CONTINUOUS ARTERIOVENOUS HAEMOFILTRATION.
A NEW KIDNEY REPLACEMENT THERAPY

P Kramer, J Schrader, W Bohnsack, G Grieben, H J Gröne, F Scheler

University Hospital, Göttingen, FRG

Summary

Twenty intensive care patients, who as an additional complication developed acute oliguric renal failure were treated solely with continuous arteriovenous haemofiltration (CAVH). The mean spontaneous filtration rate was $8.8 \pm 3.5\text{ml/min}$. IV substitution of the ultrafiltrate by $K^+$-free Ringer's lactate solution resulted in a steady state plasma creatinine level of $6.4 \pm 3.5\text{mg/dl}$. Duration of treatment was three to 24 days ($10.5 \pm 7.9\text{ days}$). Eight patients recovered kidney function and survived. Clinical experience in five intensive care units with more than 150 applications of CAVH allows the following conclusions: optimal control of water and electrolyte balance; unlimited parenteral nutrition; continuous fluid withdrawal better tolerated than intermittent withdrawal by means of dialysis. With skilled puncture of the femoral artery there was no risk of bleeding. Low dose continuous heparin administration ($10\text{IU/kg/hr}$) into the arterial blood line is sufficient for extracorporeal anticoagulation. Haemofilters can be used for a long time (two to ten days). Specially trained dialysis personnel and investment costs for machines are not necessary.

Definition

Arteriovenous haemofiltration is a simple technique, which utilises the arteriovenous pressure gradient or else the cardiac contraction force, in order to propel blood through a capillary haemofilter. While passing the semi-permeable capillaries, ultrafiltrate is separated from the blood and either removed in order to dehydrate the patient or substituted in order to change the plasma concentration of electrolytes or other substances normally contained in the urine.

Methods and materials

The particular therapeutic potential of arteriovenous haemofiltration is its simplicity [1]. The femoral artery and femoral vein are cannulated by means of a
Figure 1. Schematic representation of the equipment used in CAVH
modified Seldinger technique using a specially made catheter set (Vygon) as illustrated in Figure 1. The ultrafiltrate is conducted to a measuring and collecting device, which is positioned as low as possible on the patient's bedstead, in order to exert a negative pressure of approximately 40 cm water, which increases the filtration by approximately 30 per cent.

Both heparin solution and substitution fluid are administered by means of an Isoflux infusion system, which maintains a constant infusion rate independent of pressure changes in the blood lines and independent of the fluid level in the infusion container. In order to overcome the pressure in the arterial blood line the heparin infusion bottle (1000 ml saline + 20,000 IU heparin) has to be positioned at least 2 m above the patient.

**Minimal heparinisation**

After an initial systemic dose of 2000 IU the continuous infusion into the arterial blood line is adjusted to 10 IU/kg body weight/hr.

Figure 2 shows PTT, thrombin time and heparin concentration in the extracorporeal and systemic circulation with this heparin dose. It is obvious that this

\[ A = \text{extracorporeal circulation} \quad \text{(n = 28)} \]
\[ B = \text{systemic circulation} \]

**Figure 2.** Partial thrombin time, thrombin time and heparin concentration in systemic and extracorporeal circulation

Small heparin dose is sufficient to avoid coagulation in the haemofilter and it should not lead to bleeding complications in the patient. With this heparin regime prolonged use of haemofilters (two to ten days [2]) was obtained, provided that heparin administration was never interrupted or the patient was given an additional dose of 2000 IU intravenously, which allows a 30 minutes interruption of continuous administration. Coagulation in the haemofilter even during
serious reduction of blood flow is inhibited because of the inversely proportional increase of heparin concentration in the extracorporeal circulation (Figure 3). Occluding thrombosis of the femoral artery and vein with this procedure had not been observed. At autopsy flat fibrin deposits are usually found at the contact site between catheter and vascular wall and 1 to 2cm distal to the tip. In more than 150 arterial cannulations performed since 1977 peripheral emboli in the leg were observed in two old patients with serious atherosclerosis, but we have never seen a significant pulmonary embolism.

HEPARIN AND PTT IN RELATION TO BLOOD FLOW RATE

![Graph showing flow rate, PTT, and heparin concentration in relation to blood flow rate.](image)

Figure 3. Inverse relationship between blood flow rate and heparin concentration (n = 1)

Correction of uraemia

As demonstrated by Figure 4 the filtration rate was mainly a function of blood flow rate. As a rule, filtration rate was about 25 per cent of blood flow rate. In some patients with a low blood flow rate, but not necessarily with a low haematocrit, the filtration fraction increased to 40 per cent.

