A New Universal Anaesthetic Circuit Using a Preferential-Flow T-Piece

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SUMMARY

A new co-axial anaesthetic circuit, employing a preferential-flow T-piece which eliminates the need for valves in the circuit, has been designed. Its efficiency has been shown to compare favourably with that of conventional circuits for use in spontaneous respiration and under conditions of controlled ventilation.

The proposed system has the advantage of convenience, in that there is no need to disconnect the system from the patient nor from the anaesthetic machine when it is necessary to change from spontaneous to controlled ventilation or should a circle absorber be incorporated within the circuit.

The system has been shown to offer lower resistance than the Mapleson A circuit.


The first semi-open anaesthetic circuit which claimed universal application was the co-axial modified Mapleson...
D circuit designed by Bain and Spoerel in 1972 (Fig. 1). The efficiency and value of this circuit for controlled ventilation have been amply demonstrated. A fresh gas flow of 70 ml/kg/min is adequate to maintain normocarbia in the majority of patients during controlled ventilation, provided that the minute volume is high enough. However, during spontaneous breathing a fresh gas flow of at least thrice the minute volume appears necessary if rebreathing is to be prevented.

It has been shown that carbon dioxide levels can only be maintained by considerable active ventilation when flow rates of 150 ml/kg/min or less are used.

Fig. 1. The classification of components of the Mapleson A, Mapleson D and Bain systems.

Ungerer and Le Roux have therefore suggested an alternative universal anaesthetic circuit which still employs the useful single-limb co-axial anaesthetic device. The same modified Mapleson D circuit is used in controlled ventilation, and for use in spontaneous respiration. Conversion to the efficient Mapleson A circuit is effected by interchanging the position of the pop-off valve and the fresh gas inlet (Fig. 2). Larger diameter inner and outer tubes than are used for the Bain circuit are necessary in this circuit, otherwise gas flow resistance is excessive.

The uniqueness of the new circuit which is being proposed applies only to its use in spontaneous respiration. The pure Mapleson D circuit as in the Bain and Ungerer circuits is used for controlled ventilation. During spontaneous respiration the expired gases are directed through a 9-mm jet back into the inner fresh gas inflow tube. Dead-space gas followed by alveolar gas is preferentially directed into the inner tube system, distending the reservoir bag as it does in the Mapleson A circuit until the rise in pressure redirects the remainder of the expired gas through the outer tube system. This takes place via the perforations at the distal end of the inner tube.

It could be said, therefore, that the movement of gases through this system resembles that of the Mapleson A circuit.

APPARATUS

The Tube System

A wide variety of tube sizes can be employed in the manufacture of this circuit, the factor of importance being the ratio of the diameters of the inner to the outer tubes. Both the inner and the outer tubes which we used were corrugated. The inner tube had an internal diameter of 16 mm and an external diameter of 20 mm. The outer tube had an internal diameter of 26 mm. However, larger tubes than these would probably improve preferential flow and heat exchange.

The inner tube is connected proximally to a rebreathing bag (A in Fig. 3) on the anaesthetic machine, as in the Mapleson A circuit.

Fig. 2. The Ungerer-Le Roux interchangeable system showing the two positions of the pop-off valve.

Fig. 3. The preferential-flow circuit showing the positioning of the rebreathing bag (A) near the fresh gas inlet and the exhaust outlet (B).

Preferential-Flow T-Piece

The distal end of the inner tube is fixed to a perforated terminal connector piece. A 9-mm diameter jet protrudes through the latter beyond the perforations of the connector piece, directing exhaled gases into the inner tube against the stream of the fresh gas inflow.
Methods and Results

Two methods were employed for assessing the minimum flows required to prevent rebreathing.

Firstly, the conventional method of measuring the rise in end-expiratory carbon dioxide levels was used. A co-axial circuit, with tube diameters as have already been mentioned, was used. Samples of gas were taken from near the mouthpiece during the latter phase of expiration. Four patients were used and in each case rebreathing was shown to begin at a fresh gas flow rate of between 60 and 50 ml/kg/min (Fig. 5).

