HANDY TYPE HAEMOFILTRATION-PLASMA EXCHANGE APPARATUS

O Otsubo, T Horiuchi, S Seo, T Dohi*, F Fukui, T Inou

The Institute of Medical Science, The University of Tokyo,
*Tokyo Denki University, Japan

Summary

A simple, compact and light weight design for a machine to perform plasma exchange or haemofiltration at a desired place is required. Based on these considerations, we have designed and fabricated a portable machine having a unique volume balancing mechanism and evaluated the in vitro and in vivo fluid balancing performances.

We have obtained fully acceptable results during the evaluations and have performed clinical tests with favourable results.

Introduction

Haemofiltration therapy has been applied for several years to the treatment of cases of chronic renal failure who find difficulties in being maintained by haemodialysis [1,2]. Further development of haemofiltration apparatus has been desired. Therefore we have developed the portable plasma exchange and haemofiltration apparatus instead of the previous large and heavy machines.

Materials and methods

This apparatus is 425mm in length, 250mm in width and 170mm in height, including the following components (Figures 1 and 2).

1) Triple channel roller pump The innermost and intermediate tubings are used as an arterial and a venous line respectively, having the same flow rates, and the outermost one as a filtrate aspirating line. As the flow rates through the arterial and venous lines are the same, the substitute equivalent to the amount of ultrafiltrate removed is freely introduced into the venous line, satisfying correct fluid balance.

2) Mono roller pump The pump is placed on a bypass line of the arterial line
Figure 1. Handy type haemofiltration-plasma exchange apparatus; size: 425mm in length, 250mm in width and 170mm in height; weight: 16kg

Figure 2. Schematic diagram of haemofiltration by handy type haemofiltration-plasma exchange apparatus
interposing the triple channel roller pump to increase the arterial flow, so that the bypass flow becomes equivalent to the body weight decrease of a patient, allowing the function of haemofiltration.

3) **Fluid removal rate indicator** The rate or the integrated amount of the fluid removed can be indicated digitally by a selection switch in either direction.

4) **Arterial and venous pressure gauges**

5) **Aspirating pressure gauge**

6) **Blood bubble and substitution fluid empty detectors**

7) **Blood flow rate indicator**

8) **Alarm**

**In vitro evaluation**

Flow volume through each of the three tubings placed in the triple roller pump was measured. Water at 37°C was used as the fluid at a flow rate indication of 200ml/min and the measurements were repeated according to the combinations of the disposition of the tubings. Then the volume difference between the consumed substitute and removed ultrafiltrate was measured at an indicated flow of 200ml/min under -50, -100, -200, -300, -400 and -450mmHg of aspirating pressures each for 30 minutes duration. The flow balance was also evaluated by passing water at 37°C through the arterial line at an indicated flow rate of 200ml/min operating the mono channel roller pump for excess fluid removal at flow rate indications of 500 and 750ml/hr.

In each of the above evaluations, the consumed substitute volume was calibrated by considering the water level difference at the venous air trap between pre and post evaluations, and the venous air trap pressure downstream of the ultrafilter was maintained at the same level as the arterial pressure upstream of the triple channel roller pump by regulating the pinch cock on the substitute line manually to equalise the inflowing pressure of the arterial and venous lines prior to the triple channel roller pump for assuring the correct flow rates.

**In vivo evaluation**

In 20–25kg mongrel dogs using a shunt between the carotid artery and jugular vein 4 hours duration of haemofiltration was applied with 8 to 9 litres of fluid exchange.

**Clinical evaluation**

The subject was a case of chronic renal insufficiency (age: 69, Htc: 32%, serum protein: 7.2g/dl) to whom the haemofiltration therapy using this apparatus was adapted three times.
Results

In vitro evaluation

The difference of the flow volume from the innermost tubing in the triple channel roller pump was 0.03% and 0.02% at the intermediate and outermost tubings, respectively. The difference between the consumed substitute and the removed ultrafiltrate decreased as the aspirating pressure increased and was as small as 2% at the pressure range from -300 to -450mmHg.

In vivo evaluation

As seen from Figure 3, the ultrafiltrate volume increased with time almost linearly.

![Graph showing ultrafiltration results](image_url)

Figure 3. Results of haemofiltration by handy type haemofiltration-plasma exchange apparatus (uraemic dog: body weight 25kg)

A little more volume of the ultrafiltrate was measured when the mono channel roller pump was operated at 1000ml/hr indication, and about 8% more excess fluid removal than the indicated values resulted when the mono channel roller pump was operated at 500 and 1000ml/hr indications.

Clinical evaluation

In this system, at a 180ml/min blood flow rate, haemofiltration was performed and a filtrate volume of 23 litres obtained during 6 hours operation (Table I).
TABLE I. Comparison between the panel indication and actual measurement for removed fluid volume (clinical evaluation)

<table>
<thead>
<tr>
<th>Time (hr)</th>
<th>Triple channel roller pump (ml/min)</th>
<th>Mono channel roller pump (L/hr)</th>
<th>Removed fluid volume Panel indication (litres)</th>
<th>Actual measurement (litres)</th>
<th>Error %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>180</td>
<td>0.8</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>3.5</td>
<td>180</td>
<td>0.5</td>
<td>2.25</td>
<td>2.35</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>180</td>
<td>0.5</td>
<td>0.8</td>
<td>0.79</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Discussion

The triple channel roller pump, as the most important component of this machine, was evaluated concerning the flow volume difference through the three tubings. In particular, the two tubings for the arterial and venous lines, except for the aspirating line, should have the same flow rate to maintain correct fluid balance.

The flow volume differences between the three tubings caused by the eccentric rotation of the rotor were within 0.03%. The unbalanced flow volumes through the pump seem to be caused chiefly by the difference of the tubing dimensions, which should be improved, and by the incorrect manual regulation of the venous air trap pressure which could also be improved by such means as the use of an automatic control.

The difference in the excess fluid removal between the indicated and actual values seems to be derived from the use of tubings having different dimensions.

Conclusion

The characteristics of our machine are:

1) Simple construction by the use of the triple channel pump combined with the mono channel roller pump.

2) Easy setting of the blood bubble or substitute empty detector on the related line at a desired position.

3) Unique disposition of the mono channel roller pump on the arterial line to remove the excess fluid combined with the triple channel roller pump permitting the same flow rate of the arterial and venous line.

4) Possibility of use in an extracorporeal ultrafiltration method without operating the mono channel roller pump, or as a liver assist device.

References