Using the new vascular catheter (Vygon) for cannulation of the femoral artery
Figure 4. Relationship between blood flow rate and filtration rate as determined two hours after onset of CAVH using the D-30 SK Haemofilter (Amicon)

Figure 5. Steady state plasma creatinine in relation to ultrafiltrate substitution rate
and vein filtration rates obtained were high enough to correct renal failure, if the ultrafiltrate was substituted by a potassium free Ringer's lactate solution [2]. Figure 5 shows the steady state plasma creatinine in relation to the substitution rate in 20 anuric patients in whom we were able to maintain filtration and fluid substitution at a constant level for at least two days. The figure demonstrates an inverse relationship between the two parameters which is very similar to that observed between plasma creatinine and glomerular filtration rate.

Evaluation of method

Since treatment with machines, particularly with venovenous intermittent haemofiltration has been applied in patients with acute renal failure, it is necessary to point out advantages and disadvantages of CAVH as an alternative method.

*Advantages of CAVH* These can be summarised as: low stressing of cardiovascular system; high effective fluid withdrawal possible without circulatory failure; minimal heparinisation sufficient; no danger of air embolism or haemofilter rupture; no electricity required; highly specialised staff and high investment costs not necessary.

*Disadvantages of CAVH:* low efficiency due to low filtration rate; error in fluid balance with manual measurements of fluid more likely; not applicable in patients with advanced atherosclerosis; patients confined to bed with femoral catheters.

The use of CAVH offers further advantages for intensive supervision of patients such as simple arterial blood sampling, direct control of BP and CVP, continuous monitoring of haematocrit [3] and BP-controlled fluid withdrawal. The most important potential of this method in acute renal failure, however, is unlimited parenteral nutrition [4] without lipids. In addition 40 per cent glucose solution may be administered to the patient through the venous blood line under optimal conditions, i.e. immediate dilution by fully heparinised blood entering a large vein.

Indications for use of CAVH

In view of the features described above and based on the experience of five different intensive care units, the following indications for the application of CAVH in patients with acute renal failure are suggested:

*Special indications:* Impaired pulmonary diffusion complicated by circulatory failure. Hypernatraemia resistant to natriuretic drugs.

*General indications:* Overhydration resistant to diuretics [5]. Parenteral nutrition restricted as a result of restricted fluid administration. Hyperkalaemia and azotaemia, whereby CAVH must be used as a preventive method.
**Questionable indications:** Intoxication through poisons or drugs. Severe hyperkalaemia due to haemolysis or extensive tissue damage.

**Outlook**

Because of its low filtration rate CAVH possesses the particular cost-reducing potential of intestinal ultrafiltrate substitution by non-sterile fluid. This has been demonstrated in dogs [1, 6], and is supported by preliminary observations in man. For the use of CAVH in ESRF-patients better external av-shunts have to be available.

**Acknowledgments**

Supported by the Deutsche Forschungsgemeinschaft im Rahmen des SFB 89 (Teilprojekt II) Kardiologie Göttingen and by Contract NO1 - AM-7-2235 of the Artificial Kidney-Chronic Uremia Program, National Institute of Arthritis, Metabolism, and Digestive Diseases, Bethesda, Maryland, USA.

**References**

3 Stiller S, Mann H. *Proc ESAO* 1980; 7: 167

**Open Discussion**

PAGANINI (USA) I notice that you are accepting higher urea nitrogen levels, accepting a lower efficiency type kidney. We have been performing similar techniques of continuous filtration at the Cleveland Clinic for the past three years and have interposed periodic diffusion dialysis. I wonder, in the light of past studies correlating increased serum urea nitrogen levels and delayed wound healing, whether you have experienced any delay in wound healing, in post operative patients?

KRAMER Thank you very much for raising this important question, because in fact we are proposing and applying this method in polytraumatised patients and our policy has been to start as early as possible with hypercaloric nutrition to prevent catabolism and have a total plasma water exchange of 10–15 litres per day, and beyond that point not to care about urea. I know that from studies performed during the Korean and Vietnam Wars better healing was demonstrated if the patients were treated with aggressive haemodialysis. However, in these studies, to my knowledge, it is not possible to distinguish between the effect of lowering urea and the effect of better alimentation with daily haemodialysis. We get more freedom to administer fluid. At present I have no proof that our policy is best but I still look to further studies to prove this.