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# Ultrasound Assessment of Dehydration in Children

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**Key Words**
Pediatric dehydration, ultrasound, Inferior vena cava measurement

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**ABSTRACT**

Dehydration is a common and potentially serious condition in pediatric patients, often requiring rapid and accurate assessment to guide treatment. Traditional clinical methods for evaluating dehydration can be subjective, leading to variability in diagnosis. This study aims to assess the role of ultrasound, specifically using measurements of the inferior vena cava (IVC) and aorta, in determining dehydration severity in children. This descriptive, observational study was conducted at a tertiary care center in Maharashtra, India, over a period of three months. A total of 75 pediatric patients presenting with dehydration were included. Ultrasound was used to measure the IVC cross-sectional area, aorta cross-sectional area and IVC/aorta ratios. These measurements were correlated with clinical dehydration scales and analyzed for their accuracy and reliability in assessing dehydration severity. Statistical analysis was conducted using SPSS software version 20.0. Out of the 75 children, 52% showed no dehydration, 32% had mild dehydration and 8% each had moderate and severe dehydration. The IVC cross-sectional area was significantly larger in dehydrated patients ($p<0.01$). The IVC/aorta area ratio demonstrated good diagnostic accuracy, with a sensitivity of 82% and specificity of 75%. There was a near-perfect agreement (Cohen's Kappa=0.936) between ultrasound findings and clinical dehydration scales. Ultrasound proved to be a reliable, non-invasive tool for assessing dehydration in children. The IVC and aorta measurements, particularly the IVC cross-sectional area and IVC/aorta ratio, showed strong correlations with clinical dehydration severity, supporting their use as complementary diagnostic tools alongside traditional clinical assessments.

## INTRODUCTION

Dehydration in children is a significant concern in clinical practice, as it is often associated with a range of causes, including gastrointestinal illnesses, fever and inadequate fluid intake. Globally, dehydration is one of the leading causes of morbidity and mortality in children, particularly in low-resource settings where access to clean water and healthcare may be limited[1]. Early and accurate diagnosis of dehydration is crucial for effective management and to prevent complications such as electrolyte imbalances, shock, and even death[2].

Traditionally, clinical assessment of dehydration in children relies on physical examination findings such as dry mucous membranes, reduced skin turgor and changes in mental status[3]. However, these clinical signs can be subjective and vary significantly between individuals. The need for a more objective, reliable, and non-invasive method to assess dehydration has led to the exploration of various diagnostic tools, including biochemical tests, ultrasound and imaging techniques[4].

Ultrasound is emerging as a promising tool for the assessment of dehydration in children due to its non-invasive nature, ease of use and accessibility. It provides real-time imaging of various body structures, including the inferior vena cava (IVC) and bladder, which can offer valuable insights into the child's fluid status[5,6]. Similarly, bladder ultrasound can help assess urine volume, providing an indirect measure of hydration status[7].

The potential of ultrasound in assessing dehydration is particularly important in pediatric populations, as children can decompensate rapidly due to their smaller fluid reserves and higher metabolic rates[8]. Accurate and timely assessment of dehydration in children can significantly improve treatment outcomes and reduce the risk of complications. Despite the growing interest in ultrasound for this purpose, there is limited literature on its application in pediatric dehydration, and further research is needed to establish standardized protocols and guidelines[9].

**Aim:** To evaluate dehydration in children with sonographic aorta/ IVC cross sectional area index.

**Objectives:**

- To measure IVC and aorta cross sectional area in dehydration patient.
- To determine Aorta/ IVC diameter index.
- To compare the Aorta/ IVC area to both the Aorta/ IVC diameter and clinical dehydration scale.

## MATERIALS AND METHODS

**Source of Data:** The source of data for this study included pediatric patients presenting with dehydration, referred to the Radio-Diagnosis Department of a tertiary care center in Sangli district, Maharashtra. The data were collected from patients who met the inclusion criteria over a three-month period.

**Study Design:** This study was designed as a descriptive, observational study aimed at evaluating the role of ultrasound in assessing dehydration in pediatric patients.

**Study Location:** The study was conducted in the Radio-Diagnosis Department of a tertiary care center located in the Sangli district, Maharashtra. This center serves as a referral hospital for pediatric cases, including those with dehydration, making it an ideal location for the study.

**Study Duration:** The study was conducted over a period of three months, during which pediatric patients presenting with dehydration were enrolled and assessed using ultrasound.

**Study Population:** The study population consisted of pediatric patients diagnosed with dehydration who were referred to the Radio-Diagnosis Department for ultrasound evaluation during the study period.

