The Hollow Fibre Artificial Kidney (Cordis Dow) 1968–71

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In 1969 the clinical results of 4 to 11 months of haemodialysis therapy with the hollow fibre (Cordis Dow) artificial kidney (CDAK) were reported (Gotch et al, 1969). Since then this dialyser has been improved and the clinical response to long-term (1-3 years) haemodialysis therapy has been observed. We report here the in vivo performance characteristics of the current 1 M² Model 3A CDAK, the results of long-term haemodialysis therapy, and the results of studies on the cause of fibre occlusion by thrombus.

CURRENT IN VIVO PERFORMANCE CHARACTERISTICS (Model 3A CDAK)

All confidence limits are expressed as mean ± 2 standard variations for n observations. See Glossary for definition of symbols.

1. Contained blood volume = 98 ± 13 ml (n = 277)
2. Resistance to blood flow (ΔP_B/Q_B) = 0.114 ± 0.058 mm Hg/ml flow (n = 46, mean haematocrit = 22 vol %)
3. Resistance to dialysate flow (ΔP_D/Q_D) = 0.055 ± 0.028 mm Hg/ml flow (n = 50)
4. In vivo ultrafiltration (UFR) ml/hr:
   UFR = 1.01 ± 0.10ΔP_m - 27 ± 28 (n = 40)
5. In vivo solute clearance is shown in Figure 1 and also is compared there with that of other dialysers.
6. Mechanical integrity: there is no significant dependence of ΔP_B/Q_B, ΔP_D/Q_D, UFR/ΔP_m, clearance, or contained blood volume on ΔP_m varied from 0 to 450 mm Hg. Blood leak rate is 2% (n = 1728).

CLINICAL RESPONSE TO LONG-TERM HAEMODIALYSIS
WITH Model 3A CDAK

(1) Hours of dialysis/week
In Figure 2, values for average predialysis and postdialysis serum creatinine
during the most recent 12 months of therapy, total weekly dialysis hours, and endogenous creatinine clearance are shown correlated to body weight for each of 20 patients who have undergone 12 to 36 months (mean = 24 months) of haemodialysis on a thrice-weekly dialysis schedule with the CDAQ.

(2) Control of anaemia

Mean haematocrit was 21 vol% and mean transfusion requirement was 0.6 units of red cells/month.

(3) Control of calcium and phosphorus metabolism

Mean predialysis calcium was 9.1 mg/100 ml, mean pre- and postdialysis
phosphorus 6 and 3.6 mg/100 ml and mean predialysis calcium phosphorus product 56. In 16 patients, serial skeletal X-rays remained normal or pre-existing abnormalities improved during 12 to 36 (mean = 21) months of dialysis. In two patients, minimal X-ray abnormalities appeared after 12 to 36 months of dialysis respectively and in two patients subtotal (7/8) parathyroidectomy was performed after 17 and 25 months of dialysis respectively.

(4) Control of neuropathy

In 18 patients there was no clinical evidence of neuropathy at the start of dialysis and none has developed to date. Two patients with mild motor and sensory neuropathy at the start of dialysis recovered fully during the first 6 to 12 months of dialysis.

STUDIES ON FIBRE OCCLUSION BY THROMBUS

In 1969 we reported that excessive and variable fibre occlusion occurred in 25% of patients (Gotch et al, 1969). It was subsequently postulated that this might result from variations in the thrombogenicity of the surface of the hollow fibre kidney even though the materials used were constant. It was further postulated that this surface variability might be caused by substances adsorbed onto the blood-contacting surfaces from tap water during fabrication and processing of the kidney prior to its final preparation for clinical use.

A method was developed for comparing clotting in experimental and con-
control kidneys during a single dialysis and hence with a maximally controlled patient influence on clotting. The kidney clotting curves shown in Figure 3 were obtained by perfusing for 45 minutes and in sequence one non-tap water exposed (NTWE) DKU-1 kidney and one tap water exposed (TWE) DKU-1 kidney during each of nine dialyses. A striking but varying increase in fibre occlusion is shown to result when the kidney is exposed to tap water prior to final sterilisation and preparation for dialysis. Similar results were obtained for the Model 3A CDAK with this method of study.

The effect of tap water exposure on fibre occlusion has also been studied by comparing the magnitude and variability of fibre occlusion in NTWE and TWE kidneys used for sequential complete dialyses with individual patients serving as their own controls. In eight patients, fibre occlusion (% of fibres obstructed at the end of dialysis) in 27 dialyses with NTWE CDAK was compared with that in 27 dialyses with TWE CDAK and showed 27 ± 40% in the NTWE kidneys compared with 38 ± 52% in the TWE kidneys. In five highly thrombogenic patients, 48 dialyses with the NTWE DKU-1 were compared with 48 dialyses with TWE CDAK. Fibre occlusion in the NTWE DKU-1 kidney was 12 ± 16% compared with 56 ± 52% in the TWE CDAK kidneys.

CONCLUSIONS

The in vivo performance data demonstrate an unprecedented simultaneous optimisation of mass transfer, dynamic blood volume, resistance to bloodflow and physical size resulting from the uniform small blood channels in the CDAK.
An average of 21 (range 12-25) hours of dialysis per week with the CDAK has been demonstrated to provide satisfactory long-term (1 to 3 years) haemodialysis therapy in patients ranging from 25 to 80 kg and with residual renal function varying from anephric state to 4 ml/min creatinine clearance.

Excessive and variable fibre occlusion by thrombus in highly thrombogenic patients has been successfully controlled.

GLOSSARY

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Meaning</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>$D_B$</td>
<td>Dialysance</td>
<td>ml/min</td>
</tr>
<tr>
<td>$C$</td>
<td>Clearance</td>
<td>ml/min</td>
</tr>
<tr>
<td>$UFR$</td>
<td>Ultrafiltration rate</td>
<td>ml/hr</td>
</tr>
<tr>
<td>$Q_D$</td>
<td>Dialysate flow rate</td>
<td>ml/min</td>
</tr>
<tr>
<td>$Q_B$</td>
<td>Blood flow rate</td>
<td>ml/min</td>
</tr>
<tr>
<td>$P_{B_1}P_{Bo}$</td>
<td>Pressure-blood, -blood in, -blood out</td>
<td>mm Hg</td>
</tr>
<tr>
<td>$\Delta P_B$</td>
<td>$P_{Bo} - P_{Bi}$</td>
<td>mm Hg</td>
</tr>
<tr>
<td>$P_{D_1}P_{Do}$</td>
<td>Pressure-dialysate, -dialysate in, -dialysate out</td>
<td>mm Hg</td>
</tr>
<tr>
<td>$\Delta P_D$</td>
<td>$P_{Do} - P_{Di}$</td>
<td>mm Hg</td>
</tr>
<tr>
<td>$\Delta P_m$</td>
<td>$1/2(P_{Bi}+P_{Bo}) - 1/2(P_{Di}+P_{Do})$</td>
<td>mm Hg</td>
</tr>
<tr>
<td>$C_{Bi}C_{Bo}C_D$</td>
<td>Concentration-blood in, - blood out, -dialysate</td>
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</tbody>
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REFERENCES


