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Research Article

Investigation of Inferior Vena Cava Diameter Measurements as An Assessment Criterion in Acute Dehydration

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Abstract

Aim: Acute dehydration due to gastroenteritis is a significant and preventable cause of childhood mortality worldwide. "We used bedside ultrasonography to compare inferior vena cava/Abdominal aorta (IVC/Ao) diameter ratios before and after treatment in patients with acute dehydration and controls, offering a novel, rapid, and objective assessment tool.
Material and Method: This study included 68 children admitted to Düzce University Medical Faculty Hospital Pediatric Emergency. 34 of them were patients had acute severe dehydration, and the other 34 case were in the healthy Control Group (CG). IVC and Ao were measured in the transverse plane below the xiphoid process using bedside ultrasonography (USG).
Results: A significant difference was found in the IVC/Ao ratio between the Patient Group (PG) and CG ($p<0.001$). When PG pre- and post-treatment measurements were compared, the results were highly significant ($p<0.001$). The lack of correlation between the IVC/Ao ratio and age and weight demonstrated that it could be used in the assessment of children of all ages and weights.
Conclusion: The IVC/Ao ratio is a rapid and innovative assessment method that can be applied across various age groups and weight categories.

Keywords: Acute gastroenteritis, acute dehydration, bedside ultrasonography, inferior vena cava, abdominal aorta diameter

INTRODUCTION

Dehydration due to acute gastroenteritis is the second most common cause of childhood mortality with a rate of 9%. Worldwide, 710.000 children die each year due to acute dehydration throughout the World (1,2). Acute gastroenteritis in children cause 1.5 million outpatients, 200,000 hospitalizations, and 300 deaths annually in the United States (3). The fact that acute dehydration can be easily treated with appropriate fluid replacement makes this situation more dramatic.

The global mortality rate has started to decline rapidly in the last decade, with the incidence of diarrhea decreasing from 3.4 per hundred thousand to 2.9 per hundred thousand per year. Diarrhea mortality rates have decreased, although minor changes have occurred, such as rotavirus vaccine, improvements in infant nutrition, Oral Rehydration Fluid, and changes in the diet of children with diarrhea (4). New treatment and diagnostic methods for pediatric diarrhea will play an important role in reducing mortality (5).

In cases of no dehydration or mild dehydration, there is no need for examination. The European Society for Pediatric Gastroenterology, Hepatology, and Nutrition (ESPGHAN) 2014 guidelines do not recommend the routine use of any stool test to differentiate bacterial viral diarrhea (6-8). Thus, the lack of a definite laboratory value for acute dehydration causes the diagnosis, follow-up, and treatment of the patient to be non-specific, which causes uncertainty in the duration, amount, and adequacy of treatment.

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The most important goal in the treatment of dehydration due to acute gastroenteritis is to maintain the fluid and electrolyte balance and restore hydration. Breastfed infants should continue to be breastfed (5,6).

Adequate and safe treatment of a condition with such a high incidence in children will be possible with the use of measurements that determine the diagnosis and degree of dehydration, and mortality will decrease significantly. This will provide numerical information regarding the adequacy of treatment.

MATERIAL AND METHOD

34 patients between the age range of 6 months-11 years, admitted to Düzce University Medical Faculty Hospital within six months, and who developed acute dehydration due to acute gastroenteritis were included in the Patient Group. 34 healthy patients without acute dehydration or acute gastroenteritis were included in the study as the Control Group. Our study was approved by Düzce University Medical Faculty Hospital Ethics Committee on 27.06.2016 with the number 2016/53, and conducted in accordance with the principles of the Declaration of Helsinki.

Data Collection

Patients with acute gastroenteritis who visited the Pediatric Emergency department with complaints of vomiting and diarrhea were evaluated by the pediatrician in charge. No intervention was performed for the treatment and examinations were decided by the clinician. The patients considered to have acute dehydration due to acute gastroenteritis were reported to the researcher, who was questioned again according to the World Health Organization (WHO) dehydration rating in terms of dehydration and acute gastroenteritis (9). The control group comprised patients who presented to the pediatric emergency department with general symptoms and abdominal pain. These group consisted of healthy children without any current infection or history of acute or chronic illness. All participants underwent examination and diagnostic workup to confirm the absence of pathology and none required hospital admission.

