Yatzidis [1] introduced charcoal haemoperfusion in 1964. The initial problems with platelet depletion and microembolisation have been reduced to an acceptable level by encapsulation of the charcoal granules with semipermeable membranes [2,3].

Physically, the haemoperfusion column is a specific application of isothermal adsorption processes which, by definition, occur in three rate controlling steps: (A) diffusion of adsorbate to the adsorbent (external film diffusion); (B) diffusion of adsorbate into the pores of the adsorbent (pore diffusion); (C) adsorption at the pore surfaces.

Since adsorption rate at the pore surfaces is rapid, removal of toxins is not limited by step ‘C’. Thus, mass transfer rates attainable in charcoal haemoperfusion columns are critically limited by external film diffusion and by pore diffusion. Of these, the external film diffusion rate limitation is a function of hydrodynamic conditions, the composition of bulk flow and adsorbate-solvent interaction. Whereas the pore diffusion step is fixed by the nature of the adsorbate and of the adsorbent pore structure. Thus in practice, total adsorption rate of each adsorbent system should be maximised by minimising the external film resistance.

In this research, the effects of the secondary fluid motion caused by pulsing the blood flow in haemoperfusion columns were investigated with the hope of minimising the external film diffusion resistance so as to decrease the treatment time of haemoperfusion columns.

Experimental

Three litres of creatinine solution (10mg/100 ml) was circulated from a reservoir to the haemoperfusion column by a pulsatile pump (Harvard model 1413).

Columns (ID = 3 cm, length = 13.5 cm) equipped with filters and tubing connectors at the ends, were filled with 37 g of charcoal. Petroleum based charcoal (manufactured by MKE, Turkey) was 10 x 12 Taylor mesh (1.41/1.68
mm screen openings). It was washed with tap water and dried at 100° before fillings.

All experiments were conducted at 37° ± 0.1°C. Flow rates were varied over a wide range from 40 ml/min to 400 ml/min. Five different frequencies of pulsatile flow (10, 20, 30, 40, 50 min⁻¹) were used. Each pulsatile flow rate was repeated at pulseless flow by means of a flow integrator.

0.2 ml samples were drawn from the creatinine solution reservoir at five minutes intervals and creatinine concentrations were determined by spectrophotometric methods [4].

Results

Initial clearance rates as described in equation 1 were used to evaluate the effects of pulse frequencies and flow rates on the performance of haemoperfusion columns.

Initial clearance rate = \( \frac{V \ dc}{c_o \ dt} \)  \( t = 0 \)  \[1\]

\( V \) = total creatinine solution volume, ml

\( c \) = creatinine concentration, mg/100 ml

![Figure 1. Adsorption of creatinine at pulsatile and pulseless flow.](image-url)
\[ c_0 = \text{initial creatinine concentration, mg/100 ml} \]
\[ t = \text{time, min} \]

For a pulse free system, the initial clearance rate is related to the flow rate, but a very slight increase was observed with increasing flow rates over 200 ml/min (Figure 1). On the other hand there is a steep increase in the initial clearance rate up to the flow rate of 300 ml/min with the pulsatile regime.

With the same flow rate, initial clearances with the pulsatile regime are 40 to 150% greater than those with the pulseless regime. This enhancement increases as the flow rate increases.

In addition to flow rate, the pulse frequency is an important parameter in the study of haemoperfusion column performance. It seems better to use higher frequencies at low flow rates in order to accelerate the elimination of creatinine as shown in Figure 1. The difference between the effects of pulse frequencies diminishes at higher flow rates.

The efficiency of pulsatile flow over pulse free flow on the elimination of creatinine can be explained as follows: the secondary flow due to the pulsation may have facilitated mixing and thus may have reduced the effect of external film resistance during the course of adsorption.

References

2 Chang, TMS (1976) *Kidney Int.*, 10, 305