**Sample Size:** A total of 75 pediatric patients with dehydration were included in this study. The sample size was determined based on the number of patients referred to the Department of Radio-Diagnosis within the three-month study period, using convenient sampling techniques.

**Inclusion Criteria:**

- Pediatric patients diagnosed with dehydration.
- Patients whose parents or guardians were willing to provide informed consent for participation in the study.
- Patients presenting with complications of dehydration during the study period were also included in the study.

**Exclusion Criteria:** No exclusion criteria were applied in this study. All pediatric patients meeting the inclusion criteria were enrolled.

**Sampling Technique:** The study utilized a convenient sampling technique, enrolling all pediatric patients presenting with dehydration who were referred to the Radio-Diagnosis within the study period.

**Procedure and Methodology:** All pediatric patients diagnosed with dehydration and referred to the Radio-Diagnosis Department underwent a detailed ultrasound examination, focusing on the assessment of the inferior vena cava (IVC) and aorta diameters. The following procedure was followed:

- **Patient Preparation:** Patients were placed in a supine position for the ultrasound examination. The parents or guardians were briefed about the procedure and consent was obtained.
- **Ultrasound Equipment:** A high-resolution ultrasound machine was used for the assessment. A pediatric ultrasound probe was used to ensure accuracy in measuring the small anatomical structures of children.
- **IVC Diameter Measurement:** The diameter of the IVC was measured in the subcostal view, 1-2 cm caudal to the junction of the hepatic veins with the IVC. The measurement was taken in both inspiratory and expiratory phases to assess collapsibility, which is an indicator of hydration status.
- **Aorta Diameter Measurement:** The aorta was measured in the same subcostal view as the IVC, serving as a reference for comparison. The aortic diameter is relatively constant, whereas the IVC diameter changes with hydration status.
- **Clinical Correlation:** The ultrasound measurements, particularly of the inferior vena cava (IVC) and aorta, were analyzed in conjunction with recorded clinical indicators of dehydration. These clinical indicators included observations of dry mucous membranes, decreased skin elasticity, sunken eyes and general physical appearance, as documented in the patient's medical records. The severity of dehydration was categorized into mild, moderate and severe, based on these clinical signs, following established medical guidelines and literature.
- **Data Recording:** All ultrasound findings, including IVC diameter, aortic diameterwere recorded in a pre-designed data sheet for further analysis.

**Sample Processing:** The collected data from the ultrasound examination were processed immediately following the assessment of each patient. Measurements were confirmed by the radiologist, and any discrepancies in measurement were rechecked to ensure accuracy.

**Data Collection:**

**Data were Collected in a Systematic Manner, Including:**

- Demographic details of the patients (age, gender, clinical symptoms of dehydration).
- Ultrasound measurements of IVC and aorta diameters.
- Clinical signs of dehydration recorded from medical records.

All data were entered into a pre-designed data sheet for statistical analysis.

**Statistical Methods:** The collected data were entered into Microsoft Excel and analyzed using SPSS software (version 20.0). The statistical methods employed in the study included:

- **Descriptive Statistics:**
- Continuous variables (e.g., IVC diameter, aortic diameter) were expressed as mean and standard deviation (SD).
- Categorical variables (e.g., presence of dehydration symptoms) were presented as numbers and percentages.
- **Interpretation of Results:**
- The correlation between ultrasound findings and clinical signs helped to assess the reliability of ultrasound as a diagnostic tool for dehydration in children.

**Ethical Considerations:** Informed consent was obtained from the parents or guardians of all pediatric patients included in the study. The study was conducted in compliance with ethical standards, ensuring the confidentiality of patient information.

## RESULTS AND DISCUSSIONS

Table 1: Distribution of Study Sample Based on the Clinical Dehydration Scale

| Clinical dehydration scale | Counts | % of Total |
|---|---|---|
| No dehydration | 39 | 52.0 % |
| Mild dehydration | 24 | 32.0 % |
| Moderate dehydration | 6 | 8.0 % |
| Severe dehydration | 6 | 8.0 % |

In Table 1, the distribution of the study sample based on the clinical dehydration scale shows that 52% of the children exhibited no dehydration, while 32% had mild dehydration, and only 8% each had moderate or severe dehydration.

