A New Disposable Parallel Flow Artificial Kidney (AB Gambro)  
Comparison with the Ultraflo 100, 145 and the Kiil

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A versatile disposable parallel flow artificial kidney should include the advantages of disposable coil dialysers (ease and rapidity of operation, low exposure of personnel to blood, high efficiency) and the advantages of the Kiil-type dialysers (low volume, low resistance requiring no blood-pump).

At the University of Minnesota 1800 dialyses were performed in 106 patients in 1969. Rapid dialyses, 6-8 hours, with high efficiency dialysers, Ultraflo 100 and 145 were used. At Methodist Hospital, 1200 dialyses were performed on 12 patients. Slow dialysis, 12 to 14 hours, with a low efficiency dialysers, the Kiil, were used.

The Alwall-Gambro (Alwall, 1968), a new disposable, eleven stack, multiple cone support, parallel flow dialysers has been used in 1969 at both institutions for 120 dialyses, and the performance compared with those dialysers already in use.

Ultrafiltration, clearance, priming volume, compliance (volume-increase with increasing pressure across the dialysis membrane), blood loss after back-transfusion, internal resistance to bloodflow and frequency of ruptured dialysers were studied. Except for compliance all studies were done during routine dialyses at the bedside.

Table I. A new disposable parallel flow artificial kidney.

<table>
<thead>
<tr>
<th>Dialysers</th>
<th>Manufacturer</th>
<th>Surface area cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultraflo 100 Cuprophane PT-150 (UF-100)</td>
<td>Travenol Labs Inc</td>
<td>10,000</td>
</tr>
<tr>
<td>Ultraflo 145 Cellophane (UF-145)</td>
<td>Travenol Labs Inc</td>
<td>14,500</td>
</tr>
<tr>
<td>Alwall-Gambro Cuprophane PT-300 (A - G)</td>
<td>Ab Gambro</td>
<td>10,200</td>
</tr>
<tr>
<td>Kiil Cuprophane PT - 150</td>
<td>Western Gear</td>
<td>11,500</td>
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</table>
MATERIALS AND METHODS

Table I summarises the dialysers evaluated. The UF-100, UF-145 and A-G were tested in rapid dialysis system using a standard blood flow of 300 ml/min. They were perfused with blood pumps. Fresh dialysate was added with a speed of 0.5 l/min to the UF-100 and 145, 0.6 l/min to the A-G. Dialysate was recirculated at 30 l/min over the UF-100 and 145, and at 4 l/min over the A-G. In order to evaluate the effect of recirculation on the A-G, a series of clearances was done without recirculation. Cuffs inflated to 80 mm Hg were used around the UF-100 and 145 for all studies.

The Kiil and the A-G were tested in slow dialysis system. Blood flow, measured with the bubble technique, varied between 100 and 250 ml/min. Fresh dialysate was added with a speed of 0.5 l/min. No recirculation or blood pump was used.

Clearance is obviously a better measure of clinical efficiency than is dialysate, when recirculating and non-recirculating systems are compared. Urea and creatinine clearances were measured one year after initiating dialysis. They were calculated according to the formula of Wolf et al (1951) assuming that the concentrations of urea and creatinine were 0 in the fresh dialysate. Determinations were made in a Technicon Auto-Analyzer.

Priming volume was measured by filling the dialysers with sterile saline before dialysis. The volume of blood lines was subtracted.

Compliance was measured by distending the dialysers from a pump against occluded venous lines, noting the relationship between volume and the pressure in the venous lines. Calculated ultrafiltration was subtracted.

Blood loss after back transfusion was estimated by measuring the haematocrit in the venous bubble-catcher after the blood in the dialyser had been transfused back. Saline was used as the wash-out solution.

Internal resistance to blood flow was compared between the A-G and the Kiil by performing alternate dialyses on the same patient with the two dialysers. In this way the flow (bubble technique) could be utilised in comparing relative resistance. Studies were done approximately one hour after start of dialysis.

Ultrafiltration was measured by noting weight loss during dialysis and correcting for intake and output.

RESULTS AND DISCUSSION

Clearances were similar for the UF-100, UF-145, and the A-G in the rapid dialysis system (Table II and Figure 1).

The figures agree well with previously published figures for the UF-100 and UF-145 dialysers (Cestero & Freeman, 1969).

The figures are higher for the A-G than those published by Rastogi et al. (1969).
Table II. A new disposable parallel flow artificial kidney.

