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Original Contribution

Sonographic aorta/IVC cross-sectional area index for evaluation of dehydration in children☆,☆☆,★

Hyuksool Kwon, MD [a], Jae Yun Jung, MD [a], Jin Hee Lee, MD [b,d,*], Young Ho Kwak, MD, PhD [b], Do Kyun Kim, MD, PhD [b], Jin Hee Jung, MD [c], Ik Wan Chang, MD [b], Kyuseok Kim, MD, PhD [a]

[a] Department of Emergency Medicine, Seoul National University Bundang Hospital, Bundang-gu, Seongnam-si, Gyeonggi-do, Republic of Korea
[b] Department of Emergency Medicine, Seoul National University College of Medicine, Seoul, Republic of Korea
[c] Department of Emergency Medicine, Seoul National University Boramae Hospital, Seoul, Republic of Korea
[d] Kangwon National University College of Medicine, Chuncheon, Gangwon-do, Republic of Korea

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ABSTRACT

Objective: Current studies have not found sufficient evidence to encourage the use of ultrasound for assessing dehydration in children. We introduce a new sonographic parameter, the "aorta/inferior vena cava (IVC) cross-sectional area index" (Ao/IVCA) measured just inferior to the xiphoid process, for the effective evaluation of dehydration in children.
Methods: This is a prospective, observational study. We enrolled children who presented to the pediatric emergency department (PED) between May 2014 and January 2015. We measured the maximum diameter of the aorta from inner wall to inner wall, and the long and short axis diameters of IVC using a convex array transducer. Ao/IVCA was calculated and compared with aorta/IVC maximal diameter index (Ao/IVCD) and the clinical dehydration scale (CDS).
Results: A total of 34 children were enrolled. We found a statistically significant correlation between Ao/IVCA and CDS ($R^2 = 0.30$; $P < .001$). Ao/IVCD did not correlate significantly with CDS ($R^2 = 0.08$; $P = .11$). The ability of Ao/IVCA and Ao/IVCD to predict CDS ≥ 1 was assessed using the receiver operating characteristic analysis. The area under the receiver operating characteristic curve for Ao/IVCA was larger than that for Ao/IVCD (0.87 vs 0.75, $P = .04$). The cut-off value of Ao/IVCA that yielded the maximum value of Youden index was 1.81 (sensitivity: 72%, specificity: 89%).
Conclusions: Ao/IVCA might be a promising index for the assessment of dehydration. The diagnostic performance of Ao/IVCA for dehydration might be higher than that of the method that uses the maximum diameter of IVC and the aorta.

1. Introduction

Accurate assessment of dehydration status is critical in order to provide targeted treatment and to prevent mortality and morbidity in children with gastroenteritis. However, no individual clinical sign, symptom, or laboratory marker has demonstrated adequate sensitivity, specificity, and reliability for detecting dehydration [1,2].

Several studies have identified ultrasound of the inferior vena cava (IVC) and the aorta-to-IVC ratio as a means to identify dehydration in children [3–7]. However, recent studies and a systematic review did not find sufficient evidence to encourage the use of ultrasound for assessment of dehydration in children [2,8]. We are aware of some limitations of IVC measurement, such as elliptical cross-sectional shape of IVC, the difference between collapsibility and distensibility, the difference between the maximal and minimal diameters of IVC, and lack of reference for anatomical landmark of measurement, especially in children. For these reasons, we introduce a new sonographic parameter, the "aorta/IVC cross-sectional area index" (Ao/IVCA) for the effective evaluation of dehydration requiring oral or intravenous fluid replacement in children.

This study aims to assess the accuracy of Ao/IVCA, measured just inferior to the xiphoid process, as a predictor of dehydration compared to the aorta/IVC maximum diameter index (Ao/IVCD) and clinical dehydration scale (CDS) in children in the pediatric emergency department (PED).

2. Methods

2.1. Study design and setting

This prospective, observational study enrolled children who presented to the PED between May 2014 and January 2015. Ethical approval for the study was obtained from the 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 more than 24,000 visits to the PED each year.

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* Corresponding author at: Department of Emergency Medicine, Pediatric Emergency Section, Seoul National University Hospital, 101 Daehak-ro, Jongno-gu, Seoul, 110-744, Republic of Korea. Tel.: +82 10 8870 3528; fax: +82 2 741 7855.
E-mail addresses: gienee74@gmail.com, gienee@snuh.org (J.H. Lee).

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Table 1
Clinical dehydration scale

Characteristic	Score of 0	Score of 1	Score of 2
General appearance	Normal*	Thirsty, restless, or lethargic but irritable when touched	Drowsy, limp, cold, sweaty; comatose or not
Eyes	Normal	Slightly sunken	Very sunken
Mucous membranes	Moist	Sticky	Dry
Tears	Tears	Decreased tears	Absent tears

Friedman et al's Cinical dehydration scale [12].
Higher scores indicate more severe dehydration. Scores range from 0 to 8. A score of 0 correlates with 3% dehydration (positive likelihood ratio 2.2; 95% CI 0.9-5.3), scores of 1–4 correlate with some (3%-6%) dehydration (positive likelihood ratio 1.3, 95% CI 0.9-1.7), and 5–8 correlates with moderate to severe (6% or more) dehydration (positive likelihood ratio 5.2; 95% CI 2.1-12.8).
* "Normal" includes children who may be sleeping but are easily aroused to a normal level of consciousness. This assessment takes into account the time of day and the child's usual pattern as described by the child's guardian.
** This is assessed on the buccal mucosa and tongue, and not the lips.

