Anaesthetic breathing systems in the accident and emergency department

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SUMMARY

We report two cases where patients with an acute head injury developed hypercapnia as a result of the inappropriate use of the Magill breathing circuit. The Magill circuit is inefficient when used for controlled ventilation because the patient is ventilated with his own expired gas and develops hypercapnia. The suitability of alternative breathing systems are discussed.

INTRODUCTION

Anaesthetic breathing systems are present on the anaesthetic machines in operating theatres and also in the resuscitation room of the accident and emergency (A&E) department. Although anaesthetists are familiar with the characteristics of the various systems, other medical staff are rarely aware of the differences. The efficiency of each system varies not only with the mode of ventilation (spontaneous or controlled), but also with the fresh gas flow into the circuit.

The Magill circuit is a commonly used breathing system. Although this system is efficient when used with a spontaneously breathing patient, it is inefficient when controlled ventilation is necessary (Mapleson, 1954). Used in this manner, the fresh gas that is delivered into the system is eliminated through the pressure relief valve and the patient is ventilated with his own expired gas. Consequently, the patient will develop hypercapnia.

We report on two cases where patients with acute head injury were made hypercapnic by the inappropriate use of the Magill circuit for artificial ventilation.

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Case 1

A 17-year-old man was admitted to A&E with a fractured left humerus, fractured metacarpal and an acute head injury following a road traffic accident (RTA). Although he had not fractured his skull, he was comatose and his Glasgow Coma Score was 5 (E1,V1,M3). He was breathing spontaneously and had a clear airway. However, blood gas analysis showed that he was hypoventilating: pH 7.23, PaCO\textsubscript{2} 8.28 kPa, PaO\textsubscript{2} 34.3 kPa, Base Excess -3, FiO\textsubscript{2} 1.0.

The patient was anaesthetized, his trachea intubated and a Magill circuit was used to manually ventilate his lungs with 100% oxygen. The fresh gas flow into the circuit was greater than 10 litres per min (the rotameter cannot measure flows in excess of 10 l per min). The PaCO\textsubscript{2} was still unacceptably high (pH 7.23, PaCO\textsubscript{2} 7.5 kPa, PaO\textsubscript{2} 80 kPa, Base Excess -5, FiO\textsubscript{2} 1.0) but fell when the Magill circuit was replaced with an AMBU bag (ph 7.58, PaCO\textsubscript{2} 3.55 kPa, PaO\textsubscript{2} 28.5 kPa).

The patient was transferred to the regional neurosurgical centre where CAT scan revealed a small frontal lobe haematoma which did not require surgical drainage. The patient was weaned from ventilation within 24 h, and proceeded to make a full recovery. He was discharged home with no neurological deficit.

Case 2

A 17-year-old man was admitted to A&E following a RTA. He had sustained multiple rib fractures on the right (first, second, ninth and tenth ribs) but had no pneumothorax. He had also sustained fractures of his left orbit, his left maxilla and of his mandible. He was breathing spontaneously and had a clear airway, although there was considerable swelling and bleeding around his mouth and nose. His Glasgow Coma Score was 7 (E1,V2,M4). Although his arterial blood gases were satisfactory (pH 7.32, PaCO\textsubscript{2} 4.2 kPa, PaO\textsubscript{2} 16.6 kPa, Base Excess -8, FiO\textsubscript{2} 0.4), it was decided to secure his airway with an endotracheal tube before he was transferred by ambulance to the regional neurosurgical centre. He was ventilated through a Magill circuit with 100% oxygen at a fresh gas flow greater than 10 l min\textsuperscript{-1}. His PaCO\textsubscript{2} rose alarmingly (ph 7.08, PaCO\textsubscript{2} 11.8 kPa, PaO\textsubscript{2} 31.8 kPa, Base Excess -7, FiO\textsubscript{2} 1.0) but fell to 5.8 kPa when the Magill circuit was replaced by a ventilator and circuit with non-return valves.

CAT scan showed small intracerebral haematomas which did not require drainage. The facial injuries were surgically fixed and the patient required ventilation postoperatively in view of his underlying lung injury. However, he made a full recovery and was discharged with no residual neurological sequelae.

DISCUSSION

Within limits, cerebral blood flow varies directly with PaCO\textsubscript{2}. Therefore intracranial pressure varies directly with changes in PaCO\textsubscript{2}. In the head injured patient, a rise in PaCO\textsubscript{2} may result in a disastrous rise in intracranial pressure. Although the long-term benefits of hypocapnia in head injured patients are contentious (McDowall, 1985), it can buy valuable time before surgical decompression can be performed.
The characteristics of the Magill circuit are well known. Although the efficiency of the circuit can be improved by increasing the fresh gas flow (Sykes, 1959), this will not guarantee satisfactory conditions. The ratio of inspiratory time to expiratory time will also affect the efficiency of the circuit (Tyler et al., 1989). However, when the circuit is used for controlled ventilation hypercapnia will result.

An alternative breathing system is the Bain circuit, which is lightweight and manoeuvrable and can be satisfactorily used in either mode of ventilation (Dorsch & Dorsch, 1984a). To prevent rebreathing, a high fresh gas flow is required (2-5 times the patient’s minute volume). The system should be carefully inspected, as disconnection or kinking of the inner tube will result in rebreathing of expired gases.

Another alternative is the AMBU non-return valve plus self-inflating bellows. The design of the valve prevents rebreathing but will not allow ventilation with 100% oxygen, unless the bag is modified to allow entrainment of oxygen instead of room air. The valve is delicate and could be made incompetent by blood or vomitus (Dorsch & Dorsch, 1985b). There are also an increasing number of lightweight automatic ventilators which are suitable for short-term use and for patient transfer. These ventilators may be unfamiliar to non-anaesthetists and, in common with all ventilators, there is a risk of a patient disconnection being unnoticed.

In conclusion, no anaesthetic breathing system will provide ideal conditions for every situation that may arise in the A&E department. However, the least suitable of these is the Magill circuit. This circuit should not be used in the resuscitation room of the A&E department, where it may be the only circuit available for the artificial ventilation of a head injured patient. Advice on the suitability of the breathing systems in the A&E department should be obtained from the hospital’s anaesthetic department.

REFERENCES