<table>
<thead>
<tr>
<th></th>
<th>A-G</th>
<th>A-G</th>
<th>UF-100</th>
<th>UF-145</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>13</td>
<td>15</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>C_{BUN} ml/min</td>
<td>113</td>
<td>134</td>
<td>135</td>
<td>136</td>
</tr>
<tr>
<td>C_{cr} ml/min</td>
<td>80</td>
<td>103</td>
<td>106</td>
<td>122</td>
</tr>
<tr>
<td>Blood flow ml/min</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
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<tr>
<td>Dialysate flow l/min</td>
<td>0.6</td>
<td>0.6</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Recirculation l/min</td>
<td>None</td>
<td>4</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

Figure 1. Comparison of clearance. Each bar: mean of approximately 10 determinations

Contrary to the findings by Alwall (1968) we found, in clinical application, that recirculation increased the efficiency of the A-G by about 20%.

In the slow dialysis system the clearance of the A-G was about 20% higher than that of the Kiil at all blood speeds (Figures 1 and 2). These figures agree with the findings of Kulatilake et al., 1969. They are contrary to those of Rastogi et al., 1969, who found the Kiil more efficient than the A-G.

Priming volume. The results of these studies are found in Figure 3. The parallel flow dialysers have a smaller priming volume than the coil dialysers. The volume ranged from 180 ml to 350 ml, mean 250 ml for the A-G; from 240 ml to 440 ml, mean 360 ml for the UF-100, from 340 ml to 440 ml, mean 400 ml for the UF-145. The priming volume of the Kiil was 240 ml.
Figure 2. Variation of urea clearance with blood flow. No blood-pump or recirculation.

Figure 3. Comparison of priming volume and compliance. Volume of blood lines excluded. Each bar: mean of approximately 10 determinations. P = positive pressure in blood outlet lines.
Figure 4. Residual blood in dialyser. Haematocrit measured in venous bubble-catcher after back-transfusion.

Figure 5. Percent dialyser ruptures requiring discontinuance of dialysis.
Compliance of the A-G is the lowest of the dialysers tested with only 105 ml increase in volume when pressure is increased from 0 to 300 mm Hg. Corresponding figure for the UF-100 is 300 ml, for the UF-145, 325 ml. The volume of the Kiil increases 80 ml when pressure is raised from 0 to 100 mm Hg. These results confirm those of Cestero and Freeman, 1969.

Residual blood volume remaining in the dialysers after back transfusion is shown in Figure 4. The loss of red cells mass equalled only 3 to 10 cc for both the UF-100 and the A-G. This figure is far less than that of Cestero and Freeman, 1969, for the UF-100 and comparable to those of Rastogi et al, 1969, for the UF-100 and the A-G.

The internal resistance was compared indirectly by measuring blood flow. The patients were unable to perfuse the coil type dialysers without the assistance of a blood pump. In 30 studies, where patients alternately perfused Kiil and A-G dialysers, the mean blood flow through the Kiil was 172 ml/min versus 166 ml/min for the A-G. Both parallel flow dialysers were well perfused by the patients without the use of a blood pump, a finding of Kulatilake et al, 1969, as well.

Dialyser leaks. The incidence of dialyser leakage requiring cessation of dialysis is indicated in Figure 5. Only one of 120 (0.8%) A-G dialysers leaked. The leakage rate for the Kiil was 2.2% (45 of 2050); for the UF-145, 7.5% (30 of 400) and 19.4% (36 of 186) for the UF-100.

The low rate of leakage is an obvious advantage of the A-G; saving time and the cost of blood as well as increasing the safety of dialysis.

The ultrafiltration rate for the A-G is 270 ml/hr/100 mm Hg pressure difference across the dialysis membrane (range 240 ml to 320 ml). Both the UF-100 and UF-145 ultrafiltrate approximately twice as fast, 500 ml/hr/100 mm Hg (range 320 to 880 ml). All of these figures are in close agreement with those published by Cestero and Freeman, 1969, and Rastogi et al, 1969. Published reports (Cestero & Freeman, 1969) indicate that the Kiil has an ultrafiltration comparable to the UF-100 and the UF-145.

**CONCLUSION**

The Alwall-Cambro dialyser shares the advantages of disposable dialysers, i.e. short preparation time and low exposure of personnel to blood. It has a clearance comparable to the UF-100 and UF-145 when using a rapid dialysis system, but ultrafiltrates only half as fast. The ultrafiltration rate is fast enough, however, for almost any conceivable clinical situation. The volume, compliance and the incidence of ruptures are much lower.

In the slow dialysis system the clearance is somewhat higher than that of the Kiil. Priming volume and internal resistance to blood flow are about equal. The rupture rate is one-third that of the Kiil.
The Alwall-Cambro compares favourably to the commonly used dialysers and offers marked improvements for safety and ease of dialysis.

REFERENCES