

## TREATMENT OF ACUTE RENAL FAILURE IN THE NEWBORN BY CONTINUOUS ARTERIOVENOUS HAEMOFILTRATION

C Ronco, A Brendolan, L Bragantini, S Chiaramonte, A Fabris, M Feriani, L Menicanti, A Saccaggi, G La Greca

*St Bortolo Hospital, Vicenza, Italy*

### Introduction

Acute renal failure in newborns requires an efficient substitutive therapy to control fluid, electrolyte and acid-base balance and uraemia [1]. The rate of production of urea, for body weight or surface area, may be very high compared with adults and requires haemodialysis or peritoneal dialysis. However, haemodialysis or peritoneal dialysis may be unavailable, contraindicated because of technical problems or poorly tolerated because of the patient's clinical instability. We have used continuous arteriovenous haemofiltration (CAVH) as an alternative. As in adults, the simplicity and the rapid application of this technique may represent technical advantages while the excellent clinical tolerance allows the treatment of those patients for whom other therapies are precluded or contraindicated.

### Methods

Four patients (3 male, 1 female) aged from two to 12 days, affected by acute renal failure were treated with CAVH for a period ranging from 30 to 86 hours with the system depicted in Figure 1. Initial body weight ranged from 2.8 to 3.4kg and acute renal failure was secondary to abdominal surgery (patients 1 and 2), to cardiac surgery (patient 3) and to septicaemia (patient 4). All patients had a urine output <10ml/24hr at the beginning of the procedure.

CAVH was carried out as described by Lauer et al [2] with some modification because of the small patient size. No blood pumps were used, femoral, brachial and umbilical arteries were cannulated for arterial access, while jugular or umbilical veins were used to return the blood to the patients using short cannulas (18 or 20g) [3-5]. The extracorporeal circuit was made with shortened paediatric haemodialysis lines in order to avoid unnecessary pressure loss along the circuit. Sampling ports in the arterial, venous and ultrafiltration line were placed to provide blood and ultrafiltrate samples for chemical analysis. The

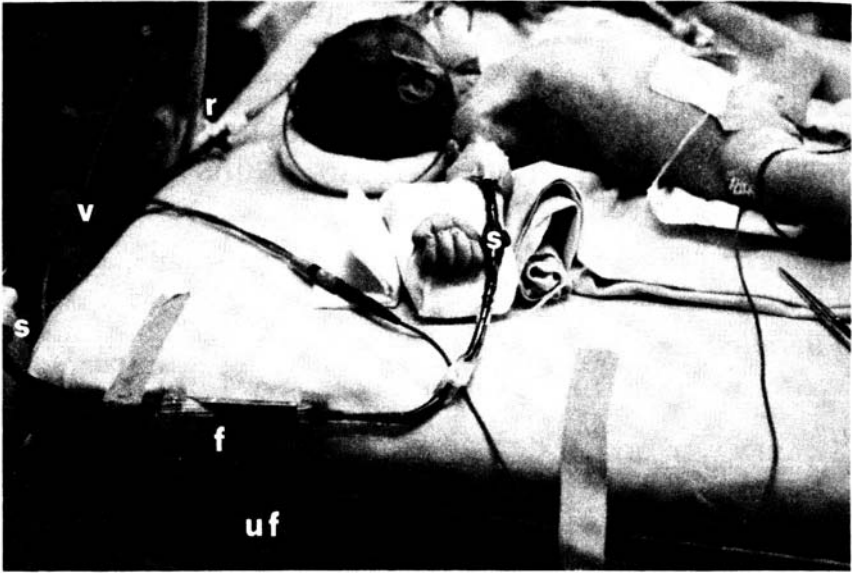


Figure 1. Continuous arteriovenous haemofiltration system applied in the newborn utilizing the brachial artery and the jugular vein. A=arterial line; V=venous line; H=heparin infusion; R=replacement solution; S=blood sampling ports; Uf=ultrafiltrate collecting system; F=haemofilter

ultrafiltration line was maintained as long as possible in order to maximize the negative pressure exerted on the membrane by the ultrafiltration column ( $1\text{cm H}_2\text{O}=0.74\text{mmHg}$ ). We used an Amicon Minifilter ( $0.005\text{m}^2$ ) with special hollow fibres (length=9cm; inner diameter 900 micra).

*Heparinization* Prior to treatment the filter and circuit were washed with 2000cc of heparinized saline solution (5000u/L). If the initial prothrombin time was  $<35$  seconds, a bolus of heparin (100u/kg/body weight) was administered at the start of the procedure. Continuous heparin infusion was provided during the treatment at the rate of 5–7u/kg/hr adjusting the infusion to the systemic blood prothrombin time.

*Substitution fluid* Ringer lactate, normal saline, alkaline or hyperalimentation solutions were used. Particular care was taken to avoid positive fluid balance.

*Treatment monitoring* Blood samples for haematocrit and total plasma protein were taken from the arterial and venous line to calculate blood flow ( $Q_b$ ), and filtration fraction [2]. Blood for electrolyte, acid-base and urea were also taken every six hours.