Outlet (B in Fig. 3)

During spontaneous respiration the exhaust outlet of exhaled gases can either be left open or a corrugated tube, at the end of which is an open-ended rebreathing bag, can be applied.

When the pure Mapleson D circuit is required for use in controlled ventilation the rebreathing bag of the inner fresh gas inflow tube is closed off. Ventilation can then be commenced using the abovementioned open-end rebreathing bag, or a closed-end rebreathing bag in conjunction with a pop-off valve, or a suitable ventilator can be plugged into the outlet. Simple mechanical ventilators may be used without modification provided they are not powered by anaesthetic gas flows, e.g. Manley. A standard 1-m length of corrugated tubing has to be interposed between the ventilator and the Bain system to prevent mixing of ventilator gas and anaesthetic gas.

Inclusion of the Circle Absorber

This is achieved firstly by disconnecting the rebreathing bag (A in Fig. 3) of the inner fresh gas inflow tube and connecting the outlet tube of the carbon dioxide absorber; and secondly by connecting the outlet (B in Fig. 3) to the inlet of the carbon dioxide absorber.

EVALUATION

Apparatus Used for Measuring Carbon Dioxide Levels

Working in a small hospital meant that neither a capnograph nor Astrup facilities were available, therefore a simple technique employing the absorption of carbon dioxide in a closed system was used. A 20-ml disposable syringe was used to collect samples of gas at various phases of the respiratory cycle. Then 1 ml of a normal solution of sodium hydroxide was injected through a two-way stopcock into the 20-ml sample of gas and the system was shaken for about 30 seconds. The sample of gas and sodium hydroxide was connected to a 2-ml pipette with water drawn up to the 1-ml level. On opening the stopcock the rise and fall of the level of water in the pipette gave an indication of the percentage of carbon dioxide absorbed by the sodium hydroxide.

A second method, which appears to be a more sensitive indicator of rebreathing, was employed in order to compensate for any inaccuracies of this fairly primitive method of measuring carbon dioxide levels. Instead of a co-axial circuit a mimic circuit with two parallel tubes was used. Gas samples from the expiratory limb near the preferential-flow T-piece were obtained just before the end of inspiration. The reason for doing this was based on the fact that gases in this circuit are eliminated in the same order as in the Mapleson A circuit, i.e. alveolar gas followed by dead-space gas and finally the fresh gas which is supplied in excess. During moderately high fresh gas flows (e.g. 70-100 ml/kg/min) the interface between alveolar and dead-space gas in the outer tube compartment is at a distant site at the end of expiration, and moves slowly towards the patient during inspiration as gases are preferentially drawn from the inner tube. This interface moves nearer to the patient as fresh gas flows are decreased, so that at the end of
inspiration there is a transition from gases with near-zero levels of carbon dioxide (dead-space gas) to high levels of carbon dioxide (alveolar gas). This transition phase occurs prior to the rebreathing of the alveolar gas.

This method is a more sensitive indicator of rebreathing as the baseline for carbon dioxide levels is 0% compared with the 5-6% baseline in the first method. It should also be noted that the rise in carbon dioxide level is obtained before rebreathing is expected to occur.

Sampling from 6 patients showed that in 4 of the patients on whom a mask was used, carbon dioxide levels began to rise at fresh gas flows of about 60 ml/kg/min. In 2 patients who were intubated and in whom a right-angled Cobb’s connection was used, carbon dioxide levels began to rise at between 75 and 65 ml/kg/min of fresh gas supply (Fig. 6).

Fig. 6. The rate of fresh gas supply at which rebreathing of alveolar gas may occur using a parallel tube configuration of the preferential-flow circuit.

Resistance

The resistances to gas flow which are encountered within the Mapleson A circuit and the preferential-flow circuit are compared. Measurements were made using a methyl alcohol manometer on anaesthetized subjects. The results obtained are represented diagrammatically in Fig. 7.

DISCUSSION

The advantages of the proposed system over current anaesthetic circuits are as follows.

