The adjustment of post-dialysis dry weight based on non-invasive measurements in children

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Abstract

Background. The clinical criteria to assess hydration status are not always reliable. Hence, the development of techniques to estimate more accurately post-dialysis dry weight (DW) remains a major challenge. The present study evaluates the value of the inferior vena cava (IVC) diameter, plasma concentration of atrial natriuretic peptide (ANP), and plasma renin activity (PRA) in determining the DW in chronic haemodialysis children.

Methods. Twelve overhydrated haemodialysis patients (4 girls, 8 boys) with a mean age of 12.8 were admitted to the study. Clinical, electrocardiographic, telecardiographic and echocardiographic findings, IVC and collapsibility indices and plasma concentrations of ANP and PRA were investigated before and after ultrafiltration (UF) therapy. Twelve age-matched normal children were studied as controls. Analysis of variance and Dunnett's test were applied for comparisons between patients and controls.

Results. Following UF therapy the patients' mean IVC collapsibility index was increased from 42.3 to 53.6% and IVC index was decreased from 1.08 to 0.81 cm/m², both statistically significant. The pre-UF therapy collapsibility and IVC indices of the patient group were significantly different from those of the control group (56.9% and 0.70 cm/m² respectively). The patients' mean plasma concentrations of ANP were 171 ± 47.4 pg/ml before UF, 129 ± 51.3 pg/ml after UF and 102 ± 38.7 pg/ml in the control group. The ANP levels of the patients showed a significant decrease following the UF therapy. PRA was measured as 0.82 ng/ml/h before UF and 1.08 ng/ml/h after UF, but the increase was not statistically significant.

Conclusions. Our findings revealed increased diameter of the IVC and plasma ANP concentrations and decreased collapsibility due to overhydration. Echography of IVC may be a promising non-invasive tool to estimate the DW in haemodialysis children. Further studies providing normative values for the IVC indices in both haemodialysis and normal children are required.

Key words: atrial natriuretic peptide; chronic haemodialysis; dry weight; echocardiography; inferior vena cava; plasma renin activity

Introduction

Dry weight (DW) is defined as the ideal weight at the end of regular dialysis treatment. While underestimation of the DW leads to hypovolaemia, inducing hypotension, overestimation leads to chronic overload and to the potential hazards of overhydration such as hypertension.

The clinical criteria for estimating hydration status are not always reliable. Hence, more accurate means of estimating postdialysis DW need to be devised. Recently some new techniques have been introduced to assess postdialysis DW more accurately. Plasma concentrations of atrial natriuretic peptide (ANP) and inferior vena cava (IVC) diameter measured by echocardiography have been suggested as reliable parameters to determine the dry weight [1–7].

The aim of this study was to investigate the validity of IVC diameter, plasma concentrations of ANP and plasma renin activity (PRA) in determining the dry weight in haemodialysis children.

Subjects and methods

Twelve haemodialysis patients (8 boys and 4 girls) with overhydration were admitted to the study. Table 1 presents the clinical criteria we used in diagnosing overhydration. The patients ranged in age from 9 to 15 years with a mean of 12.8 ± 1.6 years. They had been on haemodialysis treatment for 6–36 months. Eleven patients required dialysis three times a week and the remaining one twice a week. The duration of a dialysis period ranged between 60 and 180 min. In the present study, dry weight was defined as the ideal weight of these overhydrated children at the end of the 4-day ultrafiltration (UF) therapy. As a predetermined standard, UF therapy was applied to each patient for 4 successive
days. For each patient the amount of ultrafiltered fluid was determined as \(5\%\) of the body weight in 3 h in a dialysis period. As an exception, the amount had to be kept below \(2\%\) of the body weight at the 3rd and 4th days of UF therapy in two patients with hypotension. Clinical, electrocardiographic, telecardiographic and echocardiographic findings, IVC indices (IVCI), collapsibility indices (CI), and plasma concentrations of ANP and PRA were investigated before and after UF therapies. Given that fluid moves from the interstitium for several hours following the dialysis, IVC measurements were performed 2 h after UF therapy. Echocardiographic examination was performed on each patient using 2-dimensional and Doppler recording by the same paediatric cardiologist. The IVC anteroposterior diameter and amount of inspiratory decrease were measured just below the diaphragm in the hepatic segment in patients lying in a supine position after a 10-min rest. CI was determined as \((\text{maximal diameter on expiration–minimal diameter on inspiration}) 	imes 100\). IVCI was determined as diameter of IVC \((\text{cm}) / \text{body surface area (m}^2)\). RIA (Amerham-ANP, Biodata Renin MAIA KIT) was used for measuring plasma concentrations of ANP and PRA. The same protocol was applied to 12 age-matched children. Analysis of variance was used for multiple comparisons between patients. Student–Newman–Keuls was performed as post hoc multiple comparisons. Multiple comparisons of means with control groups were analysed by using Dunnett’s test. The patients’ pre- and post-UF therapy values, which did not have normal control groups, were compared by means of the Student’s \(t\) test. Pearson’s product moment correlation analysis was used to investigate the relationship between ANP concentrations and echocardiographic findings. The parameters of sub-groups with overt or covert clinical overhydration were compared with the Wilcoxon test. Results are reported as mean \(\pm\) standard deviation. Statistical analyses except Dunnett’s test and boxplots were carried out by means of the Statistical Package for Social Sciences for Windows. Dunnett’s formula \((d = r_s - S_s)\) and Dunnett’s \(t\) values for one-way control were used for performing Dunnett’s test.

