HIGH PRECISION AUTOMATIC ADJUSTMENT OF ULTRAFILTRATION AND REINJECTION FLOW RATES DURING THE HAEMOFILTRATION PROCEDURE

T Haas, F Khazine, G Dongrardi, O Simons, C Fraumont, J P Fendler
University of Medicine Paris-West, Poissy Hospital, France

Introduction

Extra-renal epuration by haemofiltration usually implies the use of specific monitoring and of sterile pyrogen-free fluid. The present article describes a simple system which is capable of automatically equalising ultrafiltration flow and reinjection flow at all times. Application of this system and the use of reinjection fluid from fluid provided by a dialysis generator makes it possible to carry out a session of haemofiltration with a high degree of safety using only haemodialysis equipment.

Material and methods

Ultrafiltration flow

Ultrafiltrate flow ensured by the ‘arterial’ pump of a double head pump functioning in pressure-pressure mode (Fresenius SN 752) is collected in an expansion chamber (Bellco) connected to a manometer then emptied by the ‘venous’ pump of the module into a graduated receptacle, after passage in front of a haemoglobin detector (Figure 1).

Substitution flow

The dialysis fluid provided by a generator (DS Milton Roy) from water treated by reverse osmosis is filtered through a haemofilter (Amicon D 20) connected in series in the dialysate circuit of the generator [1]: a dialysate circuit pressure of the order of +200 to +300mmHg gives filtered dialysate flows of the order of 200 to 300ml/min (Figure 1).

Sterility and absence of pyrogens of the fluid thus obtained are confirmed regularly by bacteriological studies and a Limulus lysate test [1]. Before each session, the integrity of the Amicon filter is confirmed by the injection of Dextran Blue (MW = 10⁶): absence of colouration of the substitution fluid distal to the
Figure 1. Flow diagram of fluid balance monitoring. Arterial pump, venous pump = Pressure-pressure double head pump; UF. EC = Ultrafiltration expansion chamber; RIEC = Reinjection expansion chamber; P_{UF} = Monitoring pressure of the double head pump; P_{VR} = Venous return pressure; P_{RI} = Reinjection pressure; P_{DRAIN} = Draining off pressure (P_{D} = 0); D 20 = Amicon haemofilter

filter indicates that it is suitable for use during the haemofiltration session. After each session, the Amicon filter is sterilised by formol in order to be re-used later. The substitution fluid thus produced is collected in an expansion chamber (Bellco) connected to a manometer, then reinjected by the ‘venous’ pump of the unipuncture module into the venous return of the blood circuit (Figure 1). The composition of the substitution fluid is as follows: Na 140mEq/L, K 1mEq/L, Cl 105mEq/L, Mg 1.5mEq/L, Ca 4mEq/L, acetate 35mEq/L, glucose 0mmol/L.

**Equalisation of UF and RI flow rates**

**Hypothesis** The ultrafiltration flow rate equals the reinjection flow rate if: a) the pump segments of the ultrafiltration and reinjection lines have the same internal diameter and are inserted into the same occlusive pump; b) the pressure gradients between the input and output of the 2 pump segments are equal.

**Realisation** The reinjection and ultrafiltration lines themselves (PVC) (Bellco) (Ø = 4.3mm) form the 2 pump segments.

The ultrafiltrate expansion chamber is connected to the monitoring manometer of the double pump: the pressure in this expansion chamber (P_{UF}) and its variations control the turning on and off of the arterial pump and of the ‘venous’ pump.

The ‘venous’ pump simultaneously ensures: a) collection of the ultrafiltrate from the ultrafiltration expansion chamber into a receptacle, and b) reinjection of
the substitution fluid from the reinjection expansion chamber.

Equality between the pressure gradients in the two pump segments (PRI - PVR = PUF - Pd) is obtained as follows: in the reinjection line, pressures are PRI (pressure in the reinjection expansion chamber) and PVR (pressure in the venous return of the blood circuit); in the ultrafiltration line, pressures are Pd (pressure of flow into an open receptacle at atmospheric pressure, 0 reference of pressures) and PUF (pressure in the ultrafiltration expansion chamber). The equation then becomes: PUF = PRI - PVR. When the 'venous' pump comes into operation (induced by the highest value of PUF), PRI is at its maximum value and PVR at its minimum value so the difference PRI max - PVR min gives the highest value of PUF which must be used on the monitoring manometer of the double pump in order to ensure equality: PUF max = PRI max - PVR min. The lowest value of PUF which causes the 'venous' pump to stop and the 'arterial' pump to start is then fixed arbitrarily by PUF min = PUF max - 100mmHg.

Weight loss A certain amount of ultrafiltrate is bypassed via an occlusive pump proximal to the 'arterial' pump in such a way that, theoretically, this bypass does not affect the mechanism which ensures equality between ultrafiltration and reinjection flow rates. In order to avoid sudden changes in pressure proximal to the 'arterial' pump and excessive degasification of the ultrafiltrate, the pump responsible for weight loss is monitored in the same way as the 'venous' pump by PUF max and thus does not function when the 'arterial' ultrafiltration pump is stopped.

Results

Comparison of the volume of ultrafiltrate and of the volume of reinjectate without use of the weight loss system

The volume of reinjectate (VR) is calculated by the value: volume of ultrafiltrate (VUF) + weight variation (ΔW) from the initial weight W0: VR = VUF + ΔW. The weight of the patient (W) is measured at all times on an electronic bed-scale (Fresenius). In the absence of use of the weight loss system in a patient during seven sessions, VR is close to VUF (Figure 2).

Comparison of the volume of ultrafiltrate and of the volume of reinjectate with use of the weight loss system

The volume of ultrafiltrate removed proximal to the monitor (UF derivation) (UFd) expresses the anticipated weight loss: UFd = VUF - VR. Real weight loss measured on the scale (ΔWR) is not closely similar to the anticipated weight loss (Figure 3). Real weight loss is virtually always overestimated by anticipated weight loss. On average, the difference (UFd - ΔWR) is +7.5%. However, the linear regression between ΔWR and UFd is significant and predictive (Figure 3). Once the mean error of +7.5% is accepted, the difference between true weight loss and anticipated weight loss lay for the 126 values between 0 and 330ml; in 119 cases, the error was less than 200ml.
Figure 2. Comparison of the volume of ultrafiltrate and of the volume of reinjectate without use of the weight loss system

Figure 3. Comparison of the volume of ultrafiltrate by-passed and of the real weight loss

Reference

1 Henderson LW, San Felippo M, Beans E. Trans ASAIO 1978; 24: 465