The patient (PG) and control (CG) groups were evaluated according to the WHO Dehydration scale. This case form included clinical conditions based on the WHO scale (vomiting episodes, thirst, urine output, general appearance, eyes, skin turgor, mucosal membranes, tears, pulse quality, respiratory pattern, and capillary refill time). This study included patients observed in the pediatric emergency department who presented with severe dehydration, as determined by the World Health Organization dehydration scale, and who subsequently required intravenous fluid resuscitation. The examination findings and treatment were recorded on the case form by a pediatrician who conducted the examination according to the WHO dehydration scale. Data from case forms were retrospectively included in the study.

Ultrasonographic Measurement

Prior to the study, the researcher received training in bedside USG. Abdominal Aorta (Ao) and inferior vena cava (IVC) measurements were performed with ultrasonography (USG) in the Pediatric Emergency department (General Electric/LOGIQ A5 Pro Model). The measurements were performed anteroposterior (AP) from below the xiphoid with the convex probe at 5.0 MHz frequency, in the transverse section images of the pediatric abdominal preset. The diameters of the Ao and IVC were measured by the researcher in a single view section. To increase the statistical accuracy and reduce the clinical error in the measurements made in 68 cases, two separate measurements of Ao and IVC were performed consecutively, and their average was calculated.

Measurements were recorded before and within 2-4 hours of treatment in the Patient Group at two separate times. This was recorded once for the Healthy Control Group. The workflow and overall applications are presented in Figure 1.

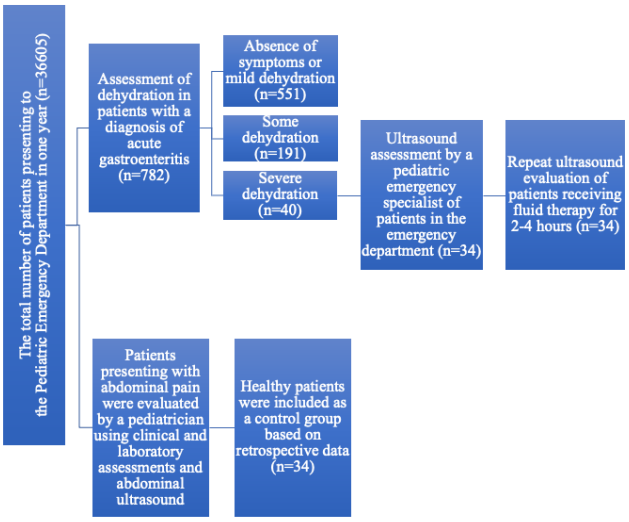

Figure 1. Emergency department evaluation process for pediatric dehydration in gastroenteritis

Exclusion criteria of the study: Patients presenting with vomiting except for severe sepsis and acute gastroenteritis, chronic gastroenteritis (>2 weeks), intoxication, congenital heart disease, heart failure, acute trauma, acute blood loss, and connective tissue diseases such as Marfan syndrome, with other chronic diseases, who received oral free liquid as treatment and 20 ml/kg saline within less than two hours were excluded from the study.

Statistical Analysis

The analysis was conducted using SPSS 23.0 (SPSS Inc., Chicago, IL, USA). Descriptive data are expressed as mean±standard deviation for continuous variables and as frequency and percentage for categorical variables. Depending on the distribution of the data, the Independent Samples t-test or Mann-Whitney U test was used to compare the groups in terms of continuous variables. The relationships between categorical variables were examined using the chi-square test or Fisher's exact test, depending on the expected value rule. In the comparison of the Patient Group before and after treatment, the Paired Samples t-test or Wilcoxon test was used depending on the distribution of the data for continuous variables, and McNemar or McNemar-Bowker tests were

used for categorical variables, depending on the number of categories. Pearson's correlation analysis was used to examine the linear relationship between the continuous variables. Statistical analyses were performed using SPSS software, and the significance level was set at 0.05.

