ORIGINAL ARTICLE

doi: 10.5455/medarh.2014.68.304-307

Published online: 15/10/2014
Published print: 10/2014

Med Arh. 2014 Oct; 68(5): 304-307
Received: July 25th 2014 | Accepted: September 2 0th 2014

The Usefulness of Clinical and Laboratory Parameters for Predicting Severity of Dehydration in Children with Acute Gastroenteritis

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ABSTRACT

Background: An accurate assessment of the degree of dehydration in infants and children is important for proper decision-making and treatment. This emphasizes the need for laboratory tests to improve the accuracy of clinical assessment of dehydration. The aim of this study was to assess the relationship between clinical and laboratory parameters in the assessment of dehydration. **Methods:** We evaluated prospectively 200 children aged 1 month to 5 years who presented with diarrhea, vomiting or both. Dehydration assessment was done following a known clinical scheme. **Results.:**We enrolled in the study 200 children (57.5% were male). The mean age was 15.62±9.03 months, with more than half those studied being under 24 months old. Overall, 46.5% (93) had mild dehydration, 34% (68) had moderate dehydration, 5.5% (11) had severe dehydration whereas, 14% (28) had no dehydration. Patients historical clinical variables in all dehydration groups did not differ significantly regarding age, sex, fever, frequency of vomiting, duration of diarrhea and vomiting, while there was a trend toward severe dehydration in children with more frequent diarrhea (p=0.004) . Serum urea and creatinine cannot discriminate between mild and moderate dehydration but they showed a good specificity for severe dehydration of 99% and 100% respectively. Serum bicarbonates and base excess decreased significantly with a degree of dehydration and can discriminate between all dehydration groups (P<0.001). **Conclusion:** Blood gases were useful to diagnose the degree of dehydration status among children presenting with acute gastroenteritis. Serum urea and creatinine were the most specific tests for severe dehydration diagnosis. Historical clinical patterns apart from frequency of diarrhea did not correlate with dehydration status. Further studies are needed to validate our results.

Key Words: Acute gastroenteritis, diarrhea in children, dehydration in children.

1. BACKGROUND

Acute gastroenteritis (AGE) is a diarrheal disease of rapid onset, with or without accompanying symptoms and signs, such as nausea, vomiting, fever, or abdominal pain (1, 2). It is one of the most common diseases in children in developed and developing countries, and has been shown to be associated with significant morbidity and mortality rates (3).

A common reason for hospitalization in children with acute gastroenteritis is greater degrees of severity of dehydration or mild dehydration accompanied by social factors (4). An accurate assessment of the degree of dehydration in infants and children is important for proper decision-making and treatment (5). Underestimation of dehydration increases morbidity and mortality, while overestimation can result in inappropriate care and public expenditure (6). However, clinical evaluation of dehydration status can be difficult despite the existence of different dehydration assessment schemes (7, 8). The most accurate method of assessing dehydration is to calculate the percentage of weight loss, albeit most of the infants and children attending accident and emergency departments do not have a record of their recent weight.

This emphasizes the need for laboratory tests to improve the accuracy of clinical assessment of dehydration (9). Many pediatricians believe that laboratory studies, including Blood Chemical Analysis (BCA), are not usually necessary to assess children with acute diarrhea (1, 10). However, serum urea and bicarbonate can be predictive for dehydration severity in small children and infants as high risk groups to dehydration (11).

2. OBJECTIVES

The aim of this study was to assess the usefulness of clinical and laboratory parameters in the assessment of dehydration.

