New Appliances

Evaluation of the EX-O3 Dialyser Cartridge

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Summary

Fifty-five dialyses were performed using the EX-O3 dialyser cartridge. The performance of the dialyser in respect of urea, creatinine, phosphate, and uric acid dialysance is comparable to that of the Travenol Ultra-Flo 100 (cuprophane). It is rather more compact, is easy to operate, has minimal blood loss, and a low priming volume. Ultrafiltration was quite adequate and the dialyses were uncomplicated by side effects. A failure rate of 7% occurred but none of the patients lost any appreciable quantity of blood.

Introduction

The EX-O3 disposable dialyser cartridge, manufactured by Extracorporeal Medical Specialities Inc., is a modification of the EX-O1 cartridge developed by Miller *et al.*¹ It is constructed as a coil from cuprophane membrane 18 μ m thick (P.T.150) in a single pathway 12 cm wide with a surface area of 0.84 m². The coil measures about 10.5 by 18.0 cm. This compact design

is adaptable to virtually all coil dialysis systems. The cartridge is supported in a rigid, non-disposable transparent plastic container, eliminating the need for an inflatable cuff (Fig. 1). A brief account of American experience with the EX-O3 cartridge has been given by Reddy *et al.*²

Methods

Fifty-five dialyses were started on 18 patients undergoing regular dialysis treatment. Forty-eight coils were used in a recirculating single-pass machine (Travenol R.S.P.) and seven in a separate Milton Roy coil adaptor canister in conjunction with a Dylade dialysate supply system. Extracorporeal blood lines were used. The dialysate exchange rate was maintained at 300 ml/min throughout the study. Blood flow rates were determined by using occlusive pumps (Sarns, Travenol) which had been calibrated by the measurement of minute volumes of normal saline delivered at varying flow rates.

Urea, creatinine, phosphate, and uric acid dialysance figures were calculated at varying blood flow rates and at regular intervals during dialysis with a fixed blood flow by using the formula of Wolf *et al.*³

$$D = Q_b \frac{A - V}{A - B}$$

where D = dialysance (ml/min), A = blood inlet concentration (mg/100 ml), V = blood outlet concentration (mg/100ml), B = dialysate outlet concentration (mg/100 ml), and Q_b = blood flow rate (ml/min). Urea, creatinine, phosphate, and uric acid levels were estimated by the Technicon AutoAnalyzer (method N11B).

Ultrafiltration rates were determined by using a constant monitoring weigh-bed scale, corrections being made for body-weight changes secondary to fluid intake and output and food consumed during dialysis. The rates are expressed in ml/hour and each estimate is taken from a three-hour period during which constant conditions of blood flow and blood outlet pressure were maintained.

Blood outlet pressure was measured by an aneroid gauge connected to the bubble trap on the venous line. In addition one Travenol R.S.P. machine was modified by the addition of two similar gauges to allow simultaneous monitoring of the blood inlet pressure to the coil, and dialysate pressure at the foot of the dialysate compartment (Fig. 2). If it assumed that the dialysate pressure gradient varies from a maximum at the bottom of the dialysate compartment to nil at the top the mean dialysate pressure should be taken to be half of the recorded inlet pressure. Mean transmembrane pressure was calculated by the formula

$$\Delta p = \frac{{}^{\text{r}}\text{BI} + {}^{\text{r}}\text{BO}}{2} - {}^{\text{r}}\text{D}$$

where Δp = mean transmembrane pressure (mm Hg), ${}^{\text{r}}\text{BI}$ = blood inlet pressure (mm Hg), ${}^{\text{r}}\text{BO}$ = blood outlet pressure (mm Hg), and ${}^{\text{r}}\text{D}$ = mean dialysate pressure (mm Hg).

FIG. 1—The EX-O3 coil and transparent plastic container.

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FIG. 2—Diagram of the modified circuit for measuring blood inlet, blood outlet, and dialysate pressures.

The volume of blood trapped in the coil at the end of dialysis was estimated in nine patients by using red cells labelled with ^{51}Cr , as described by Muir *et al.*⁴ The "wash-back" procedure employed was as follows: at the end of each dialysis the arterial cannula was removed from the patient's fistula and the blood in the arterial tubing allowed to enter the coil. The blood was then pushed through the coil by normal saline at a flow rate of 200 ml/min with the minimum venous back-pressure possible (about 50 mm Hg) in these circumstances. During "wash back" the coil and canister were removed from the dialysate compartment and shaken to facilitate drainage of the blood. The wash back was discontinued when blood was no longer visible in the venous line. About 300-400 ml of saline was used each time.

Priming volumes were estimated during initial priming and at varying venous outlet pressures by running a machine with the arterial and venous lines in a 1-litre reservoir of saline. The residual volume in the reservoir was subtracted from the total to give the volume contained by the coil and lines. The capacity of the lines was measured separately, subtraction giving the true coil capacity. Estimates were performed on two coils only.