Table 2: Comparison of Patients with and Without Dehydration Based on Their Age

| | | Any dehydration present | | |
|---|---|---|---|---|
| Age groups | | Absent | Present | Total |
| <1 year | | | | |
| | Observed | 15 | 8 | 23 |
| | % within column | 38.5 % | 22.2 % | 30.7 % |
| 1-5 years | | | | |
| | Observed | 9 | 16 | 25 |
| | % within column | 23.1 % | 44.4 % | 33.3 % |
| 6-10 years | | | | |
| | Observed | 4 | 7 | 11 |
| | % within column | 10.3 % | 19.4 % | 14.7 % |
| 11-15 years | | | | |
| | Observed | 8 | 4 | 12 |
| | % within column | 20.5 % | 11.1 % | 16.0 % |
| 16-17 years | | | | |
| | Observed | 3 | 1 | 4 |
| | % within column | 7.7 % | 2.8 % | 5.3 % |
| Total | Observed | 39 | 36 | 75 |
| | % within column | 100.0 % | 100.0 % | 100.0 % |

Table 2 compares dehydration status based on age. Children aged 1-5 years had the highest incidence of dehydration, with 44.4% of dehydrated patients falling within this age group. Conversely, only 2.8% of dehydrated patients were aged 16-17 years. The <1 year" group had 22.2% dehydration prevalence.

Table 3: Comparison of Patients with and Without Dehydration Based on Their Gender

| | | Any dehydration present | | |
|---|---|---|---|---|
| Gender | | No | Yes | Total |
| Female | Observed | 12 | 12 | 24 |
| | % within column | 30.8 % | 33.3 % | 32.0 % |
| Male | Observed | 27 | 24 | 51 |
| | % within column | 69.2 % | 66.7 % | 68.0 % |
| Total | | | | |
| | Observed | 39 | 36 | 75 |
| | % within column | 100.0 % | 100.0 % | 100.0 % |

Table 3 highlights the gender distribution of patients with dehydration. Males accounted for 68% of the total sample, with 66.7% of them dehydrated, while females made up 32% of the sample, with 33.3% of them experiencing dehydration. The gender distribution was fairly balanced between those with and without dehydration.

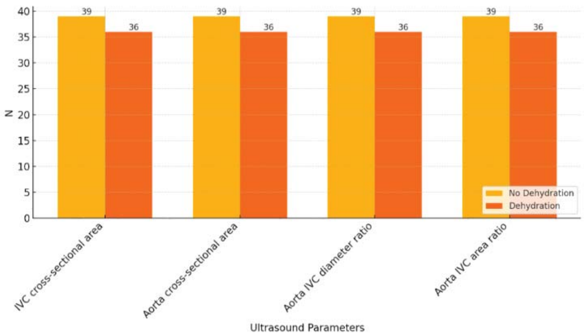
Table 4: Description of Mean Ultrasound Parameters According to Severity of Dehydration

| Ultrasound parameters | Clinical dehydration scale | N | Mean | SD |
|---|---|---|---|---|
| IVC cross-sectional area (cm) | No dehydration | 33 | 0.484 | 0.22 |
| | Mild dehydration | 18 | 0.618 | 0.24 |
| | Moderate dehydration | 14 | 0.716 | 0.17 |
| | Severe dehydration | 10 | 0.410 | 0.15 |
| Aorta cross-sectional area (cm) | No dehydration | 33 | 2.145 | 1.09 |
| | Mild dehydration | 18 | 0.675 | 0.33 |
| | Moderate dehydration | 14 | 0.747 | 0.11 |
| | Severe dehydration | 10 | 0.445 | 0.10 |
| Aorta IVC diameter ratio | No dehydration | 33 | 1.38 | 1.64 |
| | Mild dehydration | 18 | 1.14 | 0.35 |
| | Moderate dehydration | 14 | 1.146 | 0.06 |
| | Severe dehydration | 10 | 0.92 | 0.05 |
| Aorta IVC area ratio | No dehydration | 33 | 4.849 | 2 . 2 |
| | Mild dehydration | 18 | 1.219 | 0.83 |
| | Moderate dehydration | 14 | 1.072 | 0.18 |
| | Severe dehydration | 10 | 0.82 | 0.12 |

Table 5: Comparison of Mean Ultrasound Parameters Between Patients with and Without Dehydration

| | Dehydration present | N | Mean | SD | p value* |
|---|---|---|---|---|---|
| IVC cross-sectional area ($cm^2$) | | | | | |
| | No | 39 | 0.484 | 0.22 | < 0.01 |
| | Yes | 36 | 0.628 | 0.22 | |
| Aorta cross-sectional area ($cm^2$) | | | | | |
| | No | 39 | 2.145 | 1.1 | 0.38 |
| | Yes | 36 | 0.668 | 0.29 | |
| Aorta IVC diameter ratio | | | | | |
| | No | 39 | 1.38 | 1.64 | 0.36 |
| | Yes | 36 | 1.125 | 0.29 | |
| Aorta IVC area ratio | | | | | |
| | No | 39 | 4.849 | 2.2 | 0.33 |
| | Yes | 36 | 1.148 | 0.69 | |

Table 5 compares ultrasound parameters between patients with and without dehydration. The IVC cross-sectional area was significantly larger in dehydrated patients (mean 0.628 $cm^2$, $p<0.01$) compared to non-dehydrated ones. However, the aorta cross-sectional area, Aorta/IVC diameter ratio, and Aorta/IVC area ratio did not show statistically significant differences between the groups.




