Simple Instantaneous Determination of Clearance Efficiency of the Cordis Dow Artificial Kidney (Model 3)

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For financial reasons disposable dialysers are often used several times. Re-use of the Cordis Dow artificial kidney (CDAK) is limited by clotting within the kidney causing occlusion of a variable number of its fibres. Its efficiency on re-use is therefore uncertain. Clinical use of the CDAK would be facilitated by knowledge of the proportion of fibres obstructed at any time during dialysis, and of the effect of this on clearance values. We have found a simple method of determining percent fibre bundle obstruction (\%FBO) and clearance efficiency to be accurate during dummy dialysis and have applied it to patient dialysis (Figure 1). It is without extra hepatitis hazard for personnel.

Figure 1. Experimental set-up for in vivo CDAK evaluation
Figure 2. Pressure/flow (in mm Hg and ml/min) values with saline perfusion for 3 CDAKs at zero, 25%, 50%, and 75% FBO. Each point represents the average of results for 3 kidneys. Their distribution is found to correspond closely to the idealised lines (shown superimposed), described by the formula: $P = \left( F/25 \right) \left[ 1 + \left( \% \text{FBO}/50 \right)^2 \right]$

Figure 3. Nomogram giving alternative display of pressure/flow/%FBO interrelations
IN VITRO STUDIES

Pressure/flow relationships were determined at 0, 25, 50 and 75%FBO for three Cordis Dow (Model 3) kidneys during dummy dialysis. The kidneys were perfused with saline at 37°C, and a measured arc of the arterial endplate was occluded by an impermeable membrane.

The relationship between pressure drop across the CDAK, flow rate and fibre occlusion, corresponded closely to that described by the formula:

\[
\Delta P = \left( \frac{F}{25} \right) \left[ 1 + \left( \frac{\%FBO}{50} \right)^2 \right] \quad \text{(Figure 2)}
\]

where:
- \( P \) = Pressure drop across the CDAK in mm Hg
- \( F \) = Flow rate through CDAK in ml per minute
- \( \%FBO \) = Percent fibre bundle obstruction

This was more conveniently expressed in the nomogram shown in Figure 3.

IN VIVO STUDIES

The relationships between pressure drop across the kidney, rate of blood flow through the kidney and fibre bundle occlusion were studied in the same way during the first few minutes of dialysis of patients. Fourteen kidneys were studied: two were unobstructed, four were 25%, four 50% and four 75% obstructed. In addition, clearances of urea and creatinine were studied in each kidney at flow rates of 88 - 263 ml per minute. The average clearance values are plotted in Figure 4.

At each flow rate studied in each kidney a correction factor was calculated to make the original formula, calculated from dummy saline dialysis, fit the results obtained during patient dialysis:

\[
\Delta P = \left( \frac{xF}{25} \right) \left[ 1 + \left( \frac{\%FBO}{50} \right)^2 \right]
\]

where: \( x \) = correction factor

The average of all correction factors (\( \bar{x} = 3.5 \)) was then applied to the original formula and used to compare the \%FBO thereby calculated with the actual \%FBO (Figure 5).

The nomogram showing the relationship between \( \Delta P \), flow rate and \%FBO during dummy saline dialysis was recalculated for patient dialysis using the corrected formula, producing identical curves related to a different vertical axis (Figure 3).

CONCLUSIONS

(a) The extrapolation of pressure-flow relationships determined during experimental saline perfusion of the CDAK to patient dialysis did not enable a precise measurement of the degree of fibre bundle obstruction to be made (Figure 5). However, a kidney which was severely obstructed (circa 75\%FBO) could reliably be distinguished from one with little or no obstruction (circa 25\%FBO).
Figure 4. Kidney clearances vs flow at four different degrees of obstruction

Figure 5. Display of actual vs calculated ($\%FBO = 50 \sqrt{(25P/3.5F) - 1}$) fibre bundle obstruction for 14 CDAKs in vivo
(b) Consideration of haematocrit and clotting times did not account for the variation in calculated %FBO during in vivo studies. The error was similar for each individual kidney (Figure 5). The causes of such errors are not clear, but may be related to inequality of fibre perfusion.

(c) Clearances of urea and creatinine at various blood flow rates, and different degrees of fibre bundle obstruction, have been established.

(d) Because each kidney behaved consistently with respect to $\Delta P$, flow rate and %FBO relationships, serial changes during dialysis, or between successive dialyses, can be considered to reflect changes in kidney obstruction and clearance capability. Semi-quantitative deductions may be made using the nomogram provided.

(e) The combined use of the nomogram shown in Figure 3 and the family of clearance curves shown in Figure 4 allowed an immediate assessment of clearance capability and provided a readily understandable visual presentation of the effect of increasing or decreasing flow rate at any moment. As the technique involved only simply pressure and flow measurements, it was without extra hepatitis hazard.

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