status because of limitations associated with the IVC-diameter measurement [8]. Ao/IVCA may better predicts the need for fluid replacement, compared to the aorta diameter/IVC diameter index (Ao/IVCD).

However, debate continues as to which index better reflects the fluid status and the effects of fluid administration of children. Our study aim was to evaluate and compare ultrasound parameters of the IVCI, Ao/IVCD, and Ao/IVCA during fluid administration in children requiring intravenous fluid administration.

2. Methods

2.1. Study design and setting

This prospective, observational study enrolled children who presented to the PED between May 2015 and February 2016. This was a planned follow-up study which evaluated the accuracy of Ao/IVCA for detecting dehydration in children [8]. Ethical approval for the study was obtained from the Seoul National University Bundang Hospital Institutional Review Board (IRB No. B-1308/216-009). The study was conducted at an academic hospital located in a city with a population of 1,000,000 with >24,000 visits to the PED each year.

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https://doi.org/10.1016/j.ajem.2018.01.010
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2.2. Participant selection

All children under the age of 10-years, who presented to the PED with vomiting or diarrhea, and who need fluid administration were eligible for inclusion. PED physicians determined the clinical dehydration scale and need for intravenous fluid replacement according to each child's condition and dehydration-related symptoms [9]. Children received 10 ml/kg of normal saline (NS) intravenously (IV), every 30 min for 1 h. Exclusion criteria were congenital heart diseases, a clear alternative diagnosis rather than gastroenteritis at the triage unit, or life-threatening shock. The patients who did not require IV fluid administration were also excluded. The research staff obtained written consents from participants' parents/guardians.

2.3. Measurements & ultrasound protocol

Demographic data were obtained immediately after obtaining written consent. During clinical examination, the children were undressed, weighed to obtain a baseline weight, and examined. Each participant was placed in a supine position and one board-certified pediatric emergency physician, certified in critical care ultrasound, conducted ultrasound measurement of the maximum aorta diameter and the long and short axis diameters of the elliptical IVC in the transverse position (probe marker facing to the participant's right side) just inferior to the xiphoid process (Fig. 1a) in 5 min after IV fluid administration. The aorta and IVC were simultaneously visualized in cross section near the level of the entry of the hepatic veins. The investigator measured the maximum diameter of the aorta from inner wall to inner wall, and measured the long and short axis diameters of IVC. IVC cross-sectional area was calculated as 3.14 × 1/2 of the long axis diameter × 1/2 of the short axis diameter and the aortic cross-sectional area was calculated as 3.14 × (1/2 of the diameter)^2. Subsequently, longitudinal sonographic views of IVC were obtained and the diameter of IVC, just below hepatic vein, and its changes were measured during respiration (Fig. 1b). IVCI was calculated as:

Maximal diameter (expiratory) of IVC−minimal diameter (inspiratory) of IVC/maximal diameter (expiratory) of IVC

These ultrasound measurements were conducted immediately after administering the 10 ml/kg and 20 ml/kg NS boluses. We used a 4C-RS with a frequency range of 1.6–4.6 MHz convex array transducer (Vivid S5, General Electronics) at bedside.

2.4. Sample size

The required sample size of 34 was calculated based on previous study [8], using the assumption that the expected mean of Ao/IVCA was 1.61 with standard deviation (SD) of 0.1 and the change of Ao/IVCA would be 0.1 upon administration of 10 ml/kg NS, without change in SD.

2.5. Outcomes

The primary outcome was to compare initial values and changes in IVCI, Ao/IVCD, and Ao/IVCA during administration of 10 ml/kg and 20 ml/kg NS boluses. The secondary outcome was to evaluate the reliability of IVCI, Ao/IVCD, and Ao/IVCA relative to the volume of the administered bolus.

2.6. Statistical analysis

The STATA 14.2 software (Stata Corp LP, College Station, Texas, USA) was used for statistical analyses. Data were expressed as the median and interquartile range (IQR). Fisher's exact test was used for categorical data and Dunn's test was used to estimate the differences between two or more groups if the data were non-parametric. The value of the dependent variable for each 10 ml/kg bolus administered was calculated and the median value and interquartile range were reported. To express the correlation between variables, we assessed linear regression for parametric variables. We determined the utility of each method by comparing the regression coefficient of IVCI, Ao/IVCD, and Ao/IVCA, according to administration of every 10 ml/kg of NS. Probability (p) values < 0.05 were considered statistically significant.

3. Results

3.1. Participant characteristics

Thirty-four children were enrolled (Table 1) and all participants were diagnosed with gastroenteritis. The sex ratio was equal and diarrhea was the most common chief complaint.

3.2. Primary outcome

IVCI and Ao/IVCA changed significantly after administration of 10 ml/kg of NS. Between 10 ml/kg and 20 ml/kg administration of NS, no change was observed in IVCI and Ao/IVCD, but Ao/IVCA changed

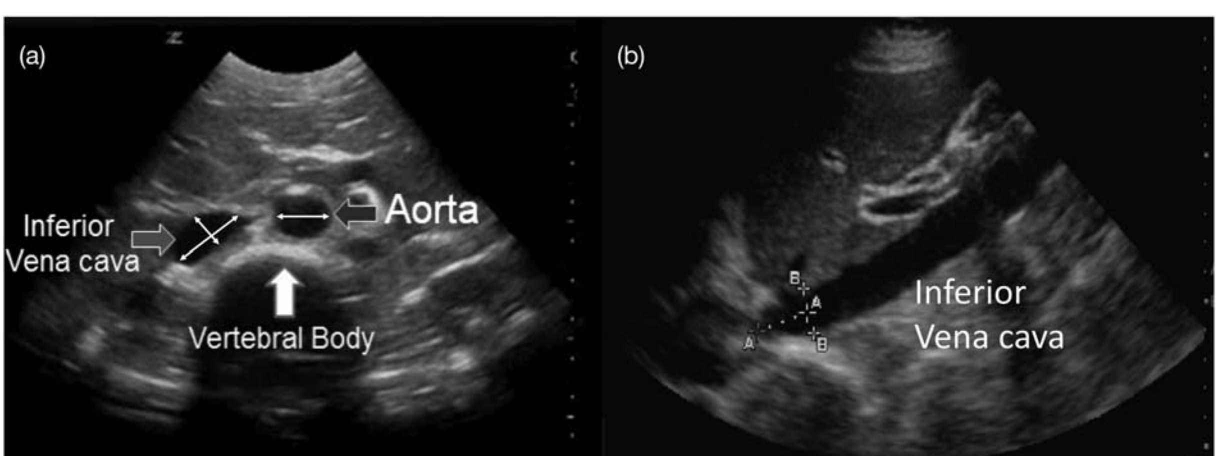

Fig. 1. Ultrasound measurement of aorta and inferior vena cava. (a) Measurement of aorta/inferior vena cava (IVC) diameter and area index. The aorta maximum diameter and the long and short axis diameters of elliptical IVC were measured in the transverse position just inferior to the xiphoid process. The aorta and IVC were simultaneously visualized in cross section near the level of hepatic veins entry. (b) Measurement of inferior vena caval index. Longitudinal sonographic views of the IVC were obtained and the diameter of IVC, just below hepatic vein, and its changes were measured during respiration.

Please cite this article as: Choi YA, et al, Comparison of sonographic inferior vena cava and aorta indexes during fluid administered in children, American Journal of Emergency Medicine (2018), https://doi.org/10.1016/j.ajem.2018.01.010