Firstly, a lower resistance during the second half of expiration than with the Mapleson A circuit has been found. The Mapleson A circuit has little resistance during the initial phase of expiration and then a constant resistance to the end of expiration from the moment the valve opens to eliminate gases. Under conditions of normal spontaneous respiration the peak resistance to expiration in the proposed circuit never exceeds that of the Mapleson A circuit, and furthermore occurs during the first and middle phases of expiration and tails off at the end. This pattern of resistance during expiration is more akin to that of normal physiological breathing than the pattern of resistance of the Mapleson A circuit. The result is a better elimination of expired gases.

The preferential flow of expired gases is achieved primarily by making use of the kinetic energy of expired gas particles to direct gas flows favourably. Gas flows in the Mapleson A circuit are directed by virtue of the resistance of the pop-off valve. Other factors which contribute to preferential flow are the resistance to gas flow through the ‘S’ bend at the preferential-flow T-piece and the slight increase in resistance to gas flow in the outer tube compartment compared with the flow of gases within the inner tube.

The minimal dead-space in the circuit combined with its low resistance would indicate that this circuit could be used on children well below the 20 kg minimum suggested weight limitation for the use of the Mapleson A circuit.

Unlike other co-axial circuits which do not have a rebreathing bag connected to the inner tube compartment, testing the integrity of the inner tube can be done without the necessity of a transparent outer tube. By simply disconnecting the T-piece and obstructing the inner tube with a finger, the rebreathing bag (A in Fig. 3) should not collapse after an initial filling from the fresh gas supply line.

Another advantage is an improved heat exchange mechanism. This is achieved in this design because the surface area over which heat exchange takes place is much larger than that of other co-axial circuit designs. Also, because larger-diameter tubes are used, there is a slower movement of fresh gases within the tube, which provides longer exposure to heat exchange. Thirdly, the thin plastic used for the inner corrugated tubing provides less insulation than thicker-walled, non-corrugated tubing.

As with other co-axial circuits, the scavenging of exhaust gases is simple.

Perhaps the most significant advantage is the ease and convenience with which this circuit can be employed. The ease of changing from controlled to spontaneous ventilation and vice versa and the inclusion of the circle
absorber have already been described. It should also be noted that the universal co-axial circuit proposed by Ungerer and Le Roux employs a functional interchange of inner and outer tubes which necessitates the flushing out of expired gases which are present in the rebreathing bag and outer tube when changing over from the Mapleson D to the Mapleson A circuit. As there is no functional interchange in this circuit, this inconvenience is not encountered.

CONCLUSION
A new anaesthetic circuit has been designed which does not fit Mapleson’s classification of semi-open circuits. It combines the advantages of being both a valveless circuit with no moving parts and a co-axial system. Despite these obvious advantages there is no sacrifice in efficiency.

REFERENCES

Two Simple Inexpensive Photographic Methods for Viewing ECG-Gated Radionuclide Blood Pool Images


SUMMARY
Although the ECG-gated radionuclide blood pool scan (GBPS) has become an established method for studying regional myocardial wall motion, it is usually performed with the aid of an expensive computer system. A simple, inexpensive method was developed to view gated radionuclide blood images by a film loop and a photographic motion detection (PHOMOT) technique. These techniques were compared with left ventricular cine angiography in 15 patients. Segmental wall movement (78 segments) showed identical results in 92% of cases. In all patients the same diagnosis was arrived at by GBPS and cine angiography. The photographic techniques developed offer a simple screening procedure to reduce cardiac nuclear medicine demand and costs.

The principle behind the method is to label the patient’s blood pool with a suitable radionuclide and then to obtain end-systolic and end-diastolic gamma-camera scintillation images of the cardiac blood pool. By comparing these images, areas of poor or paradoxical myocardial motion may be detected.

To facilitate viewing and interpretation of the images, most centres make use of a dedicated minicomputer for storage and retrieval of data. Stored data can then be replayed in a cine mode, alternately displaying the end-systolic and end-diastolic images, thus creating an illusion of a contracting heart. Hypo- or dyskinetic areas can be selected by systematically viewing the animated image. The cost of a minicomputer unfortunately precludes the effective use of GBPS in many centres with only basic gamma-camera facilities.

In this article we evaluate two simple, inexpensive photographic techniques by means of which GPBS may be viewed without the aid of a computer facility.