DIALYSIS FLUID REQUIREMENTS IN MINGLE PASS AND RECIRCULATION DIALYSIS

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Dialysis fluid for home haemodialysis can be produced in a monitored proportioning system or batch mixed in a tank—which is much cheaper. If it is batch mixed, is it more efficiently used in recirculation, in mingle pass (RSP) or in single pass?

Recirculation versus RSP

Theory: The solution of this problem is applicable to any dialyser. The aim of the theory is to predict the variation in body fluid urea concentration during treatment. The equation for a recirculation system has been derived by several authors and has the form:

\[ \frac{\text{End of dialysis level}}{\text{Pre-dialysis level}} = (a \cdot e^{-bt} + c)^n \]

where \( n \) is the number of bath changes and \( a, b \) and \( c \) are constants dependent on patient's size, dialyser performance and dialysis fluid volume. In a single pass system, \( c = 0 \) and \( n = 1 \).

The formula for an RSP system has not been previously published. It has the form:

\[ \frac{\text{End of dialysis level}}{\text{Pre-dialysis level}} = a_1 \cdot e^{-bt} + a_2 \cdot e^{-bt} \]

where \( a_1, b_1, a_2, b_2 \) depend on the solution of a quadratic equation incorporating the above variables. (The above equation is in fact the solution of a 2nd order linear differential equation with constant coefficients).

From the nature of these equations it has proved mathematically impossible, and intuitively dangerous, to draw any broad conclusions concerning the relative performance of RSP and other systems.

Throughout this theory it is assumed that the total body water is a one compartment system with perfect mixing. Data on cell wall permeability are too scant to permit extension of the theory to a two compartment system (Bell et al., 1965) but we would not expect it to affect our conclusions, at least as regards urea.

Study of the Travenol RSP machine

Figure 1 and Figure 2 show the predicted course of blood and dialysis fluid urea, in a Travenol RSP machine and in recirculation into the same volume (120 litres); the experimental points were obtained in vitro, using a 40 litre carboy stirred by motor. There is a faster early fall with the recirculation system and the final level is lower than with the RSP. Experiments have all been conducted over 5-6 hours at this volume, but the theoretical solution is similar for several sizes of tank and dialyser and several dialysis times over the clinically important range.
Can either system be made more efficient?

a. Size of recirculating tank on RSP.

Figure 3 shows the predicted effect of changing the size of the small recirculating tank (plus coil and pump dead space), on final blood urea. Efficiency is lowest when the small and large tanks are nearly equal and improves when the small tank gets smaller. However only a small gain would be achieved by reducing from the 6 litres of the Travenol RSP to the minimum of 2-3 litres permitted by pump and coil deadspace.

In the opposite direction the limiting condition (small tank so large that it contains all the fluid) amounts to straight recirculation; this is more efficient than any arrangement of RSP.
b. Rate of addition of fluid to small tank in RSP.

Our theory presupposes that fluid is added at a constant rate throughout dialysis. Two other possibilities have been considered: adding fluid faster in the first half, or adding it faster in the second half of dialysis. Both systems are slightly less efficient than a constant rate of addition.

c. Subdivision of fluid into several bath changes.

Table I shows the effect on final blood urea of recirculating into several small baths instead of one large bath, assuming instantaneous drainage and replacement of fluid. Since the changeover can never be instantaneous, it is doubtful whether frequent changes could be made more efficient than recirculation into the whole volume.

Conclusion 1:
Recirculation into the whole volume is more efficient than any practicable alternative using recirculation or RSP.

How large a recirculation tank?

The useful tank size is determined by dialyser performance, patient size and dialysing time. Figure 4 shows the effect of tank size on blood urea for a patient of 40 litre body water and several standards of coil during an 8 hour dialysis. A 250 litre tank would give 90% of the

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<td><strong>End of dialysis urea (% predialysis level) in a 6 hour dialysis using a coil of dialysance 150 ml/min</strong></td>
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<td>Number of baths</td>
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Total dialysing fluid volume = 124 litres
effect of an infinitely large tank with coils currently in use and more than 85% with any dialyser; it is even more adequate for a 6 hour run and should give about the same result as the conventional 3 baths of 100 litres with the Travenol machine.

Recirculation versus single pass

A lower clearance is acceptable in single pass as the dialysis fluid contains no urea throughout dialysis; the advantages of single pass increase with dialysing time.

Coils in single pass are inefficient (Kerr and Elliott, 1966). As this might be due to leakage of dialysis fluid around the coil, we re-examined single pass in vitro with the 1.45 coil (fibreglass and plastic screening mesh), with the coil surrounded by a pneumatic cuff and the core filled with plaster of Paris (Fig. 5). Neither coil in single pass can compete with itself in recirculation, whatever volume of dialysis fluid is involved. For the Ultraflow coil a single pass flow rate of 2000 ml/min would be required to better the 250 litre tank in an 8 hour run, quadrupling the consumption of dialysis fluid.

Conclusion 2:

Recirculation into the whole volume is much more efficient than single pass with both types of coil currently available.

Comment

Recirculation into large volumes at 37°C encourages bacterial growth and is inapplicable to prolonged dialysis. However the use of a single bath, which can be checked at the beginning of a run, has advantages in hospital treatment of acute renal failure and in fast home haemodialysis using a high performance coil. A prototype 250 litre kidney is under test with these applications in mind.

![Graph](image)

*Fig. 4. Predicted performance of a recirculating artificial kidney as a function of tank volume and dialysance.*

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'Blood' flow rate = 200 ml/min
Temperature = 21°C

Fig. 5. In vitro study of 1.45 coil in single pass.

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REFERENCES