RESULTS

Demographic Characteristics and Laboratory

The mean age of the participants in the PG was 52.85±34.34 months (min 8 months; max 132 months). In the CG, the mean age was 44.35±31.29 months (min 6 months; max 120 months). The mean weight of PG was 16.75±7.14 kg and the mean weight CG was 17.88±8.73 kg. Fifteen (44.1%) participants in the PG and 14 (41.2%) in the CG were females.

There were no significant differences between the two groups in terms of age, sex, or weight (age, p=0.29; sex, p=0.56; weight, p=0.8).

Compared to controls, patients showed significant differences in the following laboratory values: White blood cell (PG;10.78±4.88 and CG;8.81±2.50, p=0.042), Sodium (PG;137.35±4.21 and CG;145.26±2.16, p=0.001), K (PG; 4.42±0.49 and CG; 4.74±0.34, p=0.003), Urea (PG; 30.10±12.93 and CG; 20.96±6.39, p=0.001), BUN (PG;14.11±5.86 and 9.99±3.04, p=0.001), Creatinine (PG; 0.44±0.16 and CG;0.34±0.11, p=0.003), and C-reactive protein (PG;16.2±10.4 and 3.5±3.1, p=0.001). There were no significant differences in Hb, Htc, and Cl between the groups (Table 1).

Table 1. Patient group and control group laboratory values

	Patient group (n=34)	Control group (n=34)	p value
Hb	12.14±1.16	11.83±0.85	0.223
Htc	36.75±3.39	35.74±2.38	0.162
Wbc	10.78±4.88	8.81±2.50	**0.042**
Na	137.35±4.21	145.26±2.16	**0.001**
K	4.42±0.49	4.74±0.34	**0.003**
Cl	102.71±5.64	102.62±2.12	0.932
Urea	30.10±12.93	20.96±6.39	**0.001**
BUN	14.11±5.86	9.99±3.04	**0.001**
Creatinin	0.44±0.16	0.34±0.11	**0.003**
CRP	16.2±10.4	3.5±3.1	**0.001**

Hb: hemoglobin, Htc: hematocrit, Wbc: white blood cells, Na: sodium, K: potassium, Cl: chloride, BUN: blood urea nitrogen, CRP: C-reactive protein

The causative agents of gastroenteritis identified in our study were as follows: Rotavirus (n=24), Adenovirus (n=5), and Unknown (n=5).

Examination Findings

In PG, 20 individuals (58.8%) experienced reduced or no urine output. Mucosal hydration assessment revealed 4 cases (11.8%) with dry mucosa, 21 cases (61.8%) with moderately dry mucosa, and 9 cases (26.5%) with slightly dry or moist mucosa. Significant differences were observed between PG and CG in terms of urine output, thirst sensation, mucosal hydration (p<0.001), and tear production (p=0.011).

However, no statistically significant differences were found between the groups in terms of turgor tone, capillary refill time, pulse quality, respiratory evaluation, and extremity temperature.

Comparisons within the patient group before and after treatment revealed significant improvements in the thirst sensation (p=0.039), mucosal hydration (p<0.001), and tear production (p=0.031). The average peak heart rate decreased from 100/min before treatment to 90/min after treatment (p=0.005). These findings suggest that fluid therapy results in reduced thirst, improved mucosal hydration, increased tear production, and decreased tachycardia. These results emphasize the importance of assessing urine output and thirst in acute dehydration, along with the evaluation of mucosal hydration.

Ultrasonography Findings

Before the PG treatment, the mean IVC was 0.50±0.16 mm, and the mean Ao was 0.83±0.17 mm. The mean IVC/Ao ratio were 0.61±0.18. The mean IVC in CG was 0.85±0.18 mm, and the mean of Ao was 0.86±0.17 mm. IVC/Ao ratio was found to be 0.99±0.09. The IVC/Ao ratio between CG and PG found a difference (p<0.001) (Table 2).