Without Dehydration

Table 6: Interrater Reliability Between Ultrasound Diagnosis of Dehydration and Clinical Dehydration Scale

| Method | Cohen's Kappa |
|---|---|
| Subjects | 75 |
| Agreement % | 96 |
| Kappa | 0.936 |
| z | 11.6 |
| p-value | < 0.001 |

At kappa value of 0.93, near perfect agreement was observed between ultrasound diagnosis and clinical dehydration scale.

Table 6 demonstrates near-perfect agreement between ultrasound diagnosis and the clinical dehydration scale, with a Cohen's Kappa value of 0.936, indicating a high level of reliability (96% agreement) in ultrasound-based dehydration diagnosis. With Ao/IVC diameter ratio having a higher Area Under Curve (AUC), its diagnostic capability was better as compared to Ao/IVC area ratio.

In Table 7, the operating characteristics of the Aorta/IVC diameter ratio and cross-sectional area ratio for diagnosing dehydration are presented. The Aorta/IVC cross-sectional area ratio had higher diagnostic accuracy with 82% sensitivity and 75% specificity, yielding an Area Under Curve (AUC) of 0.820. In contrast, the Aorta/IVC diameter ratio had lower sensitivity (55%) and specificity (45%), with an AUC of 0.500, suggesting a limited diagnostic capability.

The table presents the diagnostic performance of two ultrasound parameters-Aorta/IVC diameter ratio and Aorta/IVC cross-sectional area ratio-compared with the clinical dehydration scale. For the Aorta/IVC diameter ratio, a cutoff value of greater than 1.1 identified 24 true positive cases (correctly diagnosing dehydration) and 17 false positives (incorrectly diagnosing dehydration in non-dehydrated patients). It also resulted in 12 false negatives (failing to diagnose dehydration) and 22 true negatives (correctly identifying non-dehydrated patients).

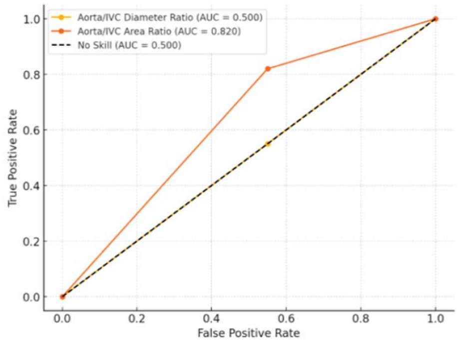



Fig. 2: ROC Curves for Aorta/IVC Diameter and Area Ratios

| | | Dehydration present based on clinical dehydration scale: Yes | No |
|---|---|---|---|
| Aorta/IVC diameter ratio > 1.1 | Yes | 24 (true positive) | 17 (false positive) |
| | No | 12 (false negative) | 22 (true negative) |

| | | Dehydration present based on clinical dehydration scale: Yes | No |
|---|---|---|---|
| Aorta/IVC cross-sectional area ratio > 0.84 | Yes | 29 (true positive) | 30 (false positive) |
| | No | 7 (false negative) | 9 (true negative) |

For the Aorta/IVC cross-sectional area ratio, a cutoff value greater than 0.84 provided 29 true positives and 30 false positives. The cross-sectional area ratio demonstrated 7 false negatives and 9 true negatives. Overall, the cross-sectional area ratio showed higher sensitivity (more true positives) but had a higher number of false positives compared to the diameter ratio, which highlights a trade-off between sensitivity and specificity in these ultrasound measures for dehydration assessment.

This Table 1 shows that 52% of the children had no dehydration, while 32% had mild dehydration. Moderate and severe dehydration were each observed in 8% of the cases. These findings are comparable to studies that reported higher incidences of mild dehydration over moderate and severe dehydration in pediatric populations Gray[10]. Clinical dehydration scales are valuable for initial assessment but can lack precision, which ultrasound can potentially improve Ijiri[11].

