ORIGINAL ARTICLE / ÖZGÜN ARAŞTIRMA MAKALESİ

Comparison of Inferior Vena Cava Collapsibility and Clinical Scales for the Assessment of Dehydration in Children With Diarrhea

İshalli Çocuklarda Dehidratasyonun Değerlendirilmesi için Inferior Vena Kava Kollapsibilite Indeksi ve Klinik Ölçeklerin Karşılaştırılması

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ABSTRACT

Aim: There is no fair predictor to determine the dehydration level in children. The objective of the study was to investigate the efficacy and reliability of the inferior vena cava collapsibility index by the use of ultrasonography to assess volume status for pediatric patients with acute gastroenteritis.

Material and Methods: This prospective study was conducted in a tertiary care hospital between December 2016 and October 2017. Patients were assessed with clinical dehydration scores and their inferior vena cava collapsibility indices were measured. The weights of the children were measured prior to treatment and one week after the improvement of symptoms. The correlation between the dehydration percentage seven days after symptom relief and inferior vena cava collapsibility index and also the correlation between clinical dehydration scale results and dehydration percentage seven days after symptom relief were determined.

Results: 190 patients enrolled in the study. 130 (68.4%) patients were found to be mildly dehydrated while 60 (31.6%) patients' dehydration levels remained moderate to severe, and of these 18 (9.4%) were severely dehydrated. The area under the curve for the caval index was determined as 0.985 (95% CI; 0.959-1). The IVCCI cutoff of >58 produced 98.3% sensitivity, 88.5% specificity, 0.79 PPV, 0.99 NPV, 1.2 +LR, and 1.01 -LR. The AUC for moderate-to-severe dehydration was 0.778 (CI 95%: 0.703-0.854) according to the CDC and 0.764 (95% CI:0.669-0.889) for the Gorelick scale.

Conclusion: USG-guided IVC index measurement is an effective and reliable method for determining the dehydration severity in pediatric patients present with acute gastroenteritis.

Keywords: Acute gastroenteritis, inferior vena cava collapsibility index, pediatrics

ÖZ

Amaç: Çocuklarda dehidratasyon düzeyini belirlemek için objektif öngörücü değerlendirme testleri ile ilgili çalışmala sınırlıdır.Çalışmanın amacı, akut gastroenteritli pediatrik hastalarda volüm durumunu değerlendirmek için ultrasonografi kullanılarak inferior vena kava kollapsibilite indeksinin etkinliğini ve güvenilirliğini araştırmaktı.

Gereç ve Yöntemler: Bu prospektif çalışma, Aralık 2016 ile Ekim 2017 tarihleri arasında üçüncü basamak bir hastanede yürütülmüştür. Hastalar klinik dehidratasyon skorları ile değerlendirildi ve sonografik inferior vena kava kollapsibilite indeksi ölçüldü. Çocukların ağırlıkları tedaviden önce ve semptomların düzelmesinden bir hafta sonra ölçüldü. Semptomların düzelmesinden yedi gün sonra dehidratasyon yüzdesi ile vena kava inferior kollapsibilite indeksi arasındaki korelasyon ve ayrıca klinik dehidratasyon skalası sonuçları ile semptomların iyileşmesinden yedi gün sonra dehidratasyon yüzdesi arasındaki korelasyon belirlendi.

Bulgular: Çalışmaya 190 hasta alındı. 130 (%68,4) hastanın hafif dehidrate olduğu, 60 (%31,6) hastanın dehidratasyon düzeylerinin orta-şiddetli düzeyde kaldığı ve bunların 18'inin (%9,4) ciddi dehidrate olduğu tespit edildi. Kaval indeks için eğri altında kalan alan 0,985 (%95 GA; 0.959-1) olarak belirlendi. >58 IVCCI kesme değeri %98,3 duyarlılık, %88,5 özgüllük, 0,79 PPV, 0,99 NPV, 1,2 +LR ve 1,01 -LR üretti. Orta-şiddetli dehidratasyon için EAA, CDC'ye göre 0,778 (CI %95: 0,703-0,854) ve Gorelick ölçeği için 0,764 (%95 GA:0,669-0,889) olmuştur.