**Results**

First we questioned whether the patients with and without clinically overt overhydration differ in terms of IVCI, CI and ANP. To investigate this matter we compared the overt overhydration subgroup, which consisted of four patients presenting with clinical signs of overhydration, with those of the covert overhydration subgroup consisting of the remaining eight patients. Wilcoxon test revealed no significant differences between the subgroups for the parameters measured either before, or after UF. Given these results, all dialysis patients were entered into further analyses as a single group.

Following the UF therapy the clinical findings of overhydration such as dyspnea and gallop rhythm disappeared. In addition the degree of hepatomegaly and venous pulsation were lowered (Table 1). The arterial blood pressure decreased in four of the six hypertensive patients. A comparison of the controls’ and the patients’ pre- and post-UF laboratory measurements in terms of mean \(\pm\) SD is displayed in Table 2. The results of the statistical analyses for the three sets of measurements are also presented. No statistically significant differences were found between the patients’ pre- and post-UF values of haemoglobin, haematocrit, serum sodium, and protein. In contrast UF seems to cause a significant decrease in patient heart rate on electrocardiography and cardiothoracic index on telecardiography. Relative mitral insufficiency observed in three of the patients before UF disappeared following the therapy.

It appears that UF therapy exerted a significant effect on the patients IVCI and CI; both indices approached normal levels. Thus, the significant differences observed between these two indices previous to UF, were not observed following UF. The same also holds true for ANP (Table 2). Boxplots presented in Figures 1, 2 and 3 allow a more visual comparison of the distribution of IVCI, CI, and ANP levels in pre- and post-UF patients and in controls. The pre- and post-UF values of PRA and \(t\) test results presented in Table 2 indicate that UF resulted in a moderate, but statistically insignificant increase in PRA. When the related boxplot (Figure 4) is examined; however, UF seems to cause a greater variability of PRA levels in patients.

The relationships between the ANP changes and CI and IVCI were investigated by means of the Pearson’s product moment correlation analysis. Previous to UF, only CI correlated with ANP in a significant manner \((r = -0.65, P = 0.02)\). Following UF, however, neither CI, nor IVCI were significantly correlated with ANP.

**Discussion**

Haemodialysis has a profound effect on fluid balance, and the importance of preventing overhydration, as well as underhydration, during haemodialysis, particularly in children, cannot be overemphasized. Since clinical variables used to determine the dry weight are not reliable, a more accurate technique is needed. The main goal of this study was to investigate the validity of some non-invasive parameters; namely IVCI, CI, ANP, and PRA, in estimating the dry weight in children.

Overhydrated children on haemodialysis were investigated before and after UF therapy. It is noteworthy that only four of the twelve patients fulfilled the clinical criteria of overhydration. The clinical findings of these patients disappeared (dyspnoea and gallop...
Table 2. Laboratory findings of patients and controls