Ultrafiltration rate ( $Q_f$ ) was measured in a graduated cylinder and samples were taken to measure sieving coefficients. In some cases pressure measurements

were carried out at different points of the circuit by water column manometry. Plasma oncotic pressure was calculated [6]. Urea kinetic studies were performed in two patients using simplified Gotch formulas.

In all patients urine output was <10cc/24hr at the beginning of the treatment. CAVH was discontinued only after six to 12 hours of diuresis restoration.

### Results

Blood flow through the circuit ranged from 15 to 28ml/min and plasma flow ranged from 9.8 to 19.6ml/min. The ultrafiltration rate ranged from 0.7 to 1.2ml/min with a filtration fraction of five to eight per cent (Figure 2).

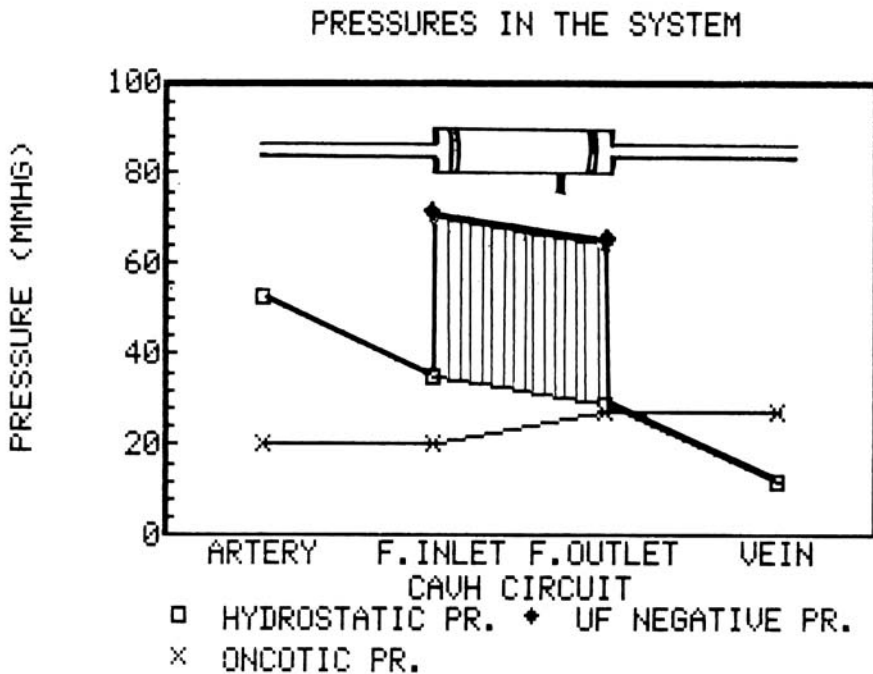


Figure 2. Pressure profile along the CAVH circuit in a neonate

These results indicate that 1) the resistance of the filter is very low; 2) in CAVH the optimal  $Q_f$  for this filter is about 1ml/min; 3) filtration fractions generally range from five to 10 per cent. In all the cases the survival of the filter was equal to the duration of the treatment and no clotted fibres were detected. Table I summarizes the data concerning the four CAVH treatments.

In all the patients the treatment was well tolerated and no complications related to the technique occurred. The amount of ultrafiltrate was replaced by substitution fluid and only slight variations in body weight were obtained

TABLE I. Continuous arteriovenous haemofiltration in four newborn infants

Patient	1	2	3	4
Diagnosis	Post-operative acute renal failure	Post-operative acute renal failure	Cardiac malformation	Septic shock
Age	4 days	2 days	2 days	12 days
Sex	Male	Male	Female	Male
Blood flow (ml/min)	28.0±3.1	25.2±2.4	15.5±4.2	22.0±3.3
Plasma flow (ml/min)	19.6±2.6	18.7±2.0	9.8±3.9	14.3±3.0
Ultrafiltration rate (ml/min)	1.1±0.2	1.0±0.1	0.8±0.3	0.7±0.2
Filtration fraction (%)	6.0±1.3	5.2±0.1	8.0±1.6	5.3±1.0
Treatment duration (hours)	86	78	30	48
Initial body weight (kg)	2.8	3.2	3.3	3.4
Final body weight (kg)	2.8	3.4	3.0	3.3
Outcome	Recovered Rest.Diur.	Recovered Rest.Diur.	Died	Changed to peritoneal dialysis

at the end of therapy. Blood pressure and heart rate remained stable during CAVH. When present, metabolic acidosis was corrected by the infusion of alkaline substitution fluid.