Sonuç: Akut gastroenterit ile başvuran pediatrik hastalarda dehidratasyon şiddetini belirlemede USG eşliğinde IVC indeks ölçümü etkili ve güvenilir bir yöntemdir.

Anahtar Kelimeler: Akut gastroenterit, inferior vena cava kollapsibilite indeksi, pediyatri

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Introduction

Diarrhea-related dehydration is a common problem in children. Delayed administration of treatment for dehydration may lead to severe fluid and electrolyte imbalance, acute renal failure, and even death (1). Diarrhea complicated by dehydration is the second leading cause of death among children under 5 years old (2). Determining the degree of dehydration is a key step in the prevention of mortality, as the severity of diarrhea is directly proportional to fluid loss (2). By contrast, misdiagnosis of dehydration in normovolemic or mildly dehydrated patients may lead to unnecessary hospitalizations (3). Therefore, the most important question that should be asked to ensure efficient and appropriate management of pediatric patients with acute diarrhea is ''Is this child dehydrated?''.

Alteration in weight percentage is regarded as the "gold standard" method for determining the level of dehydration; however, this method is inappropriate for use in the emergency department (ED) due to the 1 week later the measurement of body weights is not possible in the emergency room (4). The Clinical Dehydration Scale (CDS) and the Gorelick Scale are the most commonly used clinical dehydration scales (5). However, they are subjective scoring systems that may be influenced by the clinician's experience and may often be inadequate for accurately determining dehydration severity (6). Furthermore, these classification scales are not equally sensitive for all pediatric age groups. While they are recommended for patients in their first years of life, data concerning their use for older pediatric age groups are limited. Therefore, a rapid, non-invasive, dynamic measurement method that will enable the clinician to make the optimal decision is required.

Evaluation of inferior vena cava collapsibility through ultrasonography is a method that is frequently used in adults (7). However, the method of inferior vena cava collapsibility index for the assessment of volume status in children with acute diarrhea is limited.

We hypothesize that the evaluation of inferior vena cava collapsibility index through ultrasonography is a reliable method for the assessment of volume status, due to its non-invasive, rapid, and dynamic properties. The study's objectives were to investigate the efficacy and reliability of the inferior vena cava collapsibility index by the use of ultrasonography to assess volume status, and to compare these results with the most widely used clinical dehydration scales in pediatric patients admitted to the ED due to acute diarrhea.

Material and Methods

Study design

This single-center, prospective, observational study was conducted at a tertiary care center that receives around 350,000 ED visits annually, with pediatric patients accounting for approximately 25% of all admissions. The study was approved by the local ethics committee (KOU KAEK-2016/278). Written informed consent was obtained from all parents and from the patient him/herself if he/she was literate.

Participants

The study was conducted at the emergency department (ED) of a tertiary care training and research hospital from December 2016 to October 2017. Enrollment occurred on weekdays between 08:00 to 17:00. Patients aged between 6 months and 17 years, who had experienced at least 3 watery defecations during the last 24 hours were included in the study if the researcher who would perform ultrasonography examination was available at the time of their admission to the ED. Patients who did not consent to participation, those who had chronic liver failure, renal or cardiac failure, those who were intubated, and trauma patients were excluded from the study.

Study protocol

Written informed consent was obtained from all participants included in the study. The patients were evaluated by an emergency medicine specialist who had at least two years of experience in the emergency department. Demographic data, vital signs, physical examination findings, clinical dehydration scores, and weight were recorded, and then the principal investigator was called. Complete blood counts, blood urea nitrogen (BUN), creatinine, and venous blood gas analyses were obtained for all participants. The clinical dehydration scales were used to assess the dehydration severity of the patients by the attending physician, and the dehydration status of the patients were classified as mild, moderate, or severe. Clinical assessment of hydration status was not disclosed to the researcher who would perform the ultrasonography. The basal body weight of the patients was measured minus clothing prior to treatment. The body weights of children under 2 years old were measured using a digital baby weighing scale (Weewell Digital Baby Scale, China), while children over 2 years old were weighed using an electronic weighing scale (Tess Electronic Scale, RP LCD-300, Turkey). The first and second weights were measured using the same instruments. Ultrasonography was performed with the patient in the supine position prior to treatment. Treatment was administered in accordance with the guidelines as per the decision of the attending physician who had performed the initial evaluation. The decision to hospitalize or discharge each patient was made on the basis of the clinical and laboratory findings, dehydration severity, and tolerance of oral intake. Patients admitted to the hospital according to the recommendation of Centers of Disease Control and Prevention guideline: If caregivers

