Aggressive Zero Balance Ultrafiltration on CPB in Patients with Renal Failure May Cause Cerebral Edema: A Theoretical Analysis

Eustace J. Fontaine, BM, MSc, FRCS; Richard Warwick, MUDr, MRCS; Priya Sastry, MBChir, MA, MRCS; Michael Poullis, BSc(Hons), MBBS, MD, FRCS(CTh)

Cardiothoracic Centre, Liverpool, United Kingdom


Abstract: The objective of this study was to determine the brain volume changes that occur secondary to hemofiltration during cardiopulmonary bypass in patients with renal failure. We hypothesized that in patients with elevated urea levels, aggressive hemofiltration could be associated with cerebral edema. We constructed a simple two-compartment model similar to the urea kinetic model developed by Depner. Intracellular urea exit was assumed to be minimal based on known urea redistribution times. Calculations were based on a 70-kg patient, with an intracellular volume of 25 L, extracellular volume of 15 L, and a preoperative urea of 40 mmol/L filtered to a post-procedure urea of 6 mmol/L. Analysis showed that a standard size 1500-mL human brain filtered from a preoperative urea of 40 to 6 mmol/L over a short period will expand by 59 mL secondary to the osmotic disequilibrium secondary to hemofiltration (p < .05). The higher the preoperative urea, the larger the fluid shift. This figure does not include the cerebral edema component that is known to arise secondary to cardiopulmonary bypass. Significant cerebral edema theoretically occurs secondary to hemofiltration during cardiopulmonary bypass. More detailed mathematical urea kinetic analysis and clinical correlation are needed. Keywords: dialysis, bypass, renal failure, brain.

Hemofiltration during cardiopulmonary bypass (CPB) is used to correct hemodilution and correct electrolyte imbalance of patients with renal failure (1). Hemofiltration on or off CPB in the setting of renal failure can result in osmotic changes caused by rapid changes in serum urea concentrations. Large osmotic changes in extracellular compartments can potentially lead to cerebral edema. Cerebral edema is assumed to be the cause of dialysis disequilibrium syndrome characterized by headache, disorientation, nausea, seizures, and coma (2). Animal studies have shown that the resulting cerebral edema could be caused by the “reverse urea effect,” in which brain urea remains relatively high despite rapid decrease in plasma urea (3). We therefore set out to analyze the potential effect of aggressive filtration during CPB on brain volume.

MATERIALS AND METHODS

A simplified two-pool urea kinetic model similar to that described by Depner was used (4). We assumed that the intracellular exit of urea to be negligible in accordance to known urea distribution times during a 1-hour period of CPB. The scenario of zero balance ultrafiltration (Z-BUF) was studied. Osmotic volume changes were calculated as previously described (5). The calculations were done for a 70-kg patient with an intracellular volume of 25 L, an extracellular volume of 15 L, a blood volume of 5 L, and an interstitial volume of 10 L, and filtered from a preoperative urea of 40 mmol/L to a postoperative urea of 6 mmol/L. The model assumes that the patient does not undergo significant cooling during the procedure—this is impossible to quantify exactly, but patient temperature remains >24°C.

RESULTS

The resultant increase in brain volume from being filtered at varying levels of preoperative urea to a postop-
Sodium flux across membranes is quick, and because se-
min changing its level slowly to reduce osmotic fluid shifts. (mmol/L) Pre-Filtration Urea

Table 1. Change in brain volume after filtration on bypass.

<table>
<thead>
<tr>
<th>Pre-Filtration Urea (mmol/L)</th>
<th>Post-Filtration Urea (mmol/L)</th>
<th>Volume Change in Brain (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>6</td>
<td>59</td>
</tr>
<tr>
<td>30</td>
<td>6</td>
<td>42</td>
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</tr>
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<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>

Little consensus exists on filtration during bypass, espe-
ically with regard to filter pressure (frequently through a
three-way tap from arterial return line with no actual di-
rect pressure measurement), filter flow, fluid volume re-
moval, or the effects of pre-procedural blood chemistry.

We recommend, based on the findings of this study, that
 elective patients in renal failure are dialyzed preopera-
tively, so that their urea during cardiac surgery is near
ormal. If patients are unstable or present as emergencies,
they may benefit from continuous filtration after the pro-
cedure to try and reduce rapid osmotic changes. The rela-
tive use of hemodialysis and peritoneal dialysis depends
on geographical location and logistical factors, but gener-
ally, peritoneal dialysis is thought to be inferior (9). We
observed that patients undergoing cardiac surgery receiv-
ing peritoneal dialysis are more likely to have very el-
evated urea levels compared with patients undergoing he-
modialysis.

In summary, fluid shifts caused by filtration of patients
in renal failure undergoing CPB may potentially be asso-
ciated with deleterious effects on cerebral function. Fur-
ther work is needed in conjunction with a more detailed
urea kinetic model.

REFERENCES

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