Commentary


The first anaesthesia breathing systems were developed for delivery of nitrous oxide–oxygen mixtures for dental anaesthesia. While some of the earlier machines used wide bore tubing to connect the machine to the patient, most used a 1–2-m length of narrow bore tubing to transfer the gas mixture to the reservoir bag and expiratory valve which were situated close to the face mask. Both the Gwathmey–Woolsey apparatus of 1912 and the close copy introduced by Boyle at the beginning of World War 1 used this arrangement. However, when Magill was anaesthetizing for reconstructive surgery after the war, he found that the presence of the bag close to the patient’s face interfered with the work of the plastic surgeon, and therefore he moved the bag to the machine end of the connection tubing. By this time Magill was moving from insufflation anaesthesia to the use of a wide bore tracheal tube, and this made him realize that the connecting tubing would have to be of wide bore to reduce the resistance to breathing. The supply problem was solved initially by using corrugated tubing from First World War gas masks to connect the bag to the expiratory valve. Although the to and fro carbon dioxide absorption system was introduced by Waters in 1924 and the circle carbon dioxide absorption system followed in 1930, these systems were never used widely in the UK, their use tending to be restricted to situations where cyclopropane was required. For most other applications the Magill system retained its popularity in the UK for more than 50 yr.

When Mapleson was appointed to the post of physicist in the Cardiff department he found that anaesthetists were using several different semi-closed systems and to reduce confusion, he classified these alphabetically. “A” was the standard Magill breathing system with a tube of approximately 22 mm internal diameter and an internal volume of approximately 500 ml. “B” was a system made by Medical and Industrial Equipment Ltd which appeared to be similar to the “A” system, but in which fresh gas flow was diverted from the machine common outlet through a narrow bore tube to rejoin the breathing system by the expiratory valve. It was claimed that this arrangement enabled inspired gas concentrations to be changed rapidly, and that it decreased rebreathing, but as Mapleson’s diagram showed, the metal diaphragm in the bag mount which diverted the gas flow into the narrow bore tube caused the corrugated tube and reservoir bag to become one large rebreathing chamber. The “C” system was that used on the original Boyle’s machine, but in 1954 it would have been produced by removing the carbon dioxide absorption canister from the Water’s to and fro system. Such a system was used frequently for transport or resuscitation of patients in the days before self-inflating bags and reliable non-rebreathing valves were available. System “E” was the Ayre’s T-piece, introduced for paediatric anaesthesia in 1937, and system “D” was the Jackson Rees modification used with controlled ventilation.

In the 1950s most anaesthetists using the Magill system set flowmeters to deliver 2 litre of oxygen and 5 litre of nitrous oxide, although there was little evidence to support this choice. Molyneux and Pask had used a primitive pneumotachograph to record flows on the patient side of the reservoir bag and had concluded that much higher flows were needed to prevent rebreathing. However, Mapleson concluded from his theoretical analysis that rebreathing would be prevented if fresh gas flow was greater than alveolar ventilation. This definition of rebreathing recognized that re-inhalation of gas which had come from the apparatus and patient’s deadspace (and which therefore did not contain carbon dioxide) had no effect on gas exchange. In order to render the mathematics simple enough for the average anaesthetist to understand, Mapleson made five simplifying assumptions. These were examined in detail, and although none appeared likely to have a gross effect on the prediction, Mapleson cautiously modified his conclusion and stated that rebreathing of carbon dioxide-rich gas would be prevented completely if the fresh gas flow rate exceeded the patient’s minute volume with system A, and that a flow rate approximating to twice the patient’s minute volume was required with the other systems.

Mapleson’s prediction that there would be no rebreathing with the “A” system if fresh gas flow exceeded minute volume was soon confirmed by experiments on lung models and observations in the operating theatre, but it was not until 1967 that Kain and Nunn confirmed in anaesthetized patients that fresh gas flow could be reduced to approximately 70% of minute volume before rebreathing occurred. In the 1950s the “A” system was used frequently when assisting or controlling ventilation during short operations such as appendicectomy. Under these circumstances a mixture of fresh and expired gas is discharged from the valve during inspiration. This results in a variable degree of rebreathing. Waters and Mapleson went on to provide a theoretical analysis of the performance of systems “A”, “B”, “C” and “D” during controlled respiration and concluded that system “A” was the least efficient. However, their observations in five patients indicated that
end-tidal $P_{CO_2}$ could be maintained within normal limits with all four systems when fresh gas flow was increased to 8 litre min$^{-1}$.

Mapleson’s clear analysis of the dynamics of these breathing systems shows how important it is for the anaesthetist to have an understanding of simple physics and mathematics. It has also stimulated others to design breathing systems which preferentially dump the carbon dioxide-containing moiety of expired gas, and so decrease fresh gas requirements. But, above all, this article marked the arrival on the anaesthetic scene of one who has made many major contributions to our knowledge of the scientific basis of anaesthesia. It is a pleasure to acknowledge his selfless devotion to our specialty.

References