3. METHODS

We evaluated prospectively 200 children aged 1 month to 5 years admitted to Pediatric Clinic, who presented with diarrhea, vomiting or both. The study was obtained during two years period (2012 and 2013). Chief complaints, physical examination, demographic data, date of admission and discharge were collected in summary. Children height and weight were recorded. We also collected the results from all laboratory tests including full blood count (FBC), blood urea and glucose, creatinine, electrolyte concentrations and venous blood gases. Dehydration status was recorded using the accepted reference standard of the 'percentage of volume lost' calculated as the difference between the rehydration weight (post-rehydration body weight) and the acute weight (body weight at presentation) divided by the rehydration weight (12). Grading of dehydration was determined by the attending physician according to the World Health Organization's (WHO) criteria (13). Normality of laboratory tests was based on the test of normal range in a commonly used handbook for pediatric laboratory investigation (14). The consents were obtained from the parents or legal guardians. Electrolytes and blood gas analyses were performed on GEM Premier 3000 PAK cartridges-blood gas/hematocrit/ electrolytes metabolic, while blood urea nitrogen and creatinine were performed on ILab-650 chemistry analyzer. Data were analyzed by determining the mean and standard deviation for each result. For categorical variables a chi-square test was used. One way-ANOVA was used to compare groups. Four laboratory tests include blood urea nitrogen above 11mmol/L, creatinine more than 80 μmmo/L, venous HCO_3 below 15 mmol/L and base deficit beyond to -10mmol/L considered as cut off points for severe dehydration. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of these defined values were calculated, for estimating severe form of dehydration. A *p* value less than 0.05 was considered significant.

4. RESULTS

We enrolled in the study 200 children, 115 (57.5%) were male. The mean age was 15.62±9.03 months, with more than half of those studied being under 24 months old. Overall, 93 (46.5%) had mild dehydration, 68 (34%) had moderate dehydration, 11 (5.5%) had severe dehydration, whereas 28 (14%) had no dehydration. All children had diarrhea, whereas 175 (87.5%) had vomiting while 109 (54.5%) had an axillary temperature of ≥ 37.5°C (Table 1). The mean values for vomiting and diarrhea frequency were 5.94±3.80 per day and 6.91±3.87 per day, respectively. Data in all dehydration groups did not differ significantly regarding age, sex, fever, frequency of vomiting, duration of diarrhea and vomiting (p=NS). The more frequent diarrhea was associated with more severe degrees of dehydration (p=0.004) (Table 2).

Age (mean SD), months	15.62±9.03
Sex (M/F	115/85
Vomiting	175 (87.5%)
Fever	109 (54.5%)
Clinical dehydration	
None	28 (14%)
Mild	93 (46.5%)
Moderate	68 (34%)
Severe	11 (5.5%)

Table 1. Characteristics of children with diarrhea.(n=200), SD=-standard deviation. M=male. F=female.

Average blood urea level ±SD (mmol/L) in children with

	Dehydration status n (%)				
Variable	None	Mild	Moderate	Severe	p
Age (mean ± SD), months	15.46±9.31	15.95±9.29	15.96 ± 9.29	11.18 ±11.35	NS†
Male sex	21(75%)	53(57%)	36 (52.94%)	5 (45.45%)	NS††
Fever	17 (60.7%)	48 (51.6%)	40 (58%)	4 (36.3%)	NS††
Frequency of vomiting	5.23 ±3.68	5.88 ±3.63	6.05± 4.04	7.4 ±4 .16	NS†
(mean SD), times/ day					
Frequency of diarrhea	7.46± 3.85	6.17± 3.67	7.1±3 4	10.36± 2.73	0.004†
(mean SD), times/ day					
Duration of vomiting	3.05±2.18	2.31±1.4	2.6±1.51	1.7±0.95	NS†
(mean SD), days					
Duration of diarrhea	3.29±2.14	2.74±1.67	2.81±1.64	2.45±2.07	NS†
(mean SD), days					

Table 2. Clinical characteristics of children with different levels of dehydration (n=200) †=one way ANOVA. ††=chi square test. NS=not significant. SD=standard deviation.

no dehydration was 3.9±1.67, while in those with mild and moderate dehydration was 4.45±2.11 and 4.52±2.14 respectively. Mean urea concentrations were similar in these three groups (no dehydration, mild and moderate), p=NS. In severe form BUN was 11.31±9.98, it was higher significantly in severe dehydration compared to none, mild or moderate dehydration (p<0.001) (Table 3). One out of 93 with mild, 1 out of 63 with moderate and 4 out of 11with severe dehydration have urea concentration above