Results

The mean values for urea, creatinine, phosphate, and uric acid dialysance at hourly intervals for a period of nine hours with a blood flow of 200 ml/min are shown in Fig. 3. Urea and creatinine dialysance figures at varying flow rates are shown in Fig. 4. Similar dialysance figures were obtained for both dialysis systems. Comparable figures for the Travenol Ultra-Flo 100^s are detailed in Table I.

In Fig. 5 ultrafiltration rates (ml/hour) are plotted against blood outlet pressure (mm Hg). In Fig. 6 ultrafiltration rates are related to mean transmembrane pressures. Priming volumes at varying coil pressures are given in Table II. The initial priming volume of 140 ml rose with increase in the blood outlet pressure to 280 ml at 200 mm Hg. The mean blood loss per dialysis was

FIG. 3—Hourly urea, uric acid, creatinine, and phosphate dialysance values (ml/min $\pm$ S.D.) for the EX-O3 dialyser cartridge.

FIG. 4—Relation between urea and creatinine dialysance (ml/min $\pm$ S.D.) and blood flow for the EX-O3 dialyser cartridge.

TABLE I—Urea and Creatinine Dialysance Values for the EX-O3 and Travenol Ultra-Flo 100 Dialysers

Blood Flow (ml/min)	Urea Dialysance (ml/min)		Creatinine Dialysance (ml/min)	
	EX-O3 (Mean $\pm$ S.D.)	Travenol U.F. 100* (Mean $\pm$ S.D.)	EX-O3 (Mean $\pm$ S.D.)	Travenol U.F. 100* (Mean $\pm$ S.D.)
125	117.92 $\pm$ 3.84 (n = 6)	117.9 $\pm$ 13.8	90.63 $\pm$ 9.21 (n = 6)	94.1 $\pm$ 6.6
130	136.50 $\pm$ 4.87 (n = 6)		104 $\pm$ 4.93 (n = 6)	
150	152.25 $\pm$ 6.46 (n = 6)		117.55 $\pm$ 8.61 (n = 6)	
175	151.15 $\pm$ 9.44 (n = 7)		106 $\pm$ 11.01 (n = 6)	
200	171.60 (n = 2)	162.9 $\pm$ 11.0	130.90 (n = 2)	123.9 $\pm$ 19.6
220		195.5 $\pm$ 13.4		146.0 $\pm$ 7.6
300				

Figures by Muth (n = 36).

TABLE II—Priming Volumes of EX-O3 Dialyser Cartridge at Varying Blood Outlet Pressures

Blood outlet pressure (mm Hg)	..	..	..	Initial priming	50	80	100	120	140	150	200
Volume (ml)	..	..	..	140	160	192	207	217	240	230	280

3.5 ml, with a standard deviation of 1.5 ml. There were four coil failures out of the 55 coils used, giving a failure rate of 7%.

FIG. 5—Relation between ultrafiltration and blood outlet pressure for the EX-O3 dialyser cartridge.

FIG. 6—Relation between ultrafiltration and mean transmembrane pressure (Δp) for the EX-O3 dialyser cartridge.

Discussion

Despite its smaller surface area of 0.84 m² the efficiency of the EX-O3 is comparable to that of the 1.0 m² Travenol Ultra-Flo 100 (cuprophane) at similar blood flow rates. There was no statistically significant deterioration ($P > 0.05$) in the dialysance

figures for urea and creatinine during the nine-hour period of dialysis in contrast to that observed with other dialysers.⁶ As expected the dialysance figures increased with increasing blood flow (Fig. 4).

Ultrafiltration rates and net weight loss for individual patients were satisfactory. The maximum weight loss recorded was 3.7 kg (net), with a blood flow of 200 ml/min and a blood outlet pressure of 110 mm Hg. No attempt was made to ultrafiltrate fluid above this quantity. Ultrafiltration rates, however, showed a wide variation (Fig. 5) and were not predictable from the blood outlet pressure ($r = 0.305$; $P > 0.05$). There is, however, a correlation between the ultrafiltration rate and the mean transmembrane pressure ($r = 0.551$; $P < 0.01$) (Fig. 6).

In patients the course of dialysis with this disposable dialyser cartridge was uneventful and few patients required the administration of intravenous saline for headache, nausea, vomiting, muscle cramp, or hypotension. Bergman *et al.*⁷ made a similar observation after extensive experience with the EX-O1 dialyser. Blood loss was remarkably low, the highest recorded volume being 4.5 ml, with a mean of 3.5 ml. This compares favourably with the blood loss of 6.6 ml incurred with the Travenol Ultra-Flo 100 coil.⁴ Residual blood in the arterial and venous lines was 2.4 ml, compared with 4.0 ml for the Travenol lines.⁸

The coil failure rate was rather high at 7%. One coil was found to be faulty when tested during initial saline priming. Of the remaining coils one ruptured at the start of dialysis and two developed minor leaks, one of which was not detected until the end of dialysis when the coil was removed from the container. None of the patients lost any appreciable quantity of blood from coil failure.

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