'MAKE-IT-YOURSELF' ARTIFICIAL KIDNEY FOR AT HOME DIALYSIS*

SATORU NAKAMOTO, JOSEF ERBEN and WILLEM J. KOLFF
Department of Hemodialysis, The Cleveland Clinic Foundation, Cleveland, O., U.S.A.

Assembly of the dialyser

A dialyser was made by modifying the 'wind-it-yourself' artificial kidney described by Hillenbrand et al. (1959), and by adapting a domestic washing machine as a dialysate tank, as used by Nose and co-workers (1961).

Four single wind-it-yourself coils are suspended in a polyvinyl chloride coated metal basket in a washing machine that contains 72 litres of dialysate (Fig. 1). Each coil is made of 3.5 m long cellophane tube 4.5 cm wide, together with an 8 cm wide polyethylene screen belt around a hard polyvinyl chloride core 10 cm in diameter (Fig. 2). Each end of the cellophane tube is secured by plastic connectors to the arterial and venous silastic tubes. Within 30 minutes, either a patient or his family can make four coils with a motor-driven winding machine (Fig. 3). The four coils are connected in parallel with the arterial and venous tubes and an air-bubble catcher. The dialyser does not require a pump to obtain a sufficient blood flow.

The dialysate is prepared by adding 2,049 ml of Mallinckrodt haemoconcentrate to tap water in the washing machine to make a total volume of 72 litres at 37°C. The turbulence produced by the agitator of the washing machine is sufficient to ensure intimate contact of the bath fluid with the entire surface area of the four coils. The dialysate is changed every two hours.

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Fig. 2. A cellophane tube, a polyvinyl chloride core, polyvinyl screen belts, connectors and inlet and outlet silastic tubings to make a core are shown.

The ultrafiltration rate is increased by adding 1,000 mg of dextrose per 100 ml of the dialysate. The total blood volume, including the four coils and the arterial and venous tubings, is 400 ml. The extracorporeal system is primed with a patient's own blood, which is returned to the patient at the end of dialysis by gravity by unwinding the four coils and hanging up the tubing.

The coils and tubing are sterilized by either 4% acetic acid or ethylene oxide gas. When the

Fig. 3. A motor-driven winding machine.
Fig. 4. Relation between urea clearance and flow rate is shown with a single coil and four coils.

gas is used, the coils and tubing are sterilized in a polyethylene bag with 2 ampules of ethylene oxide gas for 24 hours at room temperature. Before the coils and tubing can be used by the patient, another 24 hours must elapse so that the ethylene oxide can become dissipated, otherwise haemolysis may occur. The polyethylene screen, and the cores of the coils may be used repeatedly. They can be washed with disinfectant in the washing machine after dialysis, after the cellophane tubing has been removed.

Results

In vitro: The in vitro studies were carried out by a single pass system with urea concentration of 200 mg per 100 ml through the dialyser against tap water. When a single coil with 0.36 m² of dialysing surface area was used, the urea clearance curve reached a plateau at the level of 32 ml per minute with flow rate of 100 ml per minute (Fig. 4). Together, the four coils have 1.26 m² of dialysing surface area, and the flow rate of 180 ml per minute gave a urea clearance rate of 110 ml per minute (Fig. 4). Ultrafiltration rate of the four-coil artificial kidney with a dialysing surface area of 1.26 m² was less than half of that of the Kolff twin-coil artificial kidney with a dialysing surface area of 1.9 m². Approximately 150 ml of fluid can be ultrafiltered with an air-bubble catcher pressure of 40 mm Hg with a flow rate of 140 ml per minute.

Clinical use: The four-coil artificial kidneys have been used for more than 300 clinical dialyses in the Cleveland Clinic Hospital (Khashagir et al., 1967). Thirty-two patient months experience has been accumulated in 11 patients at home as of June 1, 1967. Pertinent data in 5 patients on the home dialysis programme for more than 3 months are summarized in Table I. The average blood flow rate was 145 ml per minute, and the average urea clearance rate was 84 ml per minute.

The average decrease in body weight during a six-hour dialysis was 0.87 kg. Further weight loss was accomplished by osmotic ultrafiltration by adding dextrose, 1,000 mg per 100 ml of dialysate.

Because of the relatively slow blood flow through the artificial kidney, a relatively large amount of heparin sodium is required, and coagulation and formation of fibrin plugs is likely to occur. A standard amount of 15,000 units of heparin sodium is given at the beginning of dialysis; it is tolerated well except by those patients who have a tendency to bleed.

Complications

A. Leakage of blood from one or two of the four coils occurred in one of each 10 dialyses. A leak can be easily detected and the dialysis may be allowed to continue by clamping the leaking coil.
<table>
<thead>
<tr>
<th>Patient number</th>
<th>No. of months on home dialysis</th>
<th>Average wt. loss (lbs) per dialysis</th>
<th>Average B.P.</th>
<th>Average blood urea (mg/100 ml)</th>
<th>Blood flow rate (ml/min) per dialysis</th>
<th>Clinical condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>0.9</td>
<td>155/100</td>
<td>146</td>
<td>149</td>
<td>Housewife - fully rehabilitated</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>1.7</td>
<td>134/92</td>
<td>132</td>
<td>123</td>
<td>Severe peripheral neuropathy. Partially rehabilitated.</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>1.6</td>
<td>182/103</td>
<td>149</td>
<td>147</td>
<td>Housewife - fully rehabilitated.</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>2.2</td>
<td>149/102</td>
<td>133</td>
<td>178</td>
<td>Working full-time.</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>1.4</td>
<td>178/110</td>
<td>116</td>
<td>180</td>
<td>Working full-time.</td>
</tr>
</tbody>
</table>
B. Coagulation of blood in one or more coils occurred on 10 occasions, presumably because of the relatively low blood flow rate.

C. Bleeding after dialysis, manifested by extensive bruises, haematomas inside the mouth, or epistaxis, occurred in four patients. Haemorrhagic pericarditis developed during dialysis in one patient with cardiac tamponade, which required a pleuropericardial window.

D. Septicaemia occurred in three patients; organisms were *Staphylococcus aureus* in one, *Pseudomonas* in one, and *Klebsiella* in one. All three patients were treated successfully with antibiotics.

E. Overhydration, manifested by hypertension and congestive heart failure, necessitated the use of the Kolff twin-coil artificial kidney to remove a large amount of oedema fluid in four patients on six occasions.

F. One patient died of a massive brain haemorrhage in the fourth month of dialysis at home.

**Summary**

A new artificial kidney consists of four single make-it-yourself coils. After they are wound the coils are placed in a domestic washing machine, and turbulence of the dialysate is produced by the agitator; the urea clearance is 84 ml per minute with blood flow rate of 145 ml per minute. No blood pump is required and no bank blood is needed for priming. The device is desirable for dialysis at home because of its low cost, simplicity, safety, and efficiency.

**REFERENCES**