Variables	None (n=28)	Mild (n=93)	Moderate (n=68)	Severe (n=11)	p†
Urea (mmol/L) Mean (SD) Urea ≥ 11 mmol/L	1-7.1 3.9±1.67 0	1-14.7 4.45±2.11 1(1.07%)	1.0 – 11.1 4.52 ±2.14 1 (1.47%)	3.2-31.3 * 11.31±9.98 4 (36.3%)	0.001
Creatinine μmmol/L Mean (SD) Creatinine ≥ 80 μmmol/L	30-66 40.9±8.60 0	22-68 41.16±7.49 0	23 – 69 41.27 ±10.16 0	34-152 * 61.65±34.97 2 (18.1%)	0.001
pH	7.32 ± 0.06 (7.32-7.51)	7.44 ± 0.06 (7.24-7.51)	7.37 ±0.09 (7.1-7.51)	7.23 ± 0.16* (7-7.49)	0.001
HCO_3 mmol/L Mean (SD) HCO3 ≤ 15 mmol/L	14.5-25.4 21.1± 2.78 2(7.1%)	12-26 19.09 ±2.88 18(19.3)	8.5-24 16.31 ± 3.16 34(50)	5.2-17. 12.18 ±3.78 9(81.81%)	0.001
BE mmol/L BE(Mean) BE mmol/L ≤ -10	(-12-0.2) -5.9 ±3.29 4(14.28%)	(-18.04-1.8) -8.57 ± 3.91 31(33.3%)	(-22.6 to -1.1) -12.26 ±4.31 50(73.5%)	(-24.1-11) -18.96±4.92 11(100%)	0.001

Table 3. Blod urea nitrogen (BUN), creatinine and blood gas parameters in relation to degree of dehydration (none, mild, moderate and severe). *none, mild, moderate vs severe p=0.001. BE-base excess. †one way-ANOVA. SD=standard deviation

Variable	Sensitivity(%)	Specificity (%)	PPV(%)	NPV(%)
BUN ≥ 11 mmol/L	36.4	99	66.7	96.4
Creatinine ≥ 80 µmmo/L	18.2	100.0	100.0	95.5
Venous HCO3 ≤ 15mmo/L	81.8	71.4	14.3	98.5
Base deficit ≤ -10 mmo.L	100.0	55.0	11.5	100

Table 4. Sensitivity, specificity, PPV, NPV of blood urea nitrogen (BUN), creatinine, venous HCO3, base excess, for predicting of severe dehydration PPV=positive predictive value. NPV=negative predictive value.

11 mmol/L (Tab. 3), (sensitivity 36.36 %, specificity 99% , PPV 66.67, NPV 96.39 for severe form) (Table 4).

In none-dehydrated children mean ± SD of creatinine (µmol/L) was 40.9±8.60 , in mild dehydration was 41.16±7.49 while in moderate dehydration it was 41.27±10.16. Difference between none, mild and moderate dehydration for creatinine levels was not significant (p=NS). In severe dehydration creatinine level was 61.65±34.97, it was significantly higher in relation to three groups none, mild and moderate dehydration (p<0.001) (Table 3).

We observed creatinine levels above 80 µmol at 2 out of 11 patients with severe dehydration whereas none of the three other dehydration groups had creatinine levels above this value (sensitivity 18.2%, specificity 100%, PPV 100%, NPV 95.5% for severe form) (Table 4).

Mean ±SD of pH in none and mild dehydrated patients was 7.44±0.06 and 7.40±0.06, respectively, in moderate dehydration it was 7.37±0.09 and in severe dehydration 7.23±0.16. There was a statistically significant difference between severe group all the three other groups

(p<0.001) whereas no difference were noted between mild, moderate and none dehydrated groups (Table 3).

The mean ±SD of venous HCO3 level (mmol/L) in none dehydrated patients was 21.1±2.78, in mild dehydration was 19.09±2.88, whereas in moderate and severe dehydration was 16.31±3.16 and 12.18±3.78 respectively. There was a statistically significant difference between all groups (*P*<0.001) (Tab. 3). The values of venous HCO3 below 15 mmol/L were observed in 2 out of 28 with no dehydration, 18 out of 93 with mild, 34 out of 68 with moderate, and 9 out of 11 patients with severe group (sensitivity 82% specificity 71.4%, PPV 14.3, NPV 98.5, for severe dehydration form at cut off point of 15 mmol/l) (Table 4).

The mean ±SD of Base Excess (BE) in severe dehydration compared to none (-18.96 vs.-5.9), mild (-18.96 vs.- 8.57) and moderate dehydration (-18.96 vs. -12.26) decreases significantly (p< 0.001). BE average was also different between no dehydration, mild and moderate degrees of dehydration (p<0.01) (Tab. 3). We observed the values of base excess beyond to -10 mEq/L in 4 out of 28 patients with no dehydration, 30 out of 93 in mild, 49 out of 68 in moderate and 11 out of 11 patients with severe dehydration (sensitivity 100%, specificity 55.0%, PPV 11.5%, NPV 100.0 % for severe dehydration form) (Table 4).