The In PG-PreTreatment and PG-postTreatment measurements, IVC PG-PreTreatment mean was 0.50±0.16 mm, and the mean of IVC PG-PostTreatment was 0.72±0.21 mm (p<0.001). The mean Ao PG-PreTreatment was 83±0.17 mm and the mean Ao PG-PostTreatment was 83±0.18 mm. This result demonstrates that the Ao Diameter before and after dehydration can be a constant measurement that does not change. IVC/Ao ratio in PG-PreTreatment was 0.61±0.18, and 0.87±0.17, respectively (p<0.001). One of the positive results of the study was that the IVC/Ao ratio increased in favor of IVC and approached Ao after treatment (Table 2).

Table 2. IVC diameter, Ao diameter and IVC/Ao ratio; p value between PG-CG and patient group pre-treatment and post-treatment

	Patient group Pre-treatment (n=34)	Control group (n=34)	p value Between PG-CG	Patient group Post-treatment (n=34)	p value between pre-post treatment
IVC	0.50±0.16	0.85±0.18	**<0.001**	0.72±0.21	**<0.001**
Ao	0.83±0.17	0.86±0.17	0.492	0.83±0.18	0.979
IVC/Ao	0.61±0.18	0.99±0.09	**<0.001**	0.87±0.17	**<0.001**

IVC: inferior vena cava, Ao: abdominal aorta, PG: patient group, CG: control group

The correlations of IVC, Ao, and IVC/Ao with age and body weight of the PG and CG were evaluated. Highly significant results were obtained in the Pearson correlation with IVC age (months) and body weight in the CG (r=0.659, p<0.001). Pearson correlation was found to be significant for Ao (r=0.713, p<0.001). Indeed, this result was expected. Age and weight were not significant in all correlations, including the IVC/Ao ratio, CG, PG-PreTreatment, and PG-PostTreatment. This shows that the IVC/Ao ratio was not affected by variables, such as age and weight (Table 3).

Table 3. The correlations of IVC diameter, Ao diameter and IVC/Ao with the ages and body weights

		Age (month)	Body weight (kg)
IVC pre-treatment	r	0.628*	0.515*
	p	<0.001*	0.002*
	n	34	34
IVC post-treatment	r	0.741*	0.462
	p	<0.001*	0.006*
	n	34	34
Ao pre-treatment	r	0.678*	0.618*
	p	<0.001*	<0.001*
	n	34	34
Ao post-treatment	r	0.742*	0.461
	p	<0.001*	0.006*
	n	34	34
IVC/Ao pre-treatment	r	0.149	0.086
	p	0.399	0.629
	n	34	34
IVC/Ao post-treatment	r	0.299	0.216
	p	0.086	0.219
	n	34	34

IVC: inferior vena cava, Ao: abdominal aorta diameter

DISCUSSION

Although clinical anamnesis and physical examination are at the center of the diagnosis and treatment of acute dehydration in pediatric patients, this evaluation can be reflected in the treatment and follow-up in different ways, depending on the patient's anamnesis and the clinician's approach. However, laboratory evaluations do not provide clear data for clinicians. In this respect, approaching a clear measurable value in patients undergoing acute dehydration will be useful in terms of treatment and follow-up. It is very important that there is a measurement in the denominator of the ratio to be evaluated that is not affected by age, weight, or acute dehydration. Therefore, it appears that Ao is not affected by intravenous or oral treatments (10,11). In addition, Ao is directly correlated with age and weight. In this case, Ao allowed us to obtain a value independent of age and weight when proportioned to the IVC at different ages and weights. IVC diameter and IVC/Ao ratio were significant before and after treatment.

According to the data in the study, white blood cell count, sodium, potassium, urea, BUN, creatinine, and CRP levels are significantly different in dehydrated children compared to the control group (Table 1). Notably, changes in sodium and potassium levels highlight that electrolyte imbalances are a significant consequence of dehydration (12). The observed changes in Na levels in our study corroborate these findings, further indicating the impact of dehydration. Increased urea, BUN, and creatinine levels compared to the control group suggest an effect on kidney functions, although these values remained within normal limits. The increase in CRP value indicates that the body is undergoing an inflammatory response. This collectively illustrates how dehydration affects the physiological balance in children and triggers the inflammatory response. The pathophysiology of dehydration involves a loss of bodily fluids, which can lead to electrolyte imbalances, alterations in renal function, and the activation of inflammatory processes. Early diagnosis and intervention are crucial to prevent serious complications such as acute kidney injury (13).