In three patients urea was maintained under adequate control, while in patient 4 the rate of urea production exceeded the amount removed and, even in the presence of an early parenteral hyperalimentation, CAVH was unable to control the uraemia. Patients 1 and 2 recovered after 58 and 72 hours respectively; patient 3 died after 30 hours owing to cardiac arrest, despite a good metabolic control; patient 4 was changed to peritoneal dialysis because of the severe catabolic state, but he died 18 hours later from bilateral pneumonia. Urea kinetic studies in patients 1 and 4 showed values significantly different over a period of 48 hours. In patient 1 the urea generation was 0.7mg/min while the urea removal rate was 0.5mg/min. In patient 4 the urea generation rate was 1.2mg/min and the urea removal rate was 0.5mg/min. In this patient, despite CAVH treatment, the high rate of urea production made treatment ineffective in controlling uraemia.

## Discussion

The clinical results and technical performances suggest that CAVH may be a reliable technique in the newborn as well as in the adult. There are several indications for CAVH in infants.

*Fluid overload* Fluid overload, pulmonary vascular congestion or pulmonary oedema may occur in the newborn not only due to acute renal failure but also because of cardiac failure. In conditions of oliguria refractory to diuretic

therapy haemodialysis or peritoneal dialysis might be difficult, dangerous or contraindicated while CAVH may represent a reliable alternative therapy. The slow and continuous hypotonic fluid removal can be well tolerated inducing a marked reduction of ventricular overload and a negative sodium balance.

*Electrolyte and acid-base derangements* The easy manipulation of the extracellular fluid achievable with CAVH permits the treatment of several electrolyte derangements. The speed of correction depends, of course, on the rate of fluid removal and replacement. One millilitre per minute (1440ml/24hr) represents about five times the circulating volume in a newborn weighing 3kg. This relatively high turnover of fluid can be usefully applied to adjusting the absolute amount of electrolytes of the body.

*Acid-base derangements* Bicarbonate loss during CAVH can be easily measured in the ultrafiltrate. When CAVH is applied without substitution fluid to reduce the patient's fluid overload, bicarbonate losses are compensated by the reduction of the buffer distribution volume and the serum concentration does not change significantly. On the contrary, when ultrafiltration is replaced to maintain the body fluid balance, the amount of bicarbonate lost in the ultrafiltrate must be replaced to maintain the serum levels constant.

*Solute removal* CAVH is not particularly efficient in removing waste products. Despite the remarkable amount of ultrafiltrate achievable in the newborn,

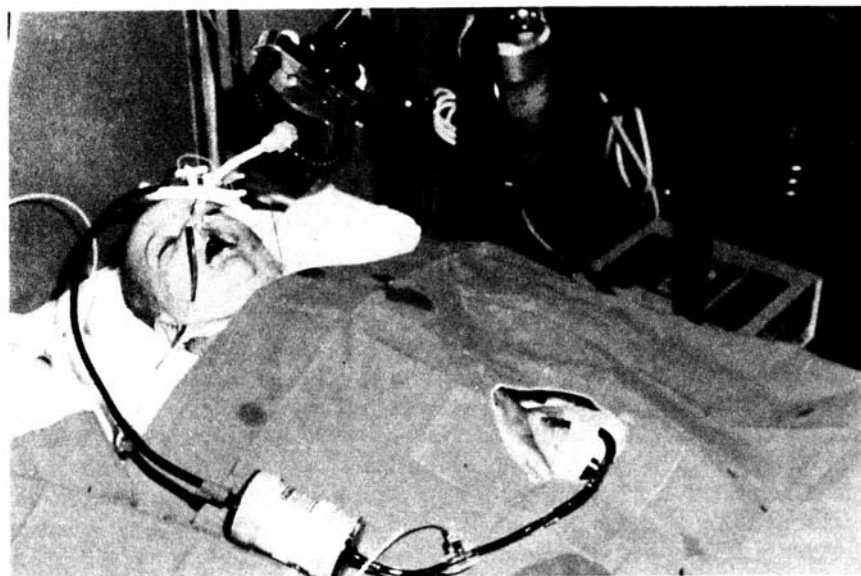


Figure 3. New prototype hollow fibre haemofilter applied to a patient

CAVH may be insufficient to control uraemia in patients with severe catabolism. Several strategies can be applied to increase the treatment efficiency when the urea generation rate exceeds 1.5–2g/day. Reduction of the protein catabolic rate and urea generation, and obtaining a positive nitrogen balance can be achieved with an early institution of parenteral hyperalimentation. Glucose solutions and mixed essential/non-essential aminoacid solutions should provide an energy intake ranging from 100 to 150Cal/kg/day in order to prevent cellular protein breakdown. Because of the relatively low rate of ultrafiltration we decided to apply to a three month old patient severely catabolic with acute renal failure, CAVH treatment with another experimental device (Figure 3). The filter used for CAVH was a prototype made by Amicon of 0.1m<sup>2</sup> surface area. The filter has the same membrane as the standard D-20 but a completely different geometry. This device had an ultrafiltration rate of 4.1ml/min with a very low blood flow. However, the filtration fraction in this treatment was 48 per cent and so we had to reduce the transmembrane pressure to avoid high viscosity of the blood in the filter.

In conclusion, the treatment appears to be safe, simple and reliable in treating those patients in whom haemodialysis or peritoneal dialysis are precluded or contraindicated.

## References

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