Age group comparisons show that the highest proportion of dehydrated children (44.4%) was in In table 2, the 1-5 years age range, while those less than 1 year made up 22.2%. These trends align with previous studies that report young children, particularly under 5 years, as being more prone to dehydration due to their higher metabolic rate and fluid turnover Ijiri[11]. This table illustrates that dehydration is less prevalent in older children, consistent with previous research showing increased resilience to dehydration as children age Zamberlan[12]. Gender distribution in table 3 reveals a relatively even split, with males making up 68% of the study population and 66.7% of dehydrated cases. The slight male predominance in dehydration prevalence has also been observed in other studies, although the difference is generally not statistically significant Badeli[13].

Ultrasound findings in table 4 highlight a significant variation in the inferior vena cava (IVC) cross-sectional area across dehydration severities, with moderate dehydration showing the largest mean value (0.716 $cm^2$). These findings align with other studies that show a correlation between IVC measurements and hydration status, making it a reliable parameter for dehydration assessment Oluwole[14]. However, in severe dehydration, the IVC area appeared smaller, potentially reflecting rapid fluid shifts and collapsing veins, as noted in severe cases of dehydration Bloise[15].

Table 5, IVC cross-sectional area was significantly larger in dehydrated patients ($p<0.01$), affirming its utility as a diagnostic tool. No significant differences were found for the aorta cross-sectional area and Aorta/IVC ratio, suggesting that while the aorta remains relatively unaffected by hydration status, the IVC is more sensitive to fluid changes Octavius[16] and Eaddy[17].

For table 6, With a Cohen's Kappa value of 0.93, there was near-perfect agreement between ultrasound and clinical assessment, indicating the reliability of ultrasound in diagnosing dehydration. This is corroborated by studies that emphasize the high reproducibility and reliability of ultrasound as a diagnostic tool for dehydration Raja[18]. A study by Chen et al. demonstrated similarly high kappa values, reinforcing the role of ultrasound as a non-invasive and objective diagnostic method Levine[19].

In table 7 The Aorta/IVC cross-sectional area ratio demonstrated a higher diagnostic accuracy, with a sensitivity of 82% and specificity of 75% and an AUC of 0.820. This performance is superior to the Aorta/IVC diameter ratio, which had a sensitivity of 55% and AUC of 0.500. These findings are consistent with those of Jehangir who reported better diagnostic accuracy for cross-sectional area ratios compared to diameter ratios in dehydration assessments Stoicescu[20]. The cross-sectional area ratio has become a preferred metric in various clinical studies for assessing dehydration severity Sarmin[21].

## CONCLUSION

The study demonstrates that ultrasound is a valuable and reliable tool for assessing dehydration in pediatric patients. Specifically, measurements of the inferior vena cava (IVC) cross-sectional area and the IVC/aorta ratios provided significant correlations with clinical dehydration scales. Ultrasound offers a non-invasive, objective method that complements traditional clinical assessments, helping to identify varying degrees of dehydration with high accuracy. This approach is particularly useful in children, where rapid and precise fluid status evaluation is crucial for effective management and treatment. As ultrasound becomes more accessible in clinical settings, its integration into standard dehydration assessment protocols has the potential to improve diagnostic accuracy and patient outcomes. Further studies are recommended to establish standardized guidelines for the use of ultrasound in pediatric dehydration assessment.

**Limitations of Study:**

- **Small Sample Size:** The study included a limited number of pediatric patients, which may affect the generalizability of the results to larger, more diverse populations. A larger sample size would provide more robust data and strengthen the conclusions.
- **Single-Center Study:** As the study was conducted in a single tertiary care center, the findings may not be applicable to other healthcare settings with different patient demographics or resource availability.
- **Operator Dependency:** Ultrasound assessments are highly operator-dependent and variability in measurements can occur based on the skill and experience of the technician or radiologist performing the scans. This could influence the consistency and accuracy of the results.
- **Lack of Longitudinal Data:** The study was cross-sectional in design, meaning it did not track changes in hydration status over time or assess how ultrasound findings correlated with fluid resuscitation and patient outcomes. A longitudinal study could provide more insights into the dynamics of dehydration and rehydration.
- **Limited Use of Additional Imaging Parameters:** While the study focused on IVC and aorta measurements, other ultrasound parameters, such as renal or bladder ultrasound, were not explored, which may have provided additional insights into hydration status.
- **Absence of a Gold Standard Comparison:** Although the clinical dehydration scale was used for comparison, there was no direct comparison to a gold standard test such as serum osmolality or blood urea nitrogen levels, which may provide a more comprehensive understanding of dehydration severity.
- **Exclusion of Severe Cases:** The study may have underrepresented children with severe dehydration who are more likely to be critically ill, potentially limiting the applicability of findings to this high-risk group.

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