In Modi et al.'s research, a statistically significant relationship was discovered between the diameters of the aorta and IVC. However, the study also cautioned that the substantial increase in IVC diameter following fluid therapy in severely dehydrated children cannot be relied upon as a dependable measure (14). It is our belief that the IVC, which is subject to various influences, should not be considered in isolation, and that a more accurate result can be obtained by utilizing the IVC/Ao ratio. The disparity in the IVC/Ao ratio between the healthy control group and post-treatment group in our study implies that dehydration-induced intravascular volume loss can be replenished with long-term oral fluid therapy. Our study allowed for unrestricted access to oral rehydration therapy. Based on this observation, we infer that assessment of severely dehydrated patients can be carried out using adequate fluid therapy, and the results can be assessed through subsequent evaluations.

One of the challenges associated with measuring IVC is that it is influenced by various factors. The standardization of measurements can be affected by the collapse of inspiratory and respiratory cycles. Although weight is not directly related to this situation, it can lead to difficulties for clinicians in determining the accuracy of measurements (15-17). To address this issue, our study obtained the largest portion of IVC measurement close to the expiration time and calculated the average of two separate measurements. We believe that this approach can improve standardization. In the study by Jauregui et al., an IVC/Ao ratio of 0.83 or higher was considered normal (16). In a study by Kwon et al., the IVC/Ao ratio was 0.54 in dehydrated patients (18). Naghipour et al. suggested that the IVC/Ao ratio was the most reliable indicator for transesophageal echocardiography in healthy children, and the mean ratio measured at the right atrium entrance was reported as 0.94 (19). In our study, the IVC/Ao ratio was 0.61 before treatment and increased to 0.87 after treatment, and it was 0.99 in the Control Group (Table 2). The values obtained in our study are consistent with those

reported in other studies, indicating that the IVC/Ao ratio can be safely used in most patient

In a study conducted by Özkan et al., 128 children with dehydration were classified into three groups based on dehydration severity: mild, moderate, and severe. Significant differences were observed in the IVC/Ao ratio between the pre- and post-treatment groups. Additionally, a meaningful difference in p value was found between the CG and PG groups in our study, which was conducted in addition to the comparison of pre- and post-treatment values (Table 2) (20).

In a prior investigation, Bellini et al., 65 patients were diagnosed with IVC collapse. This was assessed by using the Kiss-Sing score. This finding suggests a link between dehydration and the development of IVC. In addition, this study did not find a correlation between IVC measurements and biomarkers related to biochemical parameters. Our study included a control group and dehydration scale, which allowed for a more comprehensive evaluation of the IVC/Ao ratio (21).

In a comprehensive meta-analysis carried out in 2023, Kaminecki et al. scrutinized the findings of eight individual studies. The authors posited that the World dehydration assessment tool was the most effective measurement tool, and the results indicated the importance of maintaining proper hydration levels in pediatric patients (22). In our study, we observed a substantial increase in the post-dehydration IVC diameter in three of the studies included in the aforementioned meta-analysis. Additionally, our study demonstrated a noteworthy increase in the IVC/Ao ratio post-treatment, with a difference of pre-treatment.

Limitations: The fact that this was a single-center study, USG was performed by a single clinician, and children under the age of two are incompatible while performing USG, which limits the results of the study. The retrospective design of this study precluded the inclusion of urine output as a variable. Prospective studies should address this limitation by recording and analyzing the relationship between urine output, treatment duration, and IVC measurements in dehydrated patients to facilitate a more comprehensive comparison of IVC diameters. While not consisting entirely of healthy children, the control group for this study included patients presenting to the emergency department who did not meet the inclusion criteria for dehydration-related illnesses.

CONCLUSION

The IVC/Ao ratio is a fast and reliable numerical ratio that can be used in the diagnosis, treatment, follow-up, and clinical evaluation of patients with acute dehydration.

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Ethical approval: *Ethical approval for this study was granted by the Düzce University Faculty of Medicine Ethics Committee on 27.06.2016 with the number 2016/53.*

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