The Accuracy of the Bubble Flow Method for the Determination of the Blood Flow Rate During Haemodialysis

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The amount of blood propelled through the dialyser in a given time by a roller pump during routine haemodialysis may be determined by various methods:

1. Electromagnetic flowmeters, the principle of which is to measure the blood flow rate by the electric potential induced by the conductive material (blood) when moving through a magnetic field.

2. Thermal flowmeters, which determine the blood flow rate by the degree of cooling or warming obtained with the blood stream.

3. Ultrasonic flowmeters, which measure the blood flow rate by the doppler effect. A beam of ultrasonic sound is directed through the blood stream and a small fraction of it is backscattered by the cells in the blood to a receiver crystal. The resulting frequency shift is proportional to the blood flow velocity.

4. Bubble flow method (Jameson, 1968), by which the blood flow rate is calculated from the passage time of an air bubble propelled by the blood stream through a length of tubing of known volume.

Although the bubble flow method is much less expensive than the other modern techniques poor accuracy of this 'old fashioned' method might justify its replacement. In order to prove this justification the bubble flow method was tested in the present investigation.

METHODS AND MATERIALS

Figure 1 demonstrates the technique of the bubble flow method. An air bubble five tube diameters in length was introduced into the blood tubing by a sterile 2 ml syringe. The air bubble was propelled by the blood stream through one meter of a tubing, which was horizontally positioned. The passage time of the anterior front of the air bubble through this 1 m portion of tubing was measured visually using a stop watch. The volume of the 1 m of tubing was determined by two different methods:
1. Real volume: the 1 m of tubing was weighed, filled with de-aerated water and weighed again. The weight increase in grams was regarded as equal to volume in ml.

2. Effective volume: the amount of blood running from the end of the tubing during the passage of the air bubble through the 1 m of tubing was measured with a graduated cylinder.

In order to test the accuracy of the bubble flow method the blood flow rate was determined in a commonly used haemodialysis PVC-tubing (O.D. 8.5 mm, I.D. 5.0 mm) simultaneously with the bubble flow method and a volumetric method. For the latter the amount of blood running from the end of the tubing was measured during 15 seconds. The blood used for these studies had a hematocrit of 20% and was warmed to 37°C.

In a second study the influence of pressure changes in the blood tubing on the accuracy of the bubble flow method was investigated, since the testing of this method had to be performed with an open tubing system. For more detail see Kramer et al (1972).

Figure 2. A comparison between the bubble flow method and a volumetric method.
RESULTS

In Figure 2 the blood flow rate measurements obtained with the bubble flow method are plotted against blood flow rates determined simultaneously by the volumetric method. The straight full line in Figure 2 represents the identity line and the interrupted lines indicate the 5% error limits. According to Figure 2 the coefficient of variation of the bubble flow method must be less than 5%, since almost all triangles are lying within the 5% error limits. These results were obtained using the effective volume (16.8 ± 0.3 cc) instead of the real volume (19.5 ± 0.2 cc) of the 1 m length of tubing for the calculation of the blood flow rate.

Figure 3. Changes of the real volume (19.9 cc) of the 1 m tubing portion as a function of pressure changes.

Figure 3 demonstrates the volume changes of the 1 m of tubing as a function of pressure changes. Even with the unusual pressure variation of ± 300 mm Hg the volume of the tubing varies only ± 0.5 cc.

DISCUSSION

An accurate blood flow rate determination is absolutely necessary for any dialysance study. But even during routine haemodialysis accurate measurements of the blood flow rate are necessary from time to time, since the amount of blood propelled by the roller pump through the dialysers varies
with (a) the pressure in the tubing before the roller pump (Kramer et al., 1969); (b) the distance between the rolls and the tubing bed in the pump, and (c) the tubing material.

The blood flow rate cannot be measured in the closed PVC-tubing by an electromagnetic flowmeter, because the tubing wall acts as an insulator with disturbing static electricity on its surface. The probe either has to be inserted into the blood stream directly or the blood stream must be directed through an electrical current conducting tubing on which the probe may be placed. This, of course, causes problems in respect to sterilisation. The coefficient of variation of this method for clinical use is between 5 and 15% (Moran, 1967). The thermal flowmeters suffer from the same disadvantages as the electromagnetic device. The thermistors have to be inserted into the blood circuit with consequent risk of introducing infection. The ultrasonic blood flow measurement during haemodialysis has the great advantage that the probe can be placed on the PVC-tubing without disconnecting or puncturing it and it is perfectly safe. However, it is less accurate than the electromagnetic flowmeter (Sampson et al., 1970). For the use of the bubble flow method it is important that the effective and not the real volume of the 1 m length of tubing is used for the calculation of the blood flow rate according to the equation:

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\text{Blood flow rate (ml/min)} = \frac{\text{effective volume (ml) } \times 60}{\text{passage time (sec)}}
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The blood flow rate is overestimated by 10 to 15% if it is calculated from the real volume of the tubing. The difference between the real and the effective volume is explained by the thin residual blood layer (~0.2 mm), which remains on the tubing wall, while the air bubble is propelling the blood through the tubing. Pressure in the tubing before the roller pump may vary from +150 mm Hg to -150 mm Hg. This causes an error of the bubble flow method of only less than 2%.

CONCLUSION

The bubble flow method is inexpensive and yet as accurate as the best modern technique.

REFERENCES

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