cannot provide adequate care at home; substantial difficulties exist in administering oral rehydration therapy; concern exists for other possible illnesses as metabolic disorders or immune compromise complicating the clinical course; oral rehydration therapy fails; severe dehydration exists; social or logistical concerns exists; such factor as young age, unusual irritability or drowsiness, progressive course of symptoms, inpatient care was indicated. Weight loss percentage could not be estimated without knowledge of the patient's initial weight; hence, the alteration in weight one week after recovery was considered to be the optimal point of reference, based on previous literature (8). One week after their first visit, patients were contacted by phone to schedule appointments for the repeated weight evaluation and were asked to return one week after resolution of the symptoms. The weight loss percentage after one week was calculated using the formula: (last weight-first weight)/ last weight x100. Patients whose weight loss was less than 5% were classified as "mildly dehydrated" and patients whose weight loss was in excess of 5% were classified as "moderately-to-severely dehydrated". Patients who experienced weight loss between 5 and 10% were classified as "moderately dehydrated" and patients whose weight loss exceeded 10% were classified as "severely dehydrated". All data were recorded in the patients' record forms.

Ultrasonography examination

A single emergency medicine specialist, who had 5 years of experience and held basic and advanced ultrasonography education certificates awarded by the Turkish Association of Emergency Medicine, performed ultrasonography examinations for all patients. The patients who had been admitted to the hospital between 8 a.m. and 5 p.m. were included in the study as the investigator was working during these hours. Ultrasonography scans were carried out using the Sonoace R5 (USS-SAR5N20/WR, Samsung Medison, Hampshire, UK) device. The CN2-8 MHz convex probe was used and adjusted for each patient. The probe was placed in the subxiphoid region with the marker directed toward the patient's right side. When the subxiphoid image of the heart had been obtained, the probe was rotated 90 degrees so that the marker was directed toward the patient's head. Ultrasound scans were obtained in the longitudinal plane at 2 cm before the inferior vena cava (IVC) merges with the right atrium. Minimum and maximum inspiratory and expiratory diameters of the IVC were measured on the motion mode (M-mode) image. The IVC collapsibility index was measured using the following formula: (IVC expiratory diameter-IVC inspiratory diameter) / IVC expiratory diameter x 100. Measurements and calculations were recorded on patients' record forms.

Outcome measures

The primary outcome measures were defined as the correlation between the inferior vena cava collapsibility index (IVCCI) score and the dehydration percentage seven days after symptom relief. The secondary outcome measures were defined as the correlation between the clinical dehydration scale results and dehydration percentage seven days after symptom relief and the correlation between the IVCCI score and the clinical dehydration scale results.

The sample size was determined using a software application (G-Power 3.1.3, Franz Faul, Universität Kiel, Kiel, Germany). The clinically acceptable IVC collapsibility index difference between the groups was determined as 20± 10% for this study. The required sample size was determined as 102 for effect size: 0.5, alpha: 0.05, and power: 0.80.

Statistical analysis

Statistical analyses were performed using the SPSS version 21.0 for Windows (SPSS Inc. Chicago, USA) statistical package program. The socio-demographic and clinical characteristics of the patients were presented as mean ± standard deviation, median, interquartile range (IQL), 95% confidence interval (CI) and percent (%). The Student's t-test or the Mann-Whitney U-test was used to compare the continuous variables, and the chi-squared test was used to compare the intermittent variables. The diagnostic value of the IVCCI for the prediction of moderate-to-severe dehydration was evaluated using receiver operating characteristic (ROC) curve analysis. Sensitivity, specificity, negative predictive values (NPV), and likelihood ratios (LR) were estimated within the 95% CI and compared.

