ABSENCE OF TRANSCELLULAR FLUID SHIFT DURING
HAEMOFILTRATION

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Summary

Total body and extracellular fluid volume before and after haemofiltration were calculated using urea and inulin as markers. The change in plasma volume and interstitial fluid volume were also evaluated by haemoglobin concentration and haematocrit value. The extracellular fluid volume, especially interstitial fluid volume, was reduced, while intracellular fluid volume was not altered by haemofiltration.

Introduction

It is unclear whether intracellular or extracellular body fluid is removed by artificial kidneys.

Recently, transcellular fluid shift has been suggested [1] during haemodialysis (HD), so that intracellular fluid cannot be removed by HD.

HD removes extracellular fluid both into dialysate and into intracellular compartments. Thus, analysis of transcellular movement of fluid during performance of artificial kidneys is important.

We developed a simple method to calculate intracellular and extracellular fluid volume in patients undergoing haemofiltration (HF).

Fluid removal by HF was based on a decrease in extracellular fluid, especially in interstitial fluid, while intracellular fluid volume was not altered.

Methods

HF was performed in five patients who had been on routine maintenance HD for chronic renal failure.

Using two polymethylmethacrylate membrane hollow fibre dialysers (Filtrizer B-1, Toray, Japan) connected in series, 70 to 80ml/min of body fluid was ultrafiltrated.
The substitution fluid was infused by the post-dilution method [2, 3]. The composition was Na\(^+\) 140, K\(^+\) 2.0, Ca\(^{++}\) 3.5, Mg\(^{++}\) 1.5, Cl\(^-\) 107, \(\text{CH}_3\text{COO}^-\) 40 meq/L (Fuso Pharmaceutical Co., Japan). Extracorporeal blood flow rate was 200 ml/min. Usually HF was ended when 20L of body fluid had been ultrafiltrated.

Urea nitrogen and inulin concentrations were measured in plasma before and after HF, and in the total ultrafiltrate mixture.

To allow for equilibration of inulin within extracellular fluid, plasma inulin concentration was measured 60 min after HF. Haemoglobin concentration (Hb) and haematocrit value (Ht) were measured before and 60 min after HF.

**Calculation**

Assuming that urea and inulin are distributed uniformly within total body fluid and extracellular fluid, respectively, total body fluid volume (TBF) and extracellular fluid volume (ECF) before and after HF are calculated in the following way.

Since the absolute amount of markers (urea and inulin) removed by HF is known, the mass balance law is expressed as:

\[
\begin{align*}
\text{TBF}_1 \times U_1 &= \text{TBF}_2 \times U_2 + V \times U_3 \quad (\text{TBF}_2 = \text{TBF}_1 - \Delta BW) \quad 1 \\
\text{ECF}_1 \times I_1 &= \text{ECF}_2 \times I_2 + V \times I_3 = Q \quad 2
\end{align*}
\]

where \(U\) and \(I\) are the urea nitrogen and inulin concentration. Subscripts 1, 2 and 3 mean the concentration in plasma before and after HF, and in total ultrafiltrate mixture.

\(Q\) is the amount (5g) of inulin injected intravenously 45 min before HF. These relationships are schematically shown in Figure 1.

Solving equations (1) and (2), TBF and ECF before and after HF are obtained. Intracellular fluid volume (ICF) can be calculated as the difference between TBF and ECF.

**Figure 1. Principle (mass balance law) for calculation of urea space (A) and inulin space (B)**

193
The change in blood volume (BV) by HF may be evaluated by the change in Hb.

\[ BV_1 \times \text{Hb}_1 = BV_2 \times \text{Hb}_2 \]

\[ \therefore \frac{BV_2}{BV_1} = \frac{\text{Hb}_1}{\text{Hb}_2} \]

Plasma volume (PV) is represented by BV and Ht as:

\[ PV = BV \times \frac{100 - \text{Ht}}{100} \]

Therefore, the change in PV by HF is calculated by:

\[ \frac{PV_2}{PV_1} = \frac{\text{Hb}_1}{\text{Hb}_2} \times \frac{100 - \text{Ht}_2}{100 - \text{Ht}_1} \]

Furthermore, interstitial fluid volume (ISF), the difference between ECF and PV, is evaluated as:

\[ \frac{ISF_2}{ISF_1} = \frac{PV_2}{PV_1} \times \frac{\text{ECF}_1 - \text{ECF}_2}{\text{ECF}_1 - \text{PV}_1} \]

And there is a relationship among the changes in ECF, PV and ISF:

\[ \frac{ISF_2}{ISF_1} < \frac{\text{ECF}_2}{\text{ECF}_1} < \frac{PV_2}{PV_1} \]

**Results**

Table I shows body fluid volume before and after HF. Body weight was reduced from 52.3 ± 1.5 to 49.5 ± 1.5kg (p < 0.001), and TBF from 31.2 ± 2.6 to 28.5 ± 2.6L (p < 0.001). As shown in Figure 2, the decrease in TBF was mainly based on the decrease in ECF from 9.6 ± 0.3 to 7.5 ± 0.6L (p < 0.02), while ICF was not significantly altered by HF.

<table>
<thead>
<tr>
<th>TABLE I. Body fluid volume, Hb and Ht before and after HF</th>
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<tbody>
<tr>
<td>Before HF</td>
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<tr>
<td>TBF (L)</td>
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<td>ECF (L)</td>
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<td>ICF (L)</td>
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<tr>
<td>Hb (g/dl)</td>
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<td>Ht (%)</td>
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* p < 0.001; ** p < 0.02; Mean ± SEM (n = 5)
The volume change in each compartment by HF was calculated by equations (1) – (5), and shown in Figure 3. It is clear that fluid removal by HF out of ECF was largely based on the decrease in ISF.

Discussion

Body fluid volume has not been directly evaluated before and after performance of artificial kidneys.

We developed a simple method to calculate ICF and ECF before and after HF. Fluid removal by HF was derived only from extracellular fluid. ICF was not altered by HF. The decrease in ECF was largely based on the decrease in ISF.
Indirect evaluation of ICF had shown that ICF was increased by HD. In contrast to HD, ICF was not altered by HF. This point might be an advantage of HF over HD.

Furthermore, it becomes possible to consider whether a solute is removed by HF from the intracellular or extracellular component.

Since the total amount removed into ultrafiltrate by HF and the absolute amount in extracellular fluid before and after HF are known, the amount of the solute removed from the intracellular compartment should be calculated as the difference between these two.

Thus, the simple method to calculate ICF and ECF before and after HF enables us to evaluate transcellular movement of solute and water during HF. It might be important to normalise intracellular as well as extracellular fluid by artificial kidneys.

References


Open Discussion

CAMBI (Parma) Did you try to influence the sodium concentration to see if the transcellular fluid shift was higher with the so called cell washout technique?

KIMURA No, but I am trying. In this method we can know two things. One is the change in intracellular fluid volume. We are trying to see the change in ICF by high sodium haemofiltration. ICF may change dependently on the osmolality of the substitution fluid.

The other thing we can know is the amount of intracellular waste products removed by haemofiltration. Removal rate of intracellular waste products may be enhanced by cell wash haemofiltration. So, I am interested in these two different procedures, now.