<table>
<thead>
<tr>
<th>Laboratory findings</th>
<th>Patients Pre-UF (n=12)</th>
<th>Patients Post-UF (n=12)</th>
<th>Controls (n=12)</th>
<th>( r ) value*</th>
<th>F ratio*</th>
<th>Significance*</th>
<th>Significance*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Col Ind(%)</td>
<td>42.3±16.9</td>
<td>53.6±13.1</td>
<td>56.97±8.7</td>
<td>4.02*</td>
<td>P&lt;0.05</td>
<td>(10.71)</td>
<td>NS</td>
</tr>
<tr>
<td>IVCInd (cm/m²)</td>
<td>1.08±0.38</td>
<td>0.82±0.32</td>
<td>0.70±0.21</td>
<td>5.11*</td>
<td>P&lt;0.05</td>
<td>(0.24)</td>
<td>NS</td>
</tr>
<tr>
<td>ANP(pg/ml)</td>
<td>171±47.4</td>
<td>129±51.3</td>
<td>102±38.7</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Htc (%)</td>
<td>0.82±0.49</td>
<td>1.08±1.03</td>
<td></td>
<td>-0.78</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na(mEq/l)</td>
<td>22.8±1.5</td>
<td>23.4±1.3</td>
<td></td>
<td>-0.77</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein (g/l)</td>
<td>142.2±1.3</td>
<td>141.8±1.7</td>
<td></td>
<td>0.76</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECG rate/min</td>
<td>102±17.49</td>
<td>88.6±12.55</td>
<td></td>
<td>2.66*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thor. Ind(%)</td>
<td>0.58±0.058</td>
<td>0.54±0.047</td>
<td></td>
<td>6.22*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*aPaired \( r \)-test: comparisons between patients pre- and post-UF values which did not have control groups. For any test value, degree of freedom(df) is 11.

*bAnalysis of variance: comparisons between patients. Patients pre-UF and post-UF values were compared by one-way ANOVA test using Student-Newman-Keuls as post hoc multiple comparisons; df within groups is 33.

cDunnett’s test: comparisons between patients’ pre-UF values and normal controls. Each test value’s df is displayed in parentheses.

dDunnett’s test: comparisons between patients’ post-UF values and normal controls. NS, non-significant.

Fig. 1. Collapsibility indices of pre-UF, post-UF, and the control groups.

Fig. 2. Index of IVC of patients and control groups.

The diameter of IVC was one of the parameters investigated. Previous studies reported significant correlations between right atrial pressure and IVC diameter [8, 9]. It was shown that the IVC diameter was a reliable tool for estimation of dry weight in adult haemodialysis patients [1, 3, 6]. To our knowledge, no previous study has evaluated the value of the IVC diameter in junior haemodialysis patients.

It has been reported that an inspiratory decrease in IVC diameter of < 50% has a predictive value of 87% for a right atrial mean pressure of ≥10 mmHg [10]. In our study the pre-UF IVC collapsibility index of 42.3% strongly suggested that right atrial pressures of these children were increased by overhydration. Following UF, the patients IVC collapsibility index approached that of the normal group. Insufficient collapsibility of the IVC during inspiration due to increase in right atrial pressure caused by the overhydration might be a reasonable explanation for the decreased CI in patients before UF therapy.

Reportedly, IVCI is below 1.15 cm/m² in adults [1]. To our knowledge there is no study in the literature reporting on a standard value for IVCI in children. In our study the mean IVCI of the normal group was found to be 0.70±0.21 cm/m². The increased IVC diameter (1.08±0.38 cm/m²) observed in our patients provides evidence that IVC could be used as an accurate parameter of hydration state in estimating dry weight in haemodialysis children. Our data suggest
Non-invasive measurement of post-dialysis dry weight in children

**ANP Concentrations of pre-UF, post-UF patients and controls.**

**Fig. 3.** ANP concentrations of pre-UF, post-UF, and controls.

**PRA of the patients**

**Fig. 4.** PRA of the patients.

that the optimal range for IVCI in paediatric patients might be between 0.70 and 0.82 cm/m².

ANP is an important hormonal regulator of body fluid, and overhydration is a major stimulator of ANP release [3–5]. It was previously reported that the increased levels of ANP in dialysis patient is compatible with the extended diameter of IVC [3]. The significant correlation found in the present study between CI and ANP before UF therapy supports this notion.

Hypertension as a criterion for overhydration cannot be safely used, since the aetiology of hypertension in haemodialysis patients is multifactorial [11]. Because it is well known that there is a reciprocal relationship between ANP and renin [12], PRA was measured as an adjunctive parameter to evaluate ANP levels. The decreased PRA found in our patients before UF might be explained by the inhibition of renin release from the kidney by increased ANP levels.

Although the clinically overt overhydration subgroup failed to differ from the covert overhydration subgroup in terms of laboratory measurements, this might be a type II error. Further studies with larger samples are required to illuminate this point.

In conclusion, our findings revealed increased diameter of the IVC and plasma ANP concentrations and decreased collapsibility of IVC due to overhydration in haemodialysis children. Further studies are needed for setting a standard for the IVC measurements in both haemodialysis and normal children, and also for using echocardiography of IVC in estimating dry weight in haemodialysis children.

**References**


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