The mean hospital stay appeared longer for patients with severe dehydration 4.82±2.14 days versus 3.32±1.57 days for mild, 3.68±1.83 for moderate and 3.89±2.06 for none dehydration, p=0.04.

5. DISCUSSION

Several publications suggest that infants with frequent diarrhea, higher fever, or more frequent vomiting or diarrhea are more prone to becoming dehydrated (1, 15) whereas some other publications do not support these conclusions (16, 17, 18). Our study shows that historical clinical feature (age, sex, fever, frequency of vomiting, duration of diarrhea and vomiting) do not significantly correlate with dehydration severity. The frequency of diarrhea was associated with more severe degrees of dehydration (Table 2).

Systematic reviews have shown that a constellation of signs and symptoms is more valid for predicting the dehydration severity, though signs like as skin turgor, deep breathing and capillary filling time have some limitations to use for dehydration severity assessment (19).

In order to improve accuracy of assessment of clinical dehydration, several laboratory parameters have been suggested. A review of the literature reveals several publications with conflicting messages regarding the value of these laboratory variables in predicting dehydration levels (18). Serum urea was the best studied and was found a useful predictor of dehydration by some (11, 20, 21, 22, 23, 18), whereas others doubted its usefulness (24, 25, 26). The results in our study showed a trend for urea concentration to increase with the degree of dehydration. Although this trend was significantly greater in severe dehydration compared with no dehydration, it showed poor sensitivity of 36.36% while its specificity and NPV for severe dehydration was 99% and 96.4% respectively. Shaoul et all. found creatinine concentration to be an unreliable marker of dehydration, while another study showed that creatinine concentration was predictive of severe dehydration (9,18). In our study creatinine concentration did not differentiate between none, mild and moderate degrees of dehydration, but in severe dehydration it was the most specific (100%) finding test with excellent PPV (100%) and NPV (95.45%). Other investigators have looked at blood gases (pH, serum bicarbonate level and base excess) as useful clinical adjuncts in assessing the degree of dehydration in children (27). Mackenzie et al. (24) showed a correlation between low pH, large base deficit, and degree of dehydration. In another study Vega and Avner (28) showed that addition of acidosis (bicarbonate <17 mmol/L) to clinical parameters increased the sensitivity for detecting of serious dehydration. Yilmaz et al. demonstrated that if serum bicarbonate level was above 15 mmol//L or higher, there was a PPV of 93% for mild dehydration, while bicarbonate level below 15 mmol//L is suggestive for severe dehydration (11). In another study bicarbonate level (HCO_3) below 17 mmol/L was the most sensitive (98%) test while base deficit beyond -16 has a specificity of 90% (26). Another author showed that both mean serum bicarbonate and base excess were less in the presence of more severe dehydration (9). Our study showed no difference in blood pH values between none, mild and moderate dehydration while it was significantly differed among severe dehydration compared to these three dehydration groups (p<0.001). Bicarbonate concentration and base excess decreased with the increasing severity of dehydration and were significantly greater in

severe dehydration compared to mild, moderate, and no dehydration. Also, we found a significant difference between all dehydration groups ($p<0.001$). Serum bicarbonate has an acceptable sensitivity and high NPV of 98.5%, while base excess has an excellent sensitivity (100%) and high NPV (100%). Hospitalization time was shown to be dependent on clinical assessment only and was not related to laboratory parameters.

6. CONCLUSION

According to the above-mentioned results we suggest that blood gases were useful independently in augmenting clinical examination to diagnose the degree of dehydration status among children presenting with acute gastroenteritis. Serum urea and creatinine cannot discriminate between mild and moderate dehydration but they were the most specific tests for severe dehydration diagnosis. On the contrary, the historical clinical patterns apart from the frequency of diarrhea did not correlate with dehydration status. Until further validation of our results, we clearly refrain from suggesting ordering serum levels of these laboratory predictors for all children with acute gastroenteritis.

CONFLICT OF INTEREST: NONE DECLARED

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