2.2. Participant selection

All children under the age of 10 years who presented to the PED were eligible for enrollment. We selected children who presented with vomiting or diarrhea on arrival at the triage unit of PED. Patients were assessed for exclusion criteria, including congenital heart diseases, a clear alternative diagnosis rather than gastroenteritis at the triage unit, or life threatening shock. For patients who did not meet any exclusion criteria, the research staff approached the patient's parent/guardian, explained the risks and benefits of the study, and obtained written consent.

2.3. Measurements

Immediately after obtaining written consent, demographic data were obtained. During clinical examination, children were undressed, weighed to obtain a baseline weight, and assessed with CDS (Table 1). Then, the patients were laid flat and a single board-certified pediatric emergency physician with a certificate of critical care ultrasound conducted the ultrasound measurement of the aorta maximum diameter and the long and short axis diameters of elliptical IVC (Fig. 1). Subsequently, venous blood samples were taken and pH and bicarbonate were measured. CDS ≥ 1 defined dehydration that required oral or intravenous fluid replacement, because a value greater than 0 on this scale correlates with >3% dehydration (cite references from Table 1).

2.4. Ultrasound protocol

4C-RS with a frequency range of 1.6 to 4.6 MHz convex array transducer (Vivid S5, General Electronics) was used at bedside by one investigator. The investigator placed the ultrasound probe in the transverse position (probe marker facing to the patient's right side) just inferior to the xiphoid process. The aorta and IVC were visualized in cross section simultaneously 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 (Fig. 2).

2.5. Sample size

The required sample size of 47 has been calculated using the assumption that the expected correlation coefficient between Ao/IVCA and CDS is 0.4 with a power of 80%, and an α of .05.

2.6. Outcomes

The primary outcome was the comparison of Ao/IVCA with CDS and of Ao/IVCD with CDS. The secondary outcome was the diagnostic performance of Ao/IVCA and Ao/IVCD in detecting dehydration that required fluid replacement.

2.7. Primary analysis

The STATA 13.1 software (Stata Corp LP, College Station, TX) was used for statistical analyses. Data were expressed as the median and interquartile range. Fisher's exact test was used for categorical data and Kruskal-Wallis H test was used to estimate the differences between two or more groups. To express the correlation between variables, we assessed linear regression for parametric variables. Receiver operating characteristic (ROC) curves were constructed in order to evaluate the diagnostic performance of Ao/IVCA and Ao/IVCD for dehydration requiring fluid replacement. The area under each ROC curve (AUC) was calculated and expressed as the AUC and 95% CI. The cut-off value was chosen based on the highest Youden index, calculated as sensitivity + specificity − 1. The accuracy was represented using the terms sensitivity and specificity. $P < .05$ was considered statistically significant.

3. Results

3.1. Participants characteristics

A total of 34 children were enrolled (Table 2) and the final diagnosis of all participants was gastroenteritis. The sex ratio was equal and no significant difference was observed between sexes. We found that six patients (18%) had severe dehydration (CDS ≥ 5) and eight patients (24%) had no dehydration. A Kruskal-Wallis H test showed a statistically

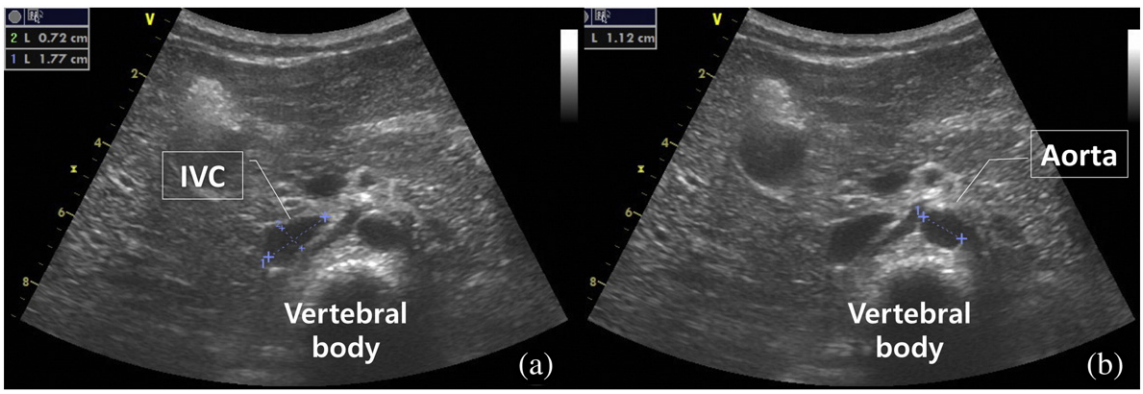

Fig. 1. Measurement of the long and short axis diameters of elliptical inferior vena cava (a), and the aorta maximum diameter (b) just below the xiphoid process.