Results

A total of 212 pediatric patients were admitted with acute diarrhea during the study period. 22 patients who met the exclusion criteria or who were lost to follow-up were excluded from the study, and, consequently, the study proceeded with 190 participants. The patients' mean age was 52.34 months (SD± 40.8) and 97 (51.05%) were male. Age, gender, vital signs on admission, and the laboratory values are presented in Table 1.

When the patients were evaluated according to weight alteration one week after recovery, 130 (68.4%) patients were found to be mildly dehydrated while 60 (31.6%) patients' dehydration levels remained moderate to severe, and, of these, 18 (9.4%) were severely dehydrated. Although moderate to severe dehydration was determined in 27 patients by using the CDC scale, according to the alteration in weight percentage these patients were mildly dehydrated. However, 23 patients with mild dehydration were determined as moderate to severely dehydrated by using Gorelick scale. Both the CDC and Gorelick scales assessed 16 patients as moderate to severely dehydrated but, according

	All Patients	Mild Dehydration	Moderate-Severe Dehydration	p
Age	52.34	54.11	48.48	0.178
m (± SD)	(± 40.8)	(± 40.53)	(± 41.44)	
Sex M	97	69	28	0.413
n (%)	(%51)	(%53.1)	(%46.7)	
Temperature	36.83	36.88	36.72	0.321
m (± SD)	(± 1.69)	(± 1.58)	(± 1.9)	
Pulse Rate m	110.99	107.35	118.9	0.002
(± SD)	(± 22.1)	(± 20.79)	(± 22.95)	
Respiratory Rate	14.78	14.51	15.37	0.141
m (± SD)	(± 3.53)	(± 3.47)	(± 3.61)	
SBP	99.72	103.12	92.35	0.000
m (SD)	(± 14.47)	(± 12.63)	(± 15.51)	
DBP	62.6	65.15	57.07	0.000
m (± SD)	(± 10.83)	(± 9.74)	(± 10.99)	
BUN/Creatinine	26.2	24.89	29.02	0.009
m (± SD)	(± 10.41)	(± 9.45)	(± 11.82)	
pH	7.39	7.4	7.37	0.000
m (± SD)	(± 0.05)	(± 0.04)	(± 0.67)	
PCO2	31.62	32.47	29.76	0.05
m (± SD)	(± 6.26)	(± 6.23)	(± 5.97)	
HCO3 m (± SD)	19.5 (± 3.7)	20.12 (± 3.28)	18.12 (± 4.18)	0.022

m: Mean, M: Male , SBP: Systolic Blood Pressure, DBP :Diastolic Blood Pressure, BUN: Blood Urea Nitrogen

Table 1. Baseline demographics, vital signs and laboratory findings of study groups.

to the alteration in weight percentage, these patients were mildly dehydrated.

While moderate to severe dehydration was found in 60 patients by using the alteration in weight percentage, of these 44 had moderate to severe dehydration according to both the CDC and Gorelick scales. The degree of the dehydration in different age groups is shown in Table 2.

The ROC curve of the IVCCI's predictive value for dehydration severity is presented in Figure 1. The area under the curve (AUC) for the IVCCI was determined as 0.985 (95% CI; 0.959-1). The IVCCI cutoff of>58 produced 98.3% sensitivity, 88.5% specificity, 0.79 PPV, 0.99 NPV, 1.2 +LR, and 1.01 -LR. The diagnostic value of the CDS and the Gorelick Scale are presented in Table 3. The AUC for moderate-to-severe dehydration was 0.778 (CI 95%: 0.703-0.854) according to the CDS and 0.764 (95% CI: 0.669-0.889) for the Gorelick Scale (Figure 2 and Figure 3).

Discussion

The present study has revealed that the CDS and the Gorelick Scale are subjective tests, with low sensitivity and specificity levels, that are susceptible to being influenced by the clinician's experience and are inadequate for determining the degree of dehydration.

	Mild dehydration	Moderate dehydration	Severe dehydration	Total
< 2 years old n (%)	33 (17.4%)	12 (6.3%)	8 (4.2%)	53 (27.9%)
2-5 years old n (%)	52 (27.4%)	17 (8.9%)	7 (3.7%)	76 (40%)
> 5 years old n (%)	45 (23.7%)	13 (6.8%)	3 (%1.6)	61 (32.1%)

Table 2. Severity of the symptoms according to the age.

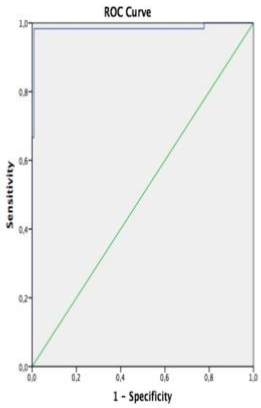

Figure 1. Inferior vena cava collapsibility index >58 predicting significant dehydration 5 % body weight change. AUC (Area under curve) : 0.985 (95% CI; 0.959-1)

However, measurement of the IVCCI by ultrasonography offers superior sensitivity and specificity for determining the degree of dehydration.

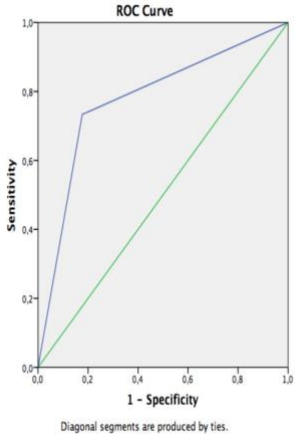

Figure 2. Clinical Dehydration Scale predicting significant dehydration 5 % body weight change. AUC (Area under curve) : 0.778 (CI 95%: 0.703-0.854)

Accurate assessment of hydration status enables clinicians to correctly determine whether there is a need for hospital admission and to assess whether a patient needs immediate intravenous fluid therapy. There is no definitive assessment method for hydration status in patients presenting with acute diarrhea in the ED. Urinary output might be difficult to measure in children experiencing frequent watery diarrhea. Laboratory tests are invasive and have limited utility for assessing hydration status (6). Clinical decision-making for the management of pediatric patients with acute gastroenteritis is a commonly used method; however, a meta-analysis including 13 studies has revealed that no signs or symptoms can securely define a child's degree of dehydration. This meta-analysis also reported that laboratory tests are unreliable indicators of hydration status (6).

	Sensitivity %	Specificity %	PPV %	NPV %	LR +	LR -
IVCCI ≥ 58	98.3	88.5	0.79	0.99	8.16	0.22
CDS ≥ 1	65.7	87	0.73	0.82	5	1.14
Gorelick Scale ≥ 8	77.13	54.4	0.77	0.82	1.6	0.42

CDS: Clinical dehydration scale, PPV: Positive predictive value NPV: Negative predictive value, LR: Likelihood ratio, IVCCI: inferior vena cava collapsibility index

Table 3. Test characteristics of clinical scales and IVCCI for predicting the ≥5% dehydration with the best cutoff points.

The Gorelick Scale and the CDS are the most commonly used clinical scoring systems. While Gorelick et al. reported their scale to have a sensitivity of 82% and a specificity of 90% for determining dehydration severity when applied by emergency nurses, Vega et al. reported lower percentages (70% sensitivity, 84% specificity) when the test was applied by emergency physicians (9). It has been reported that the sensitivity and specificity of the CDS were similar to those of the Gorelick Scale for determining moderate-to-severe dehydration (10). However, it has been reported that the CDS was effective in predicting the duration of hospital stay, the requirement for intravenous fluid replacement, and determining the need for hospital admission (11,12).

In the present study, patients were evaluated using the Gorelick Scale and the CDS. The sensitivity and specificity of the Gorelick Scale in determining hydration status were consistent with those observed in previous studies; by contrast, the sensitivity and specificity of the CDS were lower than those observed in previous studies (13). It has been suggested that the difference between our findings and those of previous studies may be attributed to the subjectivity of the clinical scoring systems.

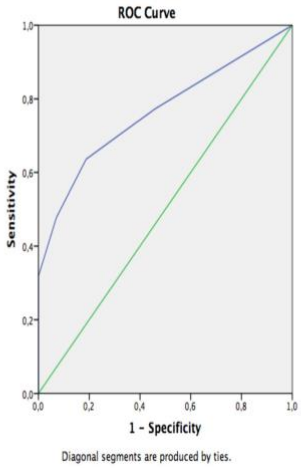

Figure 3. Gorelick 3-point scale predicting significant dehihydration 5 body weight change under 5 years old. AUC (Area under curve) : 0,764 (95% CI:0,669-0,889)

The IVCCI is a reliable method for detecting and measuring dehydration in adult patients (7). There are few studies in the literature investigating the use of IVCCI to determine hydration status in pediatric patients. Chen et al. reported a negative correlation between IVC diameter and the degree of dehydration in pediatric dehydrated patients (8). Levine et al. evaluated IVC collapsibility in 52 children presenting with diarrhea and/or vomiting and reported that when a 27% cutoff was used, the IVCCI had a sensitivity of 93% and a specificity of 35% (14). The most significant limitation of this study was its small sample size. However, our research is nonetheless important, having involved the largest study population to participate in a study of pediatric dehydration hitherto.

However, the measurement of IVC collapsibility using ultrasonography was investigated in a limited number of studies, and the small sample sizes were the major limitation for these studies. The absence of valid cutoff points for dehydration severity leads to difficulties with patient management in the ED. The present study revealed that when a > 58 cutoff was used, the hydration status of the patients were determined using the IVCCI with a sensitivity of 98.3% and specificity of 88.5%. In the light of these results, the IVCCI is a practical, effective, and reliable method suitable for use in daily practice. Ultrasonography is a useful diagnostic tool for the diagnosis of dehydration, but there are some limitations to using ultrasonography. Ultrasound equipment is expensive; on the other hand, it is less expensive than most other imaging equipment. According to the World Health Organization, the use of diagnostic ultrasound should be encouraged where there is a likelihood of clinical benefit. On the other hand, the use of diagnostic ultrasound by individuals without proper training and experience adds to the likelihood of unnecessary examinations and misdiagnosis. This renders

ultrasonography dependent on the skill and experience of the physician, and its usage is limited to physicians.

Limitations

Our study has several limitations. Since it was conducted in a single emergency department, the results cannot be generalized. To eliminate the experience gap between the users and to improve the reliability of the results, one researcher performed the ultrasonography for all patients. Enrollment only occurred during working hours, and thus selection bias may have been present and loss of study subjects may have occurred. The study included more patients than the planned sample size to minimize the study's limitations. Ten patients were lost to follow-up. Intention-to-treat analysis was not performed because the number of patients lost to follow-up constituted 5.6% of the entire study group. The optimal method for calculating weight loss percentage is based on the alteration between pre-illness and post-illness weight. However, pre-illness weights were unavailable, so weight measurement one week after resolution of symptoms was accepted as the patient's actual weight. Hospitalized patients may receive more fluid than discharged patients, so it is likely that the final weight values were greater in hospitalized patients. However, this patient group's mean IVCCI values were 92.48% (± 7.72), so dehydration degrees were severe, and for this reason, it is likely that the amount of fluid received did not significantly affect the study results.

Conclusion

Clinical scoring systems used to determine dehydration severity in pediatric patients are subjective and susceptible to being influenced by clinicians' experiences. We consider the ultrasonography-guided IVCCI method to be non-invasive, easily applicable, effective, and reliable in determining dehydration severity and reducing the number of unnecessary hospitalizations in pediatric patients presenting with acute diarrhea.

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Authors' Contribution: Study design (AEÖ,OK), case sonographer (AEÖ,OK), writing the manuscript (AEÖ,OK), statistical evaluation (OK)

Ethical Statement: Approval was obtained from Kocaeli University Non-invasive Clinic Researchs Ethics Committee (Number: KOU KAEK-2016/278). All authors declared that they follow the rules of